*Issued January* 1888.

# TRANSACTIONS

OF

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VOL I. PART II.

OCTOBER TO DECEMBER

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The Society will not hold itself responsible for any statements or opinions which may be advanced in the following pages.

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# Canadian Society of Civil Engineers.

(INCORPORATED JUNE 23RD, 1887.)

Session 1887.—PART II.

## TRANSACTIONS.

Saturday, 24th June.

T. C. KEEFER, C. M. G., in the Chair.

In accordance with Clause 4 of the Act of Parliament, 51 Vict., Cap. 124, incorporating the Canadian Society of Civil Engineers, the incorporators were summoned to meet in the Harbour Commissioners Building, Montreal, on Saturday, the 25th June, 1887, when the following resolutions were unanimously passed :—

" Resolved that Mr. T. C. Keefer be the President of the Corporate Society."

" Resolved that Messrs. W. Shanly, C. S. Gzowski and John Kennedy, be Vice-Presidents of the Corporate Society."

"Resolved that Messrs. H. T. Bovey, F. N. Gisborne, E. P. Hannaford, W. T. Jennings, S. Keefer, L. Lesage, H. D. Lumsden, A. Macdougall, H. F. Perley, H. Peters, P. A. Peterson, H. S. Poole, H. N. Ruttan, P. W. St. George, C. Schreiber and H. Wallis, constitute the Council of the Corporate Society.

" Resolved that Professor Bovey be the Secretary-Treasurer of the Corporate Society."

" Resolved that the By-Laws as submitted and modified be adopted as the By-Laws of the Corporate Society and distributed to all its members.

" Resolved that a copy of the By-Laws and Charter be bound in the Minute Book."

Thursday, 6th October, 1887.

P. A. PETERSON, Member of Council, in the Chair.

The following candidates having been balloted for were declared duly elected as

### Members.

John Roger Arnoldi.
James Anthony Bell.
Thomas Breen.
Louis Metzler Clement.
Richard Philip Fleming.
Arthur Edmund Breton Hill, B.A.Sc.
Balfour Nepean Molewsorth.
Daniel McMillan.
Robert Murray Pratt.
William Allen Ramsey.
Thomas T. Vernon Smith.
Hon. Joseph W. Trutch.

### Associate Members.

Harry Brooke Aylmer.
Charles Stewart Baker.
Francis Ferguson Busteed.
Donaldson Bogart Dowling, B.A.Sc.
William Stewart Drewry.
Napoleon Julien Giroux.
David Herbert Keeley.
Arthur Robert Trenholme Lackie.
Albert Peter Low, B.A.Sc.
John Seabury O'Dwyer, B.A.Sc.
William Henry Chitterton Smith.
Joseph Edward Woods.

### Associates.

George Charles Rainboth.
Joseph Edward Rainboth.
Alfred R.C. Selwyn, L.L.D., F.R.S.

### Students.

Frederick Bury Austin.
William S. Belcher.
Frederick Allison Bowman.
George Herbert Dawson, B.A.Sc.
Arthur Herbert Dimock, B.E.
Eli Eder Henderson.
Milton Lewis Hersey.
William Franklin Jennison.
Henry Ord Spencer Lewin.
William Haywood Lough.
Richard Prat.
William Murray Reid, B.A.Sc.
Vaughan Maurice Roberts.

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***Paper No. 6.***

## CONSTRUCTION OF A GUARD LOCK AT THE HEAD OF RAPIDE PLAT CANAL.

By L. N. Rheaume, M.Can.Soc.C.E.

The Rapide Plat Canal is a division of what are known as the Williamsburg Canals, and extends from the town of Morrisburg, Ontario, to a point up the River St. Lawrence called Flagg's Bay. It is altogether about three and a half miles long and has a lift lock, known as lock No. 23, situated at Morrisburg, a channel way and a guard lock at its head, known as lock No. 24; the whole extent affording passage to vessels drawing nine feet of water.

It is proposed to deepen and enlarge this canal so that it may correspond with the new scale of navigation throughout the St. Lawrence route, which is fixed at an available depth of fourteen feet of water.

The works in progress are confined to the head of the canal, outlines of which are shewn on plans accompanying this paper.

They consist in the enlargement of a channelway of the canal, the construction of a new lock on the landward side of the existing one, the formation of a supply-weir, and the building of a guide-pier at the upper entrance of the canal. The full extent of the section, now under contract, is 2950 feet in length, and the total cost is estimated at about a quarter of million of dollars.

The location of this structure is immediately north of the old lock, the length of its walls is 363 feet, the distance between gate quoins is 270 feet, the width between side walls is 45 feet, and their thicknesses at the base are, in the chamber 8 feet 9 inches, in the recesses 10 feet, recess buttresses 13 feet 9 inches; the counterforts are 3 feet in width by 6 feet in length. The height of walls is 23 feet, and the level of the mitre sills is 8 feet below that of the old lock.

In the excavation of a lock-pit some unforseen difficulties were met with, causing delay and necessitating operations of varying character.

For a depth of 7 feet, the material was ordinary earth, capable of being removed by ploughs and scrapers. Below this the material consisted of clay, gravel and boulders firmly cemented together, with occasional small pockets of quicksand. When exposed to the wash of water it would be loosened, so that portions of it could be pumped out; but immediately after it became dry, it would assume the form of a stiff clay which, when exposed to the sun, would become as hard as ever. Experiments were made by blasting it with dynamite, and proved unsuccessful except when it was frozen hard in winter.

The required depth of 25 feet having nearly been attained, pumps were erected to keep the lock-pit dry.

When the full width towards the south side was reached, fissures and leaks were discovered, proceeding from the foundation and chain wells of the old lock. The leaks proved of sufficient magnitude to endanger the north wall of the old lock, and a change in the method of working had to be made. It was found necessary to move the new lock-pit 10 feet further from the old one, and a dam was erected between them throughout the whole length, to protect the south bank of the pit.

In order to form the dam, a row of piles 26 feet long, 12 inches in diameter and 4 feet apart, with cast iron shoes weighing 27 pounds, was driven along the foot of the south slope. The pile driving occupied over a month. An average number of about six piles per day were driven, and the number of blows given to each pile averaged from 80 to 105. With a fall of 15 to 20 feet and an 1800 lbs. hammer, the first blow drove the pile from 6 inches to 1 foot, and the last blow ½ an inch. The piles were driven to a depth of about 12 feet, the remaining 14 feet standing above the surface. They were braced together throughout their whole extent by round timber waling pieces, firmly bolted at the crossing of each pile. To enable the row of piles to withstand the pressure of the earthwork, the heads were secured by iron straps and rods, in the following manner:—

Flat iron straps 16 feet long, 4 inches wide and ½ inch thick were secured to the wall with 12 inch fox-wedge bolts, inserted 18 inches below the top of the coping. Three connecting rods of ⅞-in iron were hooked through holes in each strap, and the other ends of the rods passed through the head of a pile, securing it by means of an iron nut and washer. On the inner face of the piles, three rows of 4 inch plank waling pieces were spiked and afforded a bearing to a double row of 2 inch sheet piles driven so as to break joint. Inside the sheet piling, puddle was rammed down to an average depth of from 4 to 6 feet.

The dam being complete, the unwatering of the lock-pit was resumed, and the entire excavation of the pit was concluded without further delay.

The lock foundation was built as follows:—

1st. Six pile trenches from 3 to 4 feet wide and 4½ feet deep were excavated across the lock-pit; one at each end of the pit, one at each end of the two mitre sill platforms, all being 73 feet long, except that at the upper end of the pit which was 70 feet long. In each of the trenches, an anchor timber of pine 12 inches square was placed, embedded in cement grouting 3 inches thick, so as to afford a proper bearing for the sheet piles. In each of the trenches at the ends of the mitre sill platforms, 14 feet apart, three anchor screw bolts 5 feet long and 1½ inches diameter, were secured to the timbers by means of heavy washers and nuts. Pine sheet piles, 4 inches thick and 6 feet long, were driven so as to bear against the timbers, the toe of each pile being bevelled off 6 inches, and embedded in cement mortar.

The trenches were filled to the top and closely packed with concrete. A space of 2 inches between the inner face of the piles and the trench was filled with cement grouting, thus making the whole perfectly watertight.

2nd. Over the whole extent of the lock-pit, a stratum of concrete 9 inches thick, and averaging from 65 to 73 feet wide, was carefully rammed down to a uniform level.

3rd. The two mitre sill platforms, each 14 ft. by 72 ft., made up of pine timbers 12 inches square, tightly closed together and having planed water-tight joints, were then laid. Each of the platforms was secured by five wrought iron screw bolts 1½ in. diameter, passing through horizontally. Both ends of the three middle bolts had double nuts and washers, and formed connection with heavy iron shackles 12 inches long and 1½ in square, which were secured to the anchor screwbolts running through the timbers at the bottom of the trenches.

The platform was raised sufficiently to admit of the spreading of a thin coating of mortar over its berth. It was then lowered into place by means of hydraulic jacks, and was well beaten down to its proper bed and bearing on sub-sills 4 inches thick, embedded in mortar.

The joints throughout were caulked with two threads of oakum, and the sheet piles on each side of the platforms were secured with 7 inch iron spikes.

4th. The remaining part of the foundation consisted of 12-inch square pine timbers, of sufficient length to reach across the space occupied by the walls, laid 6 ins. apart on two rows of 4 inch sub-sills under the seat of the walls. The sub-sills were embedded in 1½ inch cement mortar. The spaces between the timbers were carefully packed with concrete, and were levelled off with a layer of cement mortar 1 inch thick. The top of each timber was dubbed to a uniform surface, so as to ensure a true bearing for the planking. At each end of the foundation the sheet piles were secured to the adjoining timbers with 7-inch spikes.

5th. The mitre sills were of white oak timber, framed, morticed, tenoned and planed. The main sills were 49 feet long, and 19 by 16 inches in section, the mitre sills, main braces and side braces were 19 inches square, and of such length as to correspond to an angle of 27° 30′ from the half width of the lock. A check 3 inches deep was cut in the lower edges of the mitre sills to receive the ends of the first course of planking. Before putting the sills together, a check 3 inches deep by 19 inches wide was cut into the platform to receive the sills, and a strip of canvas saturated in boiling tar was placed in the check so formed. Into this the mitre sill was tightly embedded. All mortices, tenons and joints of the sills were coated with white lead. Each sill and brace was connected and fastened with straps of iron 3½ inches by ⅝ in., let in flush and fastened with rag bolts 28 inches long and 1½ in. diameter.

6th. The flooring, consisting of two courses of pine plank, was then laid. The first course, 3 ins. thick, extended over the whole area of the foundation; and the second course, 2 ins. thick, was laid between the side walls in the chamber and at both ends of the lock. The joints were planed and wedged up so as to be water-tight, every 3 feet in width of planking, in both courses, breaking joint, and the upper course breaking joint both lengthwise and transversely with the one underneath. The lower course was fastened with white oak treenails, 9 ins. by $1\frac{1}{2}$ ins. in diameter, two in each plank end, and one on alternate sides at every crossing of a timber; it was dubbed to an uniform surface before the top course was laid. The latter was fastened with 7 ins. spikes, one at each plank end and one at each crossing of a timber, on alternate sides of the plank.

The masonry of the lock walls was built of dressed limestone laid in hydraulic cement. The principal cut face stones and gate quoins were of the best gray limestone, obtained at the St. Vincent de Paul quarry, below Montreal. The remaning stones were obtained at Oak-Point, near Belleville, O. The gate or hollow quoins were 5 ft. long and 6 ft. deep. The nose of the quoins was rounded to a radius, starting at $13\frac{15}{16}$ ins., and gradually decreasing upwards to a radius of 6 ins., and the hollow was dressed to a radius of 8-ins.

The recess quoins 5 ft. long and 6 ft. deep were cut to an angle forming a recess of 3 ft. 9 ins. in depth at the base, and decreasing upwards according to the batter of the chamber wall which was 1 in 24.

The chain-well sills, averaging 7 ft. in length, were cut on an inclination, suitable to the angle required to admit of the play of the chains for the lock-gates.

In building the lock-walls, the four hollow or gate quoins were first laid, and in each a check 2 feet long, 19 ins. by 19 ins. was cut to receive the ends of the mitre sills. The recess quoins, chain-well sills and stop log grooves were then laid. At each end of the lock chamber walls, two stop log grooves, 3 ft. apart, 1 ft. wide, $15\frac{1}{2}$ ins. deep at the base, were cut into the face and carried up plumb, making them at the top 4 ins. deep. All the principal face stones having been placed in position, the backing was laid, an equal proportion being built on either side each day. In rear of the walls, at 15 ft. centres, counterforts 6 ft. long and 3 ft. wide were built throughout the chamber up to a height of 18 ft. The recess abutments were 50 ft. long, and 6 ft. from each end a chainwell 2 ft. square of cut face stone, was formed to connect with each inclined tunnel below. The position of the chamber, recess walls and counterforts being fixed, wing walls on the north side and at upper end of the south side 18 ft. long and cut to radius of 45 feet, were then located in their place. The lower end of the south wall forming almost a semi-circle of a radius of 17 ft. 11½ ins. at the base, was completed at a later date on an extended foundation similar to that of the lock chamber.

The lock-walls comprised 13 courses, varying from 29 ins. to 15 ins., diminishing upwards. Each course was successively built, and from a height of 18 ft., a frost batter at the rear was formed up to the top of the coping, except around the chainwells, which were carried up plumb to the coping. All quoins were laid alternately headers and stretchers, headers being checked so as to bond one foot over the face stones of the recess. Throughout the walls, no face stone less than 3 feet was allowed, each stone in every course bonding more than 1 foot over the subjacent stone, and headers being placed 11 feet apart from centre to centre. All vertical and horizontal joints were $\frac{3}{16}$-in. thick. The copings of the chainwells were cut semi-circular to a 6 ft. radius, and the man holes circular, 2 ft. in diameter. The remaining portion of the coping was 4 ft. wide on top, its inner arris, next the lock, being rounded off to a radius of 3 inches.

A dowel 4 inches long and 1½ in. diameter was inserted in every joint, between the coping stones, 15 inches back from the inner face and 7 ins. below the top line. A hole was drilled through the middle of each cope stone, 9 ins. into the course underneath, and 20 inches back from the face, into which a bolt of 1¼ ins. diameter, 18 ins. long, was driven when hot, and the space over and around it filled with melted sulphur mixed with sand.

The mortar used throughout the masonry was made of the best Canadian cement mixed with clean sharp sand, in the proportion of two of sand and one of cement, except in the coping joints where the mixture was one of sand and one of cement.

At each end of the north wing wall, a rock face wall of random coursed masonry was built in the shape of a reverse curve. The portion connecting the lock was a continuation of the curve of the wing wall for a length of 13 ft. 9 ins., and from thence a reverse curve was carried on for a length of 86 ft. 6 ins.

The thickness of the retaining wall at the base was 8 ft. 9 ins., with a face batter starting at ½ in. and ending at 1½ in. to the foot. The back of it was built plumb up to a height of 18 ft. and from thence a frost batter was formed up to the height of 23 ft. The top of the coping was 3 feet wide.

At the end of this wall, a cross wall with steps 16 ins. high, was built on an inclination corresponding to the adjoining slope of the bank of the channel way. The thickness of the wall was 8 ft. 9 ins. at the base, with a face batter of 1½ ins. to the foot, and in rear a frost batter was also carried up to the top of the step coping. The foundations of both retaining and cross walls were built in a manner similar to that of the lock, with the exception that the timbers were placed 1 foot apart. From the end of the South-East semi-circular wall, a rock face wall of random coursed masonry was also built to make connection with that of the old lock. Its foundation was similar to that of the retaining walls. It was built in two portions, the former, 16 ft. long, stepping up 6 feet above the lock foundation, and the latter portion, 49 feet long, stepping up 2 ft., being on the same level as the old lock walls. For the erection of the latter, a pile dam had previously been built.

At the upper end of the South-West wing of the new lock, a square face return wall was carried up plumb to the same height as the lock walls. Its thickness at the base is 9 ft., and it has a frost batter similar to that of the adjoining walls. Its length is 32 feet. To ensure the erection of this wall, a pile dam had also been built. From the end of the upper return wall will commence the abutment of the proposed supply-weir.

The construction of the supply-weir, as well as that of the lock-gates and cross-dams, will form a subject which it is proposed to describe at some future date.

From the drawings accompanying this paper Plates V and VI have been prepared.

## DISCUSSION.

Mr. Evans.

Mr. E. A. Evans would have been glad if Mr. Rheaume had mentioned from what place the "best Canadian Cement" had been obtained, and had furnished detailed particulars of its quality and of the results of his tests, as well as his opinion thereof during the progress and after the completion of the work. For his own part, Mr. Evans does not know of any Canadian cement upon which he would like to depend for any works under water.

Mr. Henshaw.

Mr. Rheaume has given us a good description of the usual form of Guard Lock (built on an alluvial formation) adopted by the Department of Railways and Canals. It differs but little from a lift lock, except in the absence of a breast wall.

It would add, however, to the interest, especially of those among us who are familiar with such work, if he would give some account of the difficulties, if any were actually encountered, especially in the foundation.

These, of course, would arise principally from pressure from the outside through the leakages he speaks of, and possibly from natural springs. We would like to know the maximum lift to which the lock is liable from the rise in the river, and also the causes and frequency or otherwise of its recurrence. These would give some idea of the pressure exerted when the water in the lock is at its inner level.

We would like to learn also whether the two pumps mentioned were used to remove leakage alone, or if there were also springs, and what the capacity and performance of these pumps were.

The plan at present adopted by the Government in the construction of locks is a great improvement on that of the Royal Engineers who built our first locks.

These being built by mathematicians rather than practical hydraulic engineers had their walls connected by inverts apparently with the object of resisting outside pressure.

The chambers of the old locks had walls built with parabolic faces connecting with the elliptical inverts which formed the bottom.

This has been found unnecessary, as the weight of the walls is ample to guard against pressure; which, indeed, is found to be very small, as a well made bank will stand alone for some time after the wall is removed.

The idea that the invert would resist pressure, in case leakage from without should find its way beneath the foundation, is also fallacious; since in such an event there would be serious danger of undermining, and the sooner it was discovered and remedied the better.

That a subtle but enormous pressure is often exercised by even apparently insignificant springs upon a tight bottom is very certain.

In 1882, a bottom similar to the one described in the "paper" was laid for the new lock at Ste. Anne de Bellevue. The chamber was 200 ft. long by 45 ft. wide. The lock pit was excavated in rock of Potsdam formation, the strata of which were much shaken and fractured. There was a dyke or fissure two feet wide running diagonally across the chamber filled with the usual detritus, out of which, at one point, issued a small spring with a slight mineral taste. Water in small quantities issued from crevices all over the foundation, which appeared to come from leakage beneath the puddle wall that separated it from the old lock; the latter being exceedingly leaky. The total quantity, however, was not so great but that the whole was easily removed by a six inch centrifugal pump, lifting about 15 feet and working about 6 hours a day. The spring was led away in a pipe laid in cement under the side wall, and is now used for drinking purposes by means of a pump on the lock bank. The bottom timbers were laid on "mud sills" let into the rock, and further secured by rag bolts 1¼ in. by 3½ ft. long (fox wedge bolts were not used because the rock was unsuitable) driven into long wooden plugs, which had been driven into holes drilled to receive them.

There was no trouble with water in concreting or cementing the chamber, and the whole foundation including planking was finished in apparently a most stable and satisfactory manner.

Two steam derricks were placed within the chamber, and about two courses on each side had been built, when the bottom was found to have risen suddenly in the middle some six or eight inches, and had it not been for the derricks it is probable that the mitre sills themselves would have been disturbed. Two inch augur holes were immediately bored all over the platform throughout which the water sprang three feet into the air but subsided gradually, and the bottom being weighted with stone gradually returned to its place. The borings showed that the entire bottom had been lifted, concrete and all. This shows one objection to the close planked wooden bottom, and there are others which lead to the conclusion that this form of construction has had its day.

The only good point about it seems to be that it resists erosion from the rush of water from the gate valves and from the wheels of steamers, but this can be avoided equally well by the use of good Portland cement concrete. It seems likely that wooden bottoms will be entirely abandoned, except perhaps where piling is necessary. The entire bottom in most cases might be made of concrete, including even the mitre sills platforms, and the mitre sills of iron castings filled in with concrete.

A hard wood plate might be placed with advantage at the bottom of the hollow quoins to give the necessary play to the socket piece of the gate pivot.

As Mr. Rheaume's paper does not go beyond the construction of a particular lock, it would be going too far to allude to other points connected with the general subject; but it is to be hoped that some of our members may give papers on the best mode of rapidly filling and emptying locks, to effect which many plans have been proposed, also on modes of opening and shutting gates other than those commonly in use.

**Mr. Dodwell**

In reply to Mr. Evans' enquiry with regard to Canadian Cements, Mr. Dodwell said that during the construction of the Ontario and Quebec Railway, between Smith's Falls and Toronto, he had had occasion to make some trials of Thorold and Napanee Cements, with a view to permitting their use by the contractors in some bridge masonry instead of Portland. Not having access to a proper testing machine, and being pretty well occupied at the time, the tests were not carried out on scientific principles, and they were somewhat crude and rough. He made a number of cakes, about 1 inch thick, of both neat cement and also with various proportions of sand. Some were allowed to set in air, and others were placed in water, after first drying somewhat in air. The general result was that the Thorold Cement showed marked hydraulic properties, and seemed to be an excellent article, setting both in air and water to a considerable degree of hardness. He would have no hesitation in using it with one to two volumes of sand for ordinary masonry.

The Napanee Cement failed to shew any hydraulic properties. Both the neat cement cakes and those with sand fell to pieces in water, and those left to set in air crumbled in the hand with but slight pressure. Judging from the samples he had tested, he considered it an inferior article and he would rather use lime. The cakes of both Thorold and Napanee Cement were broken after periods varying from one day to three about weeks. With other Canadian manufactured cements he had little or no acquaintance.

**Mr. Peterson.**

With reference to the statement that he had certified to the superior quality of Thorold Cement, Mr. Peterson remarked that he merely certified as to the correctness of certain tests made upon a barrel sent him by the manufacturer. The tests shewed the cement to be of very fair quality, but far inferior to Portland cement. In his own practise he had never used any Canadian cement for work under water with satisfactory results. He had used "Quebec" cement above water on the Intercolonial Railway, and found it, give very satisfactory results; but he had also known it to be so bad, that large quantities had to be thrown away after causing much trouble, and "Portland" cement was afterwards adopted over as much of the Intercolonial Railway as he was personally familiar with.

On the Toronto Water Works, the Commissioners insisted upon the use of Canadian cement under water, and the results were very unsatisfactory. The work was never water-tight, although a large amount of money was expended in endeavoring to make the work answer the purpose. Some of the work above water, laid in frosty weather, had to be taken down, as the cement, in the spring, was found to be no better than so much ashes. He had laid masonry in "Portland" cement in similar circumstances in very much colder weather, in fact with the thermometer nearly at zero, and in the spring had found the cement had set just as well as if laid in summer.

One of the reasons for the inferiority of our native cements is that some of the manufacturers know little or nothing as to the proper mode of manufacture, or as to the method of using it after it has been manufactured. In fact, one of them told me that his cement would not stand the test, because it had been mixed and tested neat, whereas it required at least two parts of sand to one part of cement to enable it to come up to the requirements. He was very much surprised to find that even when mixed in this manner it was much weaker than the neat cement.

Some of the manufacturers exercise little or no care in selecting the stone and less in burning it. Stones of all sizes are put in the kilns, and when drawn some of the cement is underburnt and some overburnt. Doubtless there is the material in the country for making a good cement, and it is to be hoped that the manufacturers will become acquainted with the best methods, and put them in practise so as to produce a cement in every way as reliable as Portland cement. Canadian engineers have only to insist upon a good cement, and the manufacturers will learn that they can produce it, and will do so.

Mr. Rheaume. The cement was obtained at Thorold, Ontario, and had already been highly recommended by prominent engineers. It was delivered fresh from the mills, according to the requirements.

With reference to teats as to its quality, the following observations were made:—

At the close of season 1885, only three courses of the chamber walls were laid. A portion of the foundation of the lock, at both ends of the south wall, was left incomplete when water was let in to protect the slopes of the lock pit and the masonry already laid.

In the following spring, the unwatering of the lock pit was resumed, and while proceeding to complete the foundation, in order to make proper connection, portions of the concrete previously laid had to be removed. The foundation proved perfectly impermeable and so firmly cemented that it was found hard to remove it by means of picks.

Then again, during the progress of the work, levels of each course of masonry were taken and no perceptible settling in the walls was noticed.

Thursday, 20th October.

E. P. HANNAFORD, Member of Council, in the Chair.

The following were declared to have been balloted for and duly elected as

### MEMBERS.

HENRY GEORGE CLOPPER KETCHUM.

WILLIAM RUSSELL RUSSELL.

### ASSOCIATE MEMBERS.

JOHN LOGIE ALLISON.

STUART STIRLING OLIVER.

### ASSOCIATE.

EUGÈNE RODOLPHE FARIBAULT.

### STUDENT.

FRANK McMASTER.

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*Paper No. 7.*

## SNOW SLIDES IN THE SELKIRK MOUNTAINS.

BY GRANVILLE C. CUNNINGHAM, M. CAN. SOC. C.E.

It fell to the lot of the writer to spend [illegible] winter of 1885-6 at the summit of the Selkirk Mountains, for the purpose of observing snow slides, with a view to the proper protection of the Canadian Pacific Railway from their effects. The following paper embodies a few facts that may prove of general interest to the Engineering profession.

The Selkirk Mountains form a chain lying to the west of the Rocky Mountains. They are divided from them by the Columbia Valley, running approximately north and south, and through which the river of the same name flows. This river sweeps round the northern extremity of the Selkirk chain, forming what is called the "Big Bend," and then flows southerly into Oregon Territory, scooping out a deep valley, which divides the Selkirks from the Gold Range, lying further to the west. The Selkirks are thus bounded on either side, and enclosed at their northern end, by the Columbia Valley. Their length is about 250 miles in Canadian Territory, and width from 50 to 80 miles. The range is cut across by the route of the Canadian Pacific Railway some 70 miles south of the Big Bend.

In general character these mountains are lofty, rugged, and steep; intersected and diversified by narrow passes, and precipitous, rocky canons. The height of the highest peaks is ten or eleven thousand feet above the sea; long parallel ridges of not much inferior elevation may be frequently observed in close proximity, forming between them a narrow V shaped valley, whose sides extend upwards, at an even and very steep slope, for five or six thousand feet, and along the bottom of which there flows a turbulent mountain stream. The geological strata is the lower carboniferous, the rock being for the most part the clay and slate shales of that system, with interlaminated quartz veins. Such rock necessarily crumbles and degrades easily under the action of the weather, and large masses of debris are thus constantly gathering in the valley bottoms, while the mountain sides are deeply scarred by gullies and fissures.

The Canadian Pacific Railway ascends the eastern slope of the Selkirks from the Columbia Valley by the Valley of the Beaver and Bear Creeks, following the valley of the former first for about 14 miles, and the latter for 6 miles. The altitude ascended in this distance is 2,200 feet, and as the valley of the Bear Creek falls very rapidly in the last 4 miles of its descent from the summit, the railway, in order to make the ascent on practicable grades, has to leave the bottom of the Beaver Valley some 6 miles from its point of departure from the Columbia Valley, and climb up on the mountain side, following the contour of the slope. The effect of this is to throw the line high up above the valley-bottom—at some points as much as eight or nine hundred feet—and to give deep crossings of the ravines or gullies above spoken of, by which the mountain side is fissured. Some of these bridge crossings are 150 feet deep, while one—that of Stoney Creek—is 286 feet deep, making, probably, the highest wooden bridge on the American Continent. The descent of the Western slope is made by the valley of the Ille-cille-waite River, following what has been named "Roger's Pass" out of compliment to the Engineer who recommended the adoption of this route to the company. Here, as on the eastern slope, the descent of the valley is at first so rapid that it is impossible for the railway to follow the valley bottom. But the difficulty has been cleverly got over, and the requisite fall obtained on a practicable grade, by running the line up a tributary valley and doubling back upon itself in the form of a loop. By this plan the line has been brought down to the bottom of the valley, at the cost of some three miles additional length, and the necessity for continuing it high up along the mountain side has been obviated.

The Selkirk chain forms, as it were, a lofty wall running north and south. Being very much higher than the mountains to the west, it is the first and chief barrier that the moisture laden currents of air from the

Pacific Ocean encounter on their eastward passage. This warm air is intercepted and the moisture condensed by contact with the cold Selkirks, entailing heavy rain in summer and deep snow in winter; and it is interesting to note that the snow fall on the western slope of the Selkirks (being the place where the first contact with the warm air takes places) is much heavier than on the eastern slope; while the average fall on the Selkirk range much exceeds that on the Rocky Mountains. The greater the difference in temperature, the larger will be the condensation taking place, and consequently the heavier the fall of rain or snow. Thus in cold winters the snow may be expected to be deeper than in mild. This conclusion is verified by observation. The winter of 1884-5 was extremely cold, the thermometer during the latter part of December marking, for some days, many degrees below zero, and reaching, on the 24th of that month, a minimum of—42°. This was succeeded by a January of great cold during the first half. The snow fall during that winter at the Selkirk Summit was very large, aggregating more than 30 feet in depth, while during ten consecutive days there was a fall of no less than nine feet. The winter of 1885-6 was much milder, and the total snow fall 15 ft. 9 ins. The mean temperature for the month of December was + 21¾°, and the lowest —1°; the snow fall during the same period was only 3 ft. 4½ ins. In January the mean temperature was + 2°, and the minimum —30°, while the snow fall was 7 ft. 2 ins. The greatest snow fall in any 24 hours occurred between a.m. of the 23rd and a.m. of the 24th, when 17½ inches fell with a mean temperature of —8°. From a.m. of the 23rd to a.m. of the 27th, 40¼ inches fell, while the mean temperature was 0°, and this was much the heaviest snow fall experienced in any four consecutive days. The lowest temperature occurred on the night of the 21st, when—30° was recorded; and it is significant that the period of lowest temperature immediately preceded that of greatest snow fall. February was a mild month; the mean temperature was + 27°, the minimum —2° (on the last day of the month), and the snow fall 2ft. 3½ins.

But though a high temperature causes a diminution of the snow fall, it is always accompanied by more wind than prevails with a low thermometer. Though there were no instruments for measuring wind velocities and pressures, still personal observation testified that during the mild winter of 1885–6 there were more frequent and more violent gales than during the cold winter of 1884–5. Often, too, while it was quite calm in the valleys, the gale could be heard roaring in the mountain tops. The effect of these frequent gales is to brush the snow off the exposed and prominent parts, and to heap it into the pockets and basins of the mountain side. These form the gathering places for the avalanches, or snow slides, which occur at intervals throughout the winter; and it can easily be understood how the masses of snow, thus packed in by the wind, increase until they lose their balance, as it were, and toppling over, or sliding out, rush down the mountain side, with accelerating velocity. As a matter of direct observation, slides are most frequent and largest during or immediately after very violent wind, when the thermometer is standing high. But from the preceding argument it seems probable that the wind, as the indirect agent, has more to do with the slide than the rise in the thermometer. There is never violent wind with a very low thermometer, and slides seldom occur at such temperature. Thus, though the snow fall is the prime cause of the slide, and the deeper the snow the greater the slide as a rule, yet we see that in a mild winter, with moderate fall, the more frequent and violent winds, as compared with a cold winter, tend to compensate for the reduced snow fall, by drifting the "pockets" to overflowing, and thus to maintain the avalanches at something like a constant quantity. The slides of the winter of 1885–6 were certainly less in bulk than those of 1884–5, but there was no such difference as would be inferred from a direct comparison of the respective snowfalls; and in some places slides occurred in the former year where there were none the year before. But though it is true that year by year the slides may be looked for to much the same amount, there are unmistakable evidences, in the extent and length of old slide tracks, partially covered with timber of some years' growth, that there are occasional winters when exceptional conditions prevail, and when the slides descend in stupendous volume.

There are two classes of slides; what may be called the "bench slide" and the "gully slide." The gully slide issues from a narrow and deep cleft in the mountain side, which extends upwards for perhaps one or two thousand feet. At the top of this cleft there is probably a deep pocket or basin in which the snow gathers. At the mouth, which is some 800 to 1,500 feet above the valley, the great heap of debris—the accumulation of many years—commences. It spreads out fan-like, and its width at the valley bottom may often measure over 1,200 feet. Winter after winter, and many times during the same winter, the slide rushes down the gully and shoots out upon the debris heap—the *talus* as it is called—loosening and displacing masses of rock in its course. These gully slides do not bring down large quantities of snow on each occasion; ten or twelve thousand cubic yards is about a maximum. The first slide probably follows the centre line down the talus, leaving in its course small heaps of hard packed snow. The second encounter-ing these obstructions, deflects to the right or left, following the line of least resistance; the third behaves in like manner; and so on, so that by spring the whole of the "fan" has been passed over, and the snow heaped up along its base.

The slope of these debris heaps varies from 1½ to 1, to 3 or 4 to 1, according as room is afforded in the valley for them to spread. The velocity of the slide depends upon the angle of the slope, the height from which it comes, and the condition of the snow. During early winter when the snow is light and powdery, and lying in this condition to a considerable depth, the slide is impeded by gathering snow as it descends, and the velocity is not very great, probably not exceeding 30 miles an hour. But later, when the slide-track has been worn smooth by frequent avalanches, the slide sometimes descends with terrific velocity. Observation and the careful weighing of various considerations induce one to rate this velocity as high as 100 to 120 miles per hour A measure is obtained from the velocity of the wind generated by the slide. It will readily be granted that a mass of some ten or twenty thousand cubic yards, descending rapidly, will of necessity cause a strong current of air, while at the same time the velocity of the current will not be greater than that of the mass generating it. On both sides of one of these fast snow slide tracks, at the bottom of the slide, may sometimes be seen the evidences of great wind force. Healthy trees, from a foot to two feet in diameter, are broken, leaving shattered stems 15 to 20 feet in height, split and torn as if struck by lightning. Sometimes the wind continues beyond the slide, tearing for itself a track through the standing timber, and leaving a sharply defined lane in its rear.

The velocity of wind required to do such work must be very great. The writer has personally noticed the action on standing timber, of a gale having a recorded velocity of 68 miles per hour (in Scotland, February, 1884), and though large numbers of trees were blown down, yet the effects were much milder, and the velocity plainly less than those of a snow slide wind. The effects produced by the latter are more comparable to those of the most violent tornado, the velocity of which has been recorded as over 100 miles per hour. Again, the velocity acquired by a body falling 2,000 feet freely in space would be 240 miles per hour. If we assume that on a steep slide track, having a similar vertical height, one half of this velocity were acquired—and with a good crust on the snow and other conditions existing favourable to velocity, this is not an unwarrantable assumption—it would amount to 120 miles per hour. In experiments made with a toboggan having on it a man weighing 180 lbs., on a snow slide track with a slope of 1 in. 36 (angle 15° 30′), it was found that the velocity acquired in a run of 318 feet was 43·36 miles per hour. The vertical height corresponding to this slope and distance is 85 feet, and the velocity that would be acquired by a body falling freely through 85 feet vertical is 50.6 miles per hour. Doubtless the velocity acquired by a toboggan is greater than that acquired by a snow slide on a similar slope, but still this experiment goes to shew that the velocity of a slide may be even considerably greater than that assumed. The writer had only one opportunity of personally noting the time of descent of a fast slide. This was one which occurred on the 5th of February. The time of descent, after issuing from the mouth of the gully, about 800 feet above the valley, was somewhat less than 20 seconds; the rate of final velocity would, therefore, be something over 50 miles per hour, without allowing for the initial velocity the slide may have had on leaving the gully. The slide track was not steep, and there were no wind effects produced in standing timber at the foot of the slide.

It is only from considerations such as the foregoing that any estimate of the velocity of slides has been arrived at. It is seldom that one happens to be sufficiently near to a slide at the time of its occurrence, or in a sufficiently safe position, to observe its time. But though there is evidence to show that very high velocities are sometimes attained, yet it seems probable that such is not frequently the case.

The other form of avalanche occurs when the snow gathers upon a wide "bench," situated perhaps two or three thousand feet above the valley. When the accumulated snow becomes too great to hold its position longer, it slips over the edge, and rushes down the mountain side, on a track from a thousand to fifteen hundred feet in width. The quantity of snow brought down in this manner is very much greater than that by the gully slides, and though the velocity is usually less the effects are more overwhelming. In one such slide, covering a track 1100 feet wide, the quantity brought down roughly measured 250,000 cubic yards, and in former years the quantity has been far in excess of that. These bench slides do not come frequently during the same winter, as do the gully slides. It seems as though the whole winter's accumulation were carried off in one effort, and not brought away piece meal as in the other case.

The weight of hard packed snow composing a slide varies from 25 to 38 lbs. per cubic foot, according to the state of the atmosphere and the amount of pressure to which it has been subjected in coming down. In spring, when wet snow rolls down in large balls, the weight is greater than in midwinter; but some slides that had come down in midwinter, when the snow was perfectly dry, weighed 34 and 35 lbs.

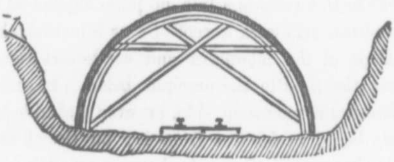
per cubic foot. The greater the velocity of a slide, the heavier the snow composing it becomes, owing to its being more compacted than when the slide travels slower.

The time of year when slides are largest and most frequent is from the middle of January to the latter part of February. These are "winter slides," formed of large masses of quite dry snow. In March and April there are numerous "sun slides," caused by the melting of the snow and ice, but these are not of any importance as compared with the others.

In erecting structures for the protection of the line of Railway, the governing principle is that they should offer no resistance to the slide. The force generated by the rapid descent of masses so large and heavy, is such that no structure that could be built would withstand it. Where the line runs along, and is "benched" into the mountain side, in the manner that has been described, the shed is constructed so as to continue the slope of the mountain, and shoot the slide across the track into the valley below; and the more nearly the slope of the shed roof coincides with that of the mountain side, the less will be the shock it receives from the passage of the snow. Where the line runs along the valley bottom, and slides descend from both sides, strong cribs are built parallel to the track, with roofing between, while the backs are filled in with earth at a gentle slope, that allows the slide to rise up and pass over the line. By carefully observing the action of slides, and erecting sheds at all places where required, the line can be so protected as to run trains in safety, and with regularity, throughout the winter, no matter how great the avalanches may be. Though the Company has not succeeded in doing this thoroughly during the past winter, yet this failure has arisen rather from the impossibility of erecting all the requisite sheds during the short preceding season, than from inability to cope with these great forces of nature.

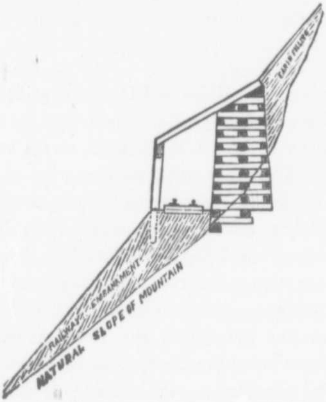
## DISCUSSION.

Mr. Schaub. The snow sheds on the Union and Central Pacific roads, in crossing the Rockies and Sierra Nevada Range, are very light and flimsy structures, as compared with those in the Selkirks, on the line of the Canadian Pacific Railway. The sheds, with the exception of, perhaps, a few in the Sierra Nevada Range, rather serve the purpose of a snow-fence than a snow-shed. They merely prevent the snow from direct fall and drift, especially the latter, from filing up the track in deep cuts and ravines, though there are along the route a great many snow-fences that also serve this purpose, as they ordinarily do in this part of Canada. At Sherman, at the summit of the Rockies, one finds merely an ordinary snow-fence along the track, as there is no chance for heavy drifting of snow. In section, the snow-sheds on the Union Pacific Railway resemble a tunnel.



The curves are made by bending the ribs of the roof, which are covered with boarding, and are heavily braced inside. As an evidence of their flimsy character, it might be remarked, that in mid-summer it is not dark in these sheds, owing to the light pouring through large rifts in the roof. In winter, the snow packs to a great depth on the sheds without excessively taxing their strength, as the snow is so thoroughly wedged in between the sides of the ravine. In the Sierra Nevada Range, the sheds are more durably built in order to resist slides and a heavier fall of snow, but even here no such snow-slides are experienced as in the Selkirks.

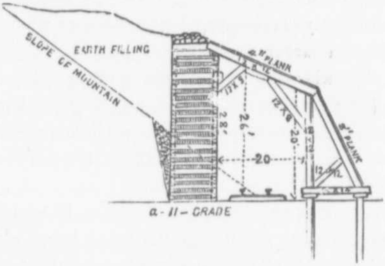
Mr. Smith. Mr. T. Vernon Smith stated that the snow-sheds in the Beaver Valley, where the track is benched into the side of the mountain, with an elevation of perhaps 2000 feet on the right-hand side going west, and a descent of 700 and 800 feet to the river on the left hand, consist of a heavy crib-work filled solid with stone against the mountain side, 15 or 16 feet broad at the base, and battering on the outside, perhaps, 3 or 4 inches to the foot, the fall next the railway being perpendicular. At the back of this, the space between the crib-work and the mountain is filled solid with earth-work, which is carried up above the crib-work so as to continue the slope of the mountain to the snow-shed.



The wall next to the river is a line of piles, capped at the top, and between this and the crib-work a roof of 4 or 5 inch planks is laid to continue the slope of the mountain and earth-work, and launch the fallen snow over the shed to the precipice below. In some places this crib-work is close to the mountain side, or even imbedded in it, while in others it may be 40 or 50 feet from it; but in all cases that had come under his observation, the space between was filled up solid with earth-work, and the first shock of the snow fell where the direction of its motion would be diverted more towards the horizontal than on the natural slope of the mountain, and would be taken either on this earth filling or on the crib-work. The roof itself is not calculated to take such a shock as would necessarily be inflicted by an immense body of snow striking it almost perpendicularly, but is intended to guide it over the track after its final direction has been given to it by the massive structure on the right hand side of the track. The work is heavy and expensive, and is very well put together. The diagram shews the section of a snow-shed about a mile west of Stoney Creek, where the slope of the mountain is unusually steep.

Mr. Wragge.

Mr. E. Wragge stated that perhaps he might be able to supplement the remarks made by Mr. Vernon Smith, inasmuch as he had made two visits to the Selkirk Range—one in the summer of 1885, before the observations made by Mr. Cunningham were taken; and the second in the autumn of 1886, when several of the snow-sheds were completed, and others were in course of construction. In most of those which he saw on the mountain slopes, the outer framework carrying the roof of the sheds was constructed of an A frame, and the piles were chiefly used where the shed was in the valley and where they were placed on both sides and roofed over with an ordinary strong timber roof, and where no cribwork was employed.



The attached sketch, which was given to Mr, Wragge by the designer of the sheds, Mr. J. H. Armstrong (the Resident Engineer of the Canadian Pacific Ry. in the Mountains), shews the form of shed adopted where cribs were placed on the mountain side. Mr. Wragge explained that the greater number of snow-sheds were placed near the summit, or in the valley of the Ille-Cille-Waet. The slides being more frequent there than in the Beaver River Valley, it was originally proposed to run the Railway on the north side of the Ille-Cille-Waet after passing the summit of the pass; but these slopes being subjected to the power of the sun were literally an almost continuous avalanche path, so that a shed, some miles in length, would have been rendered necessary; the line was therefore diverted from these slopes, and in order to get down into the valley, the "loop" referred to by Mr. Vernon Smith had been found requisite. The roof of the sheds was a source of much consideration to the designer, on account of the large boulders, weighing several tons, which are brought down with the avalanches; but it was understood that during the first winter, no case of any boulder having come through the roof had occurred; the principal trouble had been that the sheds in some instances had not been made of sufficient length, but Mr. Van Horne had informed him, they were being extended, and others were being constructed.

At some of the sheds, memorably one about $\frac{3}{4}$ of a mile in length, near the Glacier House, where there is a fine view down the valley of the Ille-Cilie-Waet, a track had been laid outside the shed, so that trains in the summer might keep outside, the shed being used only in the winter.

Mr. Cunningham states that the snow or rain fall on the western slopes is much greater than that on the eastern side, which is easily understood in connection with the conditions described; but, in the speaker's opinion, Mr. Henshaw.

he is in error in assuming the precipitation to be in proportion to the temperature instead of to the amount of vapour in the atmosphere. In snow fall, condensation begins at the temperature of 32° Fahr., and from that to a lower point the fall would be practically the same, the difference being in the dryness of the snow. But, as he says, "high temperatures are always accompanied with stronger winds;" it is, therefore, natural that a larger precipitation should be carried over to the eastern slope than when low temperature prevails. He shews that the snow fall in 1884–5, a very cold winter, was very much greater than in 1885–6, a much milder one, but he does not locate the fall. It would be instructive to know the relative fall on the eastern and western slopes in both winters.

It is well known that the precipitation on the Pacific Coast ranges is due to the vapour-laden winds from the ocean being arrested in their passage eastward by the lofty and frigid barrier these mountains present. The Andes, in South America, are so high as to form a complete bar; so that while their western slopes are deluged with rain or buried n snow, the eastern slopes and the plains beyond are an arid wilderness of rocks or sand, in which the streams flowing from their snowy summits rapidly dwindle away and disappear. This range becomes lower as it trends north, until in Canada a considerable proportion of vapour is enabled to escape over the summit and fall upon the slopes and country lying east. What proportion this represents it would be very interesting to know.

Other points not stated are the relative frequency and importance of the slides on the eastern and western slopes, and the difference, if any of the precautions required to evade them.

The modes given for ascertaining the velocity of the slides seem very doubtful and unreliable, the conditions of the phenomenon and the experiments being so dissimilar. The deductions from the force of the wind produced by the descent of the avalanche are very extraordinary, and to the speaker inexplicable. The only thing he knows to the effect of which may be compared is a railway train running at high speed. In such a case the disturbance produced in the air has a very limited area, and is inappreciable within a short distance from the track. A train running, say at forty miles an hour, in the autumn, will raise and violently agitate the fallen leaves scattered on the track; but there is very little tendency in them to follow the train, except in the immediate rear draft, and they settle down again not very far from where they rose.

The only reliable mode adopted was that of direct observation. Given the ascertained time, distance, and slope, and you have sufficient data for practical purposes, though of course mass, and condition of slope, would add modifying factors. Initial velocity can be neglected, as it is practically included in the observed speed.

Mr. Stoess.

Mr. Cunningham appears to theorize that a cold winter brings more snow than a milder winter; but as a colder winter he cites winters having cold periods of short duration. Now, snow falls during mild weather, and slides more frequently happen at such times; from all experience, it appears that slides are attended by a high thermometer, a low barometer, and occur during or after a heavy fall of snow; wind is also more prevalent during mild weather; therefore it would be generally reasoned that a heavy fall of snow takes place during a mild winter, that is during the mild weather of the winter, there being intermediate cold periods giving a colder record than a less severe winter as regards cold and snow.

Referring to the winter of 1884–85, it might be pointed out that the preceding summer and autumn were very wet, the rain changing to snow, and the snow only ceasing at the beginning of a cold period in the month of December; thus the snow had accumulated in large masses about the mountain tops, eventually discharging in the extremely heavy snow-slides of the following February.

Tempestuous seasons are always attended by great variations of the thermometer and barometer, whether the season be winter or summer, the country Canada or Australia.

The winter of 1886-87 was severe as regards snow fall and periods of cold, although preceded by a dry summer and a fairly dry fall. The coldest periods happened at the end of December, and middle of January and February; the records shewing throughout a colder average than the winter of 1885–86. The larger slides discharged only in the beginning of March, being about a month later than those of the previous two years, the later period being caused by the late snow fall.

The wind has, doubtless, a great influence on the slides, the direction of the wind governing the greater fall of snow on one side of the mountain ridges or the other, thereby causing heavier slides in some localities in different winters than in others.

As regards the weight of snow-slide material, I have weighed some as high as 43 pounds per cubic foot, but the average is about 30 pounds per cubic foot.

The theories on snow-slides as stated by Mr. Cunningham from his own observations have been proved to be on the whole true; but further experience is still required. It was, however, remarkable how closely slides were predicted last winter by readings of the barometer and thermometer—in fact the traffic could be, and to a certain extent was, safely regulated by it.

The drawings upon Plate VII, have been prepared by Mr. Stoess to accompany his criticism, and shew the various kinds of sheds built in 1886.

As regards weight alone, the design of the sheds exceed the requirements, but it is advisable to have heavy work in order to withstand the wrenching to which the sheds are subjected. The idea of the crib-shed is due to Mr. George Ellison, who was in charge during the winter of 1885–86, and was adopted with some modification. The sheds stood the test in a highly satisfactory manner in every way, there being in one instance, a snow-slide standing forty feet deep on a shed roof.

In the structures at present under construction round timber has been used to a much greater extent than last year, braced or framed work being adopted instead of the heavier crib-work. Those parts of the line that are being protected by sheds built this year are not subject to such heavy slides, and the idea of these latter sheds is that the crib shall simply and merely act as a retaining wall, the snow-slide itself to be carried over the track by the framed structure supporting a planked slope carried up to meet the natural slope of the mountain.

The following table gives the weather record for the Selkirk Section.

| | Month. | Snowfall | Depth of snow on Ground. | Thermometer. | | |
|---|---|---|---|---|---|---|
| | | feet. | feet. | Max. | Min. | |
| Winter 1886–87. | Dec. '86 | 9.92 | Greatest depth 10'.0" | +35 | -20 | |
| | Jan. '87 | 10.84 | | +32 | -16 | Heaviest snow fall 19 ins. in 24 hours. |
| | Feb. | 2.58 | | +36 | -36 | |
| | March | 8.00 | | +46 | - 7 | |
| | April | 1.75 | | +53 | +15 | |
| | | 33.09 | | | | |
| Winter 1885–86. | Dec. '85 | 7.75 | 4.0 | +37 | - 8 | |
| | Jan. '86 | 8.85 | 5.5 | +34 | -24 | Heaviest snow fall 27 ins. in 24 hours. |
| | Feb. | 5.75 | 5.5 | +49 | +5 | |
| | March. | 2.80 | 4.6 | +56 | 0 | |
| | April. | 0.35 | | +65 | +28 | |
| | | 25.50 | | | | |

Mr. Cunningham

In reply, the author of the paper regrets that he is unable to furnish more accurate statistics in regard to snow fall than those already given. No precise measurements were made in previous winters; but measurements taken with some degree of care, by a man residing at the Selkirk summit during the cold winter of 1884–5, shewed that the snow fall aggregated 30 feet, whereas, at the winter camp during 1885–6, situated near the summit, the snow fall was only 15-ft. 9-ins. On the western slope, during the winter last named, the snow fall exceeded that on the eastern by very nearly 50 per cent., but the writer has not now the figures at hand to give the result with greater precision.

The wind velocity of a slide is a very remarkable phenomenon, and not comparable to anything else in nature that the writer is acquainted with. That the wind is so produced there can be no manner of doubt, and it is equally certain that its destructive effects are such as have been described. Instances were observed where the slide in descending at some wide part of the valley encountered some obstruction, such as a rise of the ground, which caused it to diverge from the straight line, while the wind would continue in the line of the original path, tearing up and breaking a lane through the standing timber in a place that the slide had not touched. When the writer said " a *measure* of the velocity of the side was obtained from the velocity of the wind," he would more precisely have expressed his meaning by saying "an idea." As Mr. Henshaw says, the only reliable mode of obtaining the velocity is from direct observation. But it must be borne in mind that this is by no means an easy thing to obtain. It is by mere chance that one happens to see a slide coming down, and the first instinct, when the roar is heard, is to find out whether one is in a safe place or not. The slides come quite as often in the night as in the day time—that is the "winter slides," not those caused by the sun—which, of course, increases the difficulty of observation.

3rd. November, 1887.

JOHN KENNEDY, Vice-President, in the Chair.

***Paper No. 8.***

## NOTES ON PETROLEUM AS FUEL.

By L. M. Clement, M. Can. Soc. C.E.

Among the first trials in California of petroleum as fuel, were those on the ferry steamer "Thoroughfare," used for transferring freight cars across the Bay of San Francisco.

Results of the trials on this steamer were chronicled in the newspapers and freely quoted by railroad and engineering journals and in works on fuel.

No mention was made of the quality of the Ione coal, with which the petroleum was compared, nor of the theoretical value of either fuel.

Ione coal is a brown lignite of very inferior quality, too poor a fuel for general use, and compared with the ordinary commercial coal of this coast is about as three (3) tons to one (1).

The comparaison of such a coal with petroleum, without making known its quality, would create false impressions among those who have not given fuel values any thought. They, of course, would assume that the coal was at least equal to the coals ordinarily used.

The analysis below of the Ione coal will be sufficient to establish its theoretical comparative value with other coals.

ANALYSIS OF IONE COAL.

| | | |
|---|---|---|
| Water | 36·30 | per cent. |
| Volaitle carbonaceous matter | 35·10 | " |
| Fixed carbon | 16·15 | " |
| Ash | 12·45 | " |
| | 100·00 | |

Adding the water and ash, and deducting we have,

| | | | |
|---|---|---|---|
| Water | 36·30 | | |
| Ash | 12·45 | 48·75 | |
| | | 51·25 | per cent. |

51¼ per cent. of combustible material remains, and of this fully 20 per cent. will be used in the evaporation of the hygroscopic water contained in the coal; of the remaining 31 per cent., not over 80 per cent. will be the equivalent in quality of a good British bituminous coal.

It is probable that one ton of average British bituminous coal is equal in evaporative power to four tons of the Ione coal.

### PROXIMATE ANALYSIS OF PETROLEUM.

| | | |
|---|---|---|
| Heavy Naptha distilling between 170 and 250 degrees Fah | 3·76 | per cent. |
| Light illuminating distilling between 250 and 400 degrees Fah | 31·70 | " |
| Lubricating oil distilling between 400 and 520 degrees Fah | 39·10 | " |
| Asphaltum Maltha and loss | 25·44 | " |
| | 100·00 | " |

### ULTIMATE ANALYSIS OF PETROLEUM.

| | | |
|---|---|---|
| Carbon | 84·00 | per cent. |
| Hydrogen | 12·50 | " |
| Nitrogen and Oxygen | 2·40 | " |
| Water, ash and loss | 1·10 | " |
| | 100·00 | " |

The consumption of upwards of six thousand (6,000) tons of Ione coal, and thirteen thousand six hundred (13,600) barrels of petroleum on the steamer "Thoroughfare," shewed the cost per mile for coal and firemen to be $128\frac{73}{100}$ cents and for the petroleum and firemen, $62\frac{09}{100}$ cents, or $66\frac{64}{100}$ cents per mile in favour of the petroleum, *i.e.* 51·77 per cent.

| | |
|---|---|
| Price of Ione coal per 2,000 pounds | $3.90 |
| " petroleum per barrel | $1.69 |

Five hundred and fifty two and one half ($552\frac{1}{2}$) pounds of Ione coal were consumed per mile, and fourteen and five hundredths ($14\frac{05}{100}$) gallons of petroleum.

When a fair quality of coal is compared with petroleum, there is a very different shewing; instead of $552\frac{1}{2}$ pounds per mile, only $191\frac{3}{10}$ pounds of the Carbon Hill coal were consumed.

### ANALYSIS OF CARBON HILL COAL.

| | | | |
|---|---|---|---|
| Water | 1·50 p. cent. | 1·50 p. cent. | 1·70 p. cent. |
| Volatile carbonaceous matter | 34·00 " | 35·00 " | 36·68 " |
| Fixed carbon | 53·75 " | 54·35 " | 50·45 " |
| Ash | 10·75 " | 9·15 " | 11·70 " |
| | 100·— | 100·— | 100·— |

| Name of Steamer. | Tonnage. | Number, kind and size of engines. | | | | Remarks. |
|---|---|---|---|---|---|---|
| | | No. | Kind. | Ins. dia. | Ft. stroke | |
| Thoroughfare | 1012 | 2 | High Pressure | 22 | 7 | Boilers.<br>See Plate 7. A |
| Piedmont. | 1854 | 1 | Low Pressure Horizontal. | 57 | 14 | |

### TRIALS ON STEAMER "THOROUGHFARE" OF PETROLEUM AND CARBON HILL COAL.

13,708 miles with petroleum for four months.
$7,329.97=cost of petroleum " " including firemen.
53.47 cts. = $7,329.97 ÷ 13,708=cost per mile with petroleum.
$191\frac{3043}{}$ pounds of Carbon Hill coal per mile were consumed, costing 2½ mills per pound, or $5 per 2,000 lbs.
47.83 cts. = $191\frac{3043}{}$ × 2½ mills=cost of Carbon Hill coal per mile.
6.13 cts. = cost per ton of extra firemen firing Carbon Hill coal.

53.96 cts. = cost per mile of Carbon Hill coal, including extra firemen over those needed firing petroleum.
0.38 cts. = less cost of water per mile.

53.58 cts. = cost per mile of Carbon Hill coal.
53.47 cts. = cost per mile of petroleum.
0.11 cts. = in favour of petroleum per mile.
Price of Carbon Hill coal, $5 per 2,000 pounds.
Price of petroleum, $1.65 per barrel of 42 gallons.

During the trials on the steamer "Thoroughfare," with both fuels, gauge pressure, throttle and revolutions of the engine were the same.

Trials were also made of petroleum and Carbon Hill coal on the steamer "Piedmont" by the writer. Prices of both fuels were the same as on the "Thoroughfare."

317,500 pounds Carbon Hill coal were consumed on the trial, or 276.67 pounds per mile.
69.167 cts. = 276.67 × 2½ mills = cost of coal per mile.
17.557 " = cost per mile of firing coal.

86.724 " = cost of coal and firing per mile.
20,124 barrels of petroleum were consumed in 44,307 miles, costing $33,204.60.
74.940 cts. = $33,204.60 ÷ 44,307= cost per mile
9.576 " = cost of firing petroleum.
84.516 " = cost of petroleum and firing.
2.208 " = Difference in favour of petroleum.

With the coal the "Piedmont" made the trips in nineteen (19) minutes and with petroleum twenty (20) minutes, from the go-ahead to jingle bell.

Steam gauge pressure would fall in crossing, and while in the slips it was necessary to continue the burning of petroleum, or in other words, it was necessary to bottle the steam, while the steamer remained in the slips, otherwise the trip could not be made even in twenty (20) minutes.

Using Carbon Hill coal, steam pressure of fifty (50) pounds (highest allowed by law on this steamer) was easily maintained, and while lying in the slips, doors and dampers were closed.

Assuming that the consumption of fuel on the same steamer varies as the square of the speed multiplied by the distance, the ratio would be 1 to 1.109.

74.94 cts. = cost of petroleum for time of 20 minutes.
83.108 " = 74,94 cts. × 1,109 = cost of petroleum for speed of nineteen (19) minutes.
9.576 " = cost of firing petroleum.
92.684 " = cost of petroleum and firing to make time of nineteen (19) minutes.
86.724 " cost of coal and firing.
5.90 " difference in favour of coal at equal velocity, or time in crossing.

The result of the trials indicate that petroleum on the steamer ‘ Thoroughfare ” is slightly cheaper than Carbon Hill coal, with petroleum at $1.65 per barrel and Carbon Hill coal at $5 per 2,000 pounds.

On the "Piedmont," petroleum is the cheaper if no value is placed on the difference in time.

Since the above trials were made petroleum has been reduced to $1.40 per barrel, a reduction of about 15 per cent.; the price of Carbon Hill coal remains the same. This reduction so far as the fuel value is concerned, places petroleum beyond comparison, although there may be some question as to its safety on passenger steamers.

The apparatus for supplying the petroleum to the furnace is substantially the same as that used in Russia, and is so constructed that a jet of steam meets the petroleum at the mouth of the burning pipe atomizes it into a finely divided vapour, which burns with a loud roaring noise.

When the supply of petroleum is properly adjusted there is no smoke and the combustion appears complete.

## DISCUSSION.

Dr. Dudley. The experience of the Grazi-Tsaritzin Railroad in Russia, which Dr. Dudley visited last year, indicates that for heat production a pound of petroleum is as good as 1¾ pounds of coal. This figure, which Mr. Thomas Urquhart, the Locomotive Superintendent of this Railroad, has drawn from a year's consumption on 143 locomotives, is confirmed by the experiments made on the Pennsylvania Railroad during the last six months, and also by other experiments on petroleum burning elsewhere, that have come to his knowledge.

The coal used against the oil in Russia was a fine quality of Anthracite, and also Bituminous coal of much the same quality as mentioned in Mr. Clement's paper under the name of Carbon Hill coal. The coal used in the experiments on the Penna. R.R. was Westmoreland and Penn. Gas, which gives an analysis almost the same as the Carbon Hill coal.

The oil principally used in Russia has a flashing point of about 280 degrees, a burning point of about 325 degrees, and weighs not far from 7.3 pounds per gallon. The oil used on the Penna. R.R. was very similar in composition.

Still further, the experiments of Mr. Urquhart indicate that where all the economies are taken into the account, a pound of oil is as good as two pounds of coal. The ascertained economies which have been counted in making this estimate are, a saving in the handling of fuel and ashes, and economies in repairs to locomotives. It is undoubted that there are still economies connected with fuel oil that have not yet been worked out, so that the balance sheet between coal and fuel oil may be fairly regarded as having some things still not mentioned, in favour of the oil.

Using the kind of coal and the kind of oil mentioned above and the ratio above referred to, the following results are obtained:

Suppose the oil to weigh 7.3 pounds per gallon, and that a barrel of oil contains 42 gallons, 6½ barrels of oil make almost exactly a ton of oil. The price, therefore, of 6½ barrels of oil is the price of a ton of oil. This divided by 1¾ gives the equivalent price of a ton of coal, when the fuel account alone is considered, and divided by 2 gives the equivalent price of coal when all the ascertained economies are considered.

The above data reduced give the following simple rule. Multiply the price of oil per barrel by 3.71, and the product will be the equivalent price per ton of coal, when fuel account alone is considered, or multiply by 3.25 and the product will be the equivalent price per ton of coal, when all ascertained economies are considered.

These data enable the calculation to be made very quickly as to whether it is better to use coal or oil in any locality. If you are considering oil in competition with coal multiply as above. If you are considering coal in competition with oil divide the prices of coal per ton by the above factors, and the quotient will be the price you can afford to pay for oil per barrel. Of course, if the oil used weighs more or less per gallon than the figure given above, the factors will be changed accordingly, and still further, if a barrel of oil is more or less than 42 gallons, the figures must be changed.

Mr. Blackwell.

It may be safely stated that unless it be natural gas there is probably no more handy and simple form of fuel than a burning jet of atomised petroleum. For instance, with a barrel of petroleum, a few feet of gas pipe, and a jet of steam from the boiler, a furnace of about 8 cubic feet capacity can be kept at welding heat for 10 hours. The whole matter simply resolves itself into a question of cost.

At the Keystone Spring Works in this city, two re-heating furnaces for railway spring work were run with petroleum for six months. The system was abandoned simply on account of the excessive cost of the oil in this market.

The average result of six months work may be stated as follows:—

| | Quality. | Value. | Am't.consumed per day. | Cost per day | Equivalents. |
|---|---|---|---|---|---|
| Coal. | Lehigh (best) | $6.50 per ton 2240 lbs. | 425 lbs. | $1.04 | 1 ton of coal at $6.50 |
| Oil. | Gas Oil. | 5c. per gallon. | 36 gals. | $1.80 | 180 gals. of oil at $9.00 |

In fact it may be stated broadly and in round numbers, that oil must be bought in this market at about 2¾ cents per gallon, to compare favourably with Anthracite coal, and at about 2½ cents per gallon to compare with Nova Scotia coal. The price of oil in this market today is about 4½ cents per gallon.

The burner which was used in this instance is here for your inspection. It was found advantageous to keep the oil in the main supply tank at a temperature of about 80° F., in order that the oil might reach the burner in a thoroughly thin and fluid condition, otherwise the paraffine wax in the oil would have not only clogged up the pipes and burner, but an actual waste of fuel would have occurred, owing to some of the paraffine wax reaching the furnace in a semi-solid state, and passing away up the flue unburnt, in the form of brown smoke.

It was also found very desirable and advantageous to super-heat the steam in its passage towards the burner. This can readily be accomplished by passing a few feet of the steam pipes through a portion of the brickwork of the furnace to which the burner is attached, so that it may be moderately heated without being exposed to the full heat of the furnace.

The experiment at the Keystone Spring Works was made two years ago, and improved burners, which possibly give a more efficient and economical result, have come into use.

That gigantic corporation, the Standard Oil Co., in some parts of the U. S., where they have a larger product of petroleum than they can market, are offering their fuel oil to manufacturers and fuel users generally, at 65 cents per barrel, or say 1½ cents per gallon, with a guarantee that 150 gallons (i. e., $1.85 worth) are equal to 1 ton of bituminous coal. While this may probably be slightly overstated, yet it is, without doubt, very near the mark.

At the works of the Keystone Spring Co., in Philadelphia, nothing but fuel oil is used. In these works about 5,000 tons of bars of steel per annum are re-heated and worked up into railway springs, and a superior burning device has been adopted, of which a tracing is submitted for inspection.

After an experience of three years, it has been found, on the average, that 152 gallons of oil (Am.) at 2¾ cents per gallon, worth $4.18, are equal to one ton of Lehigh coal at $5.00 per ton (2240). In addition to this, the entire expense of coaling up furnaces, clearing out ashes, carting ashes away to dumping ground in distant parts of the city, and the handling of coal is saved, which is estimated to amount to $800 per annum. Under date of October 29, Mr. Schoer, Superintendent of the Keystone Spring Works, Philadelphia, states as follows:—

"We think we save 20 per cent. by the use of fuel oil at 2¾ cents per gallon, as against Lehigh coal at $5.00 per ton. In addition to that we get a better product from our furnaces, on account of the entire absence of sulphur in the oil; we also get more heat from our furnaces in a given time, on account of the furnaces not being checked and cooled down slightly every time we coal up."

Mr. Barnett. Mr. J. D. Barnett's experience with petroleum as a fuel dates back some 18 years when the apparatus shewn on the accompanying drawing exhibited was experimented with in a locomotive engine at Montreal.

A cast-iron box, or retort, occupied the place of the grate at the bottom of the furnace. Through independent pipes, air, steam, and oil were delivered within the retort, the under side of it being heated to assist in volatilizing the oil, the combined vapours or gas passing through and around the regenerative metal burners, where combustion took place. Various styles of burners are shewn, and were experimented with. The heating of the retort could be accomplished by waste heat, or by flame from burners fitted in its base, taking their supply of gas from the upper part of the retort.

The result was unsatisfactory; the conversion of oil to gas appeared to be imperfect; probably the wax gathered, and closed some of the passages; the air admitted internally was in volume not a fraction of what was required, and that admitted externally (or around the sides of the retort) had a cooling effect upon it, and as this air had no fair opportunity of getting warmed and mixed, and also as metal burners (or contact with metal) at any temperature whatever, tend to prevent —even when it does not quench—flame combustion, it is not surprising that the evaporation of water was low, the products of combustion densely black, depositing soot thickly, and that they were pungently offensive in odor.

It is to be regretted that Mr. Clement, in his paper, did not use some more convenient unit of comparison than the local market costs of the fuels experimented with, as the first impression received from it is that crude or natural oil has but a slightly higher calorific value than average bituminous coal. A closer attention shews, that with the compared fuels at prices current at given time and place, oil had not the commercial advantage which its superior energy as fuel would naturally give it.

The analysis of Ione coal clearly indicates its poor quality, but as only a rough approximation to the calorific value of even *good* fuels can be made from the information given by simple analysis, much less can the value of a lignite be so obtained.

If analysis could be taken as a basis for comparison, the Carbon Hill coal with 88 per cent. of combustible matter is equal to *average* British coal, and the consumption of Ione coal for equal evaporation should be, according to Mr. Clement, four times that of C. H. coal, but it is only 2.88 times.

Inferring that the oil is measured by the U. S. gallon, and that it has a s. g of .85, its thermal value per unit weight compared with Ione coal is 5½ to 1, and with C. H. coal 1·91 to 1·00.

A comparison of market values shows that C. H. coal costs per lb. 25 cents, and oil 55 cents, that is, they are as 1 to 2·2. In other words, the experiment shews oil to have a thermal value of 1·91 and a cost of

2·2, so that any industrial economy in its use must have resulted from the saving of labour in *handling* the fuel and ashes.

A comparison on the basis of combustible matter contained per lb. of fuel shews ($\frac{96\cdot5}{88\cdot0}=1\cdot09$) that with but 9 per cent. additional combustible, oil has 2·2 times the thermal value of coal absolutely realized. That is—per lb. of actual combustible—oil will do twice as much work as C. H. coal.

Any result varying far from this figure would have been open to serious question, even if the percentage of combustible in the coal had equalled that in the oil, and the explanation for this apparent anomaly —though often lost sight of—is simple.

Accepting the theory that heat is motion (rapid molecular movement), then the greater the freedom or the looser the particles of carbon, the greater will be the utilizable amount of heat developed, because a smaller part of its energy is consumed in the mechanical work of giving its atoms that freedom necessary before they can swing (vibrate) freely. In other words, in addition to its chemical energy, it has *potential* energy due to its condition (position). The old terminology would say that the oil had absorbed latent heat in being raised from the solid to the fluid state.

It is seldom forgotten that heat is absorbed (work done) in changing fluid to a gas, but the fact is not so often brought home that energy is similarly used (heat rendered latent) in converting solids to fluids. Every unit weight of fluid fuel has within itself the latent heat of fusion; hence the poorest fluid fuel has a higher thermal power than the richest solid, and in solid fuels their value per unit weight is usually inversely as their densities. Even Mr. L. Urquhart, in making a comparison between oil refuse and coal, infers that Anthracite should have a higher evaporative power than bituminous coal, because it has a higher percentage of carbon; whereas, the law that compression or compactness inversely qualifies the thermal value of all fuels comes into operation here, and the effect is tha Anthracite has not the thermal position that its excess of carbon should give it over bituminous coal, whatever other advantages it may possess for domestic and metallurigical purposes. One main reason why Welsh Anthracite has not been extensively used is, it may be inferred, because it is a more compact substance than American Anthracite.

This explains why the application of the ordinary formula (Dulong's) to a simple chemical analysis of fuel was often far from giving even an approximation to its industrial value; and if faulty when applied to coal, it should never be, although it commonly is, applied to hydro-carbons. It is probable that Dulong's formula is based on carbon as a solid, and hydrogen as a gas, and it is open to question if hydrogen is in a gaseous state when combined with coal, so that the formula is untrustworthy for both constants used. Hence the necessity for such practical tests as those carried out by Mr. Clement, who it is hoped will tell more about the type of spray-jet used, and its actual location, about the boiler, the shape and size of furnace, and, if possible, the temperature of the escaping products of combustion in the smoke-box; also if any part of the furnace—especially that on which spray and flame would impinge—were faced with fire-brick; and lastly, the amount of air supplied to the furnace; as the total absence of smoke, and the lower steam pressure obtained when oil was burnt—when compared with other petroleum experiments—lead to the inference that an excessive supply of air was admitted, that it was cold, and perhaps admitted close to furnace sheets, or perhaps that the temperature of the steam passing through the injection jet was too low to produce the maximum effect.

Certainly oil fuel had the poorest effect on the Piedmont, with a low-pressure steam jet to feed the oil into the furnace; and there can be no doubt that the mechanical work done in giving motion to the oil and changing it into spray would further condense the steam, so that it would enter the furnace as a vapour, not as a gas. It is because work is performed by the jet, that *super-heated* steam for injection gives a better result, not only with hydro-carbons, but with dust fuel also.

Mr. Barnett next described the injector or spray-jet as used by Mr. T. Urquhart. (A copy of his drawing is appended to this paper, see Plate VII. C.) It is practically the standard apparatus for delivering fluid fuel in Southern Russia, not only in locomotive and stationary service, but also in the steamships plying to and from its ports. In such an instrument there is the least possibility of carbon solidifying to coke and choking the mouth of the nozzle. In most other forms of spray nozzles it is at times necessary that the oil flow should be cut off and steam at full pressure turned through the oil passage, with the object of clearing it by blowing out all collected impurities.

The practice usually followed in raising steam from cold water, if pressure cannot be borrowed from a companion boiler to work the spray injector, is to light a wood fire in the furnace, which is kept going until steam of just sufficient pressure to start the injector is developed, after which the wood fire is dispensed with. Many engine-houses are now equipped with a continuous steam pipe having suitable branches and couplings to all stills, so that if one boiler is alive any or all others using fluid fuel can be raised from cold water to a full head of steam in twenty minutes, while it ordinarily occupying two hours to do this with bituminous coal unassisted.

The use of fluid fuel—whatever types of injectors were used—did not prove a success until the surface upon which spray was thrown was lined with fire-brick; and better results have followed the use of a combustion chamber (within the furnace) whose sides, top, bottom, and one end are all of refractory material. This also has been improved upon by freely perforating the chamber walls with air passages, so that not only is the supply of air liberal in amount and well distributed, but its temperature is raised before meeting the oil-spray; an incidental advantage is, that the life of the fire-brick is materially lengthened. The later and more perfect chamber, as used by Mr. Urquhart in a locomotive, is shewn on Plate VII C, the major part of the structure being carried in what was originally the ash-pan, the air inlets being controlled by its damper doors. The injector is located below the foundation ring of furnace.

The risk in steamship service—resulting from the formation of explosive gases at comparatively low temperatures in the bunkers carrying the stored fuel—is practically *nil* where (as in the boats of the Caspian Sea and the Sea of Azof) refuse from the refining still is used. And it should not be forgotten that the injector shown on Plate VII. C. is, with the one hundred and forty locomotives of the Grazi and Tsaritsin Railway, used exclusively in feeding this safe fuel.

It is not easy to answer the question, "are further economies in the burning of fluid fuel possible?" laboratory experiment not having settled the theoretical or ultimate thermal value of fuel in this favourable condition, it cannot be said how near to this limit present practice has attained; but the inference, drawn from a comparison of many experiments, is that as yet the goal is afar off.

To illustrate the use of crude petroleum for the reduction of metal and ore Mr. Barnett quoted from Mr. W. K. McClees, Secretary of the Poughkeepsie Iron and Steel Co.: "We have two deoxidizers, each over a puddling furnace. * * * They were filled with pulverized magnetic ore and pulverized charcoal. * * * As it requires about twelve hours to deoxidize the ore, the furnaces were both charged with scrap-iron, in order to get the heat utilized, and make bar while waiting on the ore. The petroleum was turned on from a half inch pipe which entered a blast tuyère, anatomizing the oil completely as it entered the combustion chamber of the furnace. A half shovelful of burning charcoal ignited it in ten seconds after entering, when a blast near by carried the flame over the bridge upon the iron, passing on through the deoxidizer, then through the boiler. The rapidity of the melting of scrap astonished old iron-makers, and the quality of the bar, considering the quality of the scrap, was also astonishing."

This favourable result no doubt can be excelled if the fuel is converted into gas in a separate retort, and delivered into combustion chamber mixed with hot air.

Mr. T. B. Brown remarked there is no doubt of the possibility of using liquid fuel on steamships, as in the instances mentioned in the paper just read, the Black Sea steamers, and Mr. Tarbutt's experiments on the "Himalaya" and "Flora." Shipping men have been much interested in this question, and I have seen very exhaustive reports from the consulting engineers of some of the large steamship lines. Mr. Brown

The chief attractions of liquid fuel are its greater specific gravity as compared with coal, and consequent saving of cargo space; its higher evaporating power—requiring less oil than coal for a given quantity of work—and the great economy in the stoke trade—by the doing away with stokers—who would be replaced by an attendant. But the use of oil fuel requires that it shall be obtainable at a certain price, and everywhere where coal is, if it is to compete. No sane steamship owner would dream of liquid fuel if there was a prospect that his supply might run out and no means of replenishing at hand. The Black Sea steamers running in the oil trade are not a criterion of general trades.

Special arrangements of furnaces, steam injectors, and full pumps are required; also an auxiliary boiler to get up steam in the first instance, and a distilling apparatus to replace the fresh water exhausted by injector, in order to counteract the increased tendency to scale.

Another objection to oil fuel is fear of explosion, and this alarm is strongly entrenched in the commercial mind.

Probably the ballast tanks could in some degree be adopted for storage, and the oil being heavier than water would, in most cases of leakage, be covered with water; still the presence of the danger is felt, especially in passenger steamers.

And lastly, the price of oil must be greatly reduced before it can compete seriously with coal. At present, in the U. K., a ton of oil costs twice as much as a ton of best coal, and this disparity would be greatly increased as the steamer got farther from the oil centres.

Steamship men realize that liquid fuel is one of the possibilities of the future, but not sufficiently imminent to cause any anxiety as to the depreciation of their property by its sudden adoption.

The paper gives interesting and valuable facts as to the use of petroleum oil on the Pacific coast, but they scarcely afford sufficient data for general use. The discussion has so far shewn that it is much superior to coal for industrial purposes, particularly where it is desirable to maintain a regular temperature, as in smelting, etc. It saves Mr. Henshaw.

labour in handling, and space in storing; is cleaner, and avoids much cost and inconvenience in getting rid of the products of combustion. The various appliances for its consumption are so simple that there is little margin for improvement, economically speaking, so that, on the whole, the chief points regarding its adoption may be reduced to the questions of safety and cost. Its chief danger arises from liability to explosion from generation of gas, but there would seem to be no difficulty in contriving tanks that would be perfectly safe. Another danger is the effect of its strong odour upon delicate goods, as in a ship's cargo, but this also can be obviated.

The cost of its handling, storage, and use, compares very favourably with that of coal. So far the balance between oil and coal seems decidedly in favour of the former, and the question becomes one of first cost.

Here the evidence of Mr. Blackwell and others, is to the effect that at a certain cost, it has been found unprofitable, and the opinion has been expressed that in order to be profitable it should not cost over 2½ cents per gallon, at the current rate of coal. But it was shewn that oil is now to be had at 60 or 70 cents a barrel, equal to 1½ to 1¾ cents per gallon. Now, if this price is maintained, the question appears to be settled. But will it be maintained?

It is known that two great monopolies control the oil interest, The Standard Oil Co. in the Western Continent, and the Nobel in the Eastern. How this difficulty is to be overcome it is hard to say. No one can be blind to the fact that the present tendency in commercial and industrial matters is towards concentration of capital, and the extinction of small capitalists. The Inter-state Law unquestionably owes its existence to a desire to combat this tendency, but more than this is necessary if the spread of socialism and anarchy, which this concentration provokes and fosters is to be prevented. For engineers, however, these facts seem to point to the necessity of fire-boxes and furnaces which can, without difficulty, be quickly converted from oil burning to coal burning purposes, for without such a precaution there seems little likelihood of the use of oil as a fuel becoming general, for a very long time at least.

# APPENDIX.

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See K for the Dunkard Creek oil wells of Greene county.

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17th November, 1887.

JOHN KENNEDY, Vice President, in the Chair.

The following candidates were declared to have balloted for and duly elected as

### MEMBERS.

| | |
|---|---|
| PETER S. ARCHIBALD. | WILLIAM BROUARD MACKENZIE. |
| ALEXANDER WILSON COOKE. | WILLIAM CALDWELL MITCHELL. |
| JOHN WATSON CHANDLER. | EDWIN GILPIN MILLIDGE. |
| NARCISSE BELLEAU GAUVREAU. | ROBERT FITZGERALD UNIACKE. |
| EDWIN GILPIN, JR. | LOUIS ANDRÉ VALLÉE. |

### ASSOCIATE MEMBER.

FREDERICK WILLIAM COWIE, B.A.SC.

### ASSOCIATE.

GEORGE LAWSON, PH.D., L.L.D.

### STUDENTS.

JEAN LEON CÔTÉ.
FREDERICK LYON FELLOWES.
HERBERT WILLIAM ARCHER KILGOUR.

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***Paper No. 9.***

## THE WORKS ON THE RIVER MISSOURI AT ST. JOSEPH

BY H. H. KILLALY, M. CAN. SOC. C.E.

The works which form the subject of these notes were undertaken in connection with a bridge, which was, at the same time, being built across the Missouri River, at St. Joseph, Missouri.

A general description of the latter, as to location, etc., is necessary to explain the circumstances under which the former were undertaken.

These works were built under authority of an "Act of Congress," approved March 5th, 1872; and entitled: "An Act to authorize the "construction of a bridge across the Missouri River, at or near St. Jo-"seph, Missouri." In this Act it is stated "that the corporation build-"ing said bridge may, if not unauthorized by the provisions of its "charter of incorporation, enter upon the banks of said river, either "above or below the point of the location of said bridge for a distance "of seven miles; and erect and maintain break-waters; or use such other "means as may be necessary to make a channel for said river; and "confine the flow of the water to a permanent channel; and to do whatever may be necessary to accomplish said object; but shall not impede or obstruct the navigation of the said river; and all plans for "such works or erections upon the banks of the river shall first be submitted to the Secretary of War for his approval.

"This Act also provides that the bridge, at the option of the corporation building the same, may be built as a drawbridge, with a pivot "or other form of draw, or with unbroken continuous spans; provided, "that if the same shall be made of unbroken continuous spans, it shall "not be of less elevation in any case than fifty (50) feet above extreme "high-water mark, nor shall the spans of said bridge be less than three "hundred and fifty (350) feet in length. That if a bridge shall be "built under this Act, as a drawbridge, the same shall be constructed "as a pivot drawbridge, with a draw over the main channel at an "accessible and navigable point; and with spans of not less than one "hundred and sixty (160) feet in length in the clear on each side of the "central or pivot pier of the draw, and the next adjoining spans to the "draw shall not be less than two hundred and fifty (250) feet, and "said spans shall not be less than thirty (30) above low water mark "and not less than ten feet above high water mark."

In selecting a location for the bridge much scope was not allowed to the engineer, as the terms of his instructions required that the bridge be placed within the limits of the corporation of the city of St. Joseph.

These restrictions gave a distance of only about 2½ miles, in which to select the best location for the bridge. More extensive surveys were, however, required in order to obtain a knowledge of the river, with a view to controlling its movements and compelling it to follow a permanent course through the bridge. Within the above described limits, soundings, and borings to rock, were made upon several trial lines, and finally a location was selected, on the east side of the city, within the corporation boundary, and at a point where, in the opinion of the chief engineer, a bridge could be constructed more economically than at any other point within the fixed limits, and where it was considered that the natural formation of the river offered greater facilities than at any other point in the neighbourhood or within a distance of some miles.

The location of the bridge was fixed at this point for the following reasons:—

1st. That the channel, both at high or low water, was narrower than at any other point.

2nd. That the bed rock was found at a less depth than elsewhere; and in very regular form, varying from 45-ft. to 48-ft. below ordinary water.

3rd. That the permanency of the banks was greater than at any other point embraced in that portion of the river surveyed in connection with this work.

4th. That at this point the channel had, for a great many years, followed the same course, hugging the east bank, and unaffected by the many changes taking place in the stretch of the river above. The width of channel at the site chosen for the bridge, was, at ordinary high water, only 1500 ft, and at ordinary low water, 350 ft.; the depth at low water being from 15-ft. to 20-ft.

The treacherous nature of the Missouri "bottom," together with the constant changes which occur in the channel, rendered it necessary that the piers should be placed on the bed rock, and the lowness of the banks settled the question of a high or low bridge, in favour of the latter.

The masonry of the bridge, as built, consists of one small abutment on the east bank, and five river piers; the former placed on the top of the bank and founded at a depth of 3 feet below the natural surface; the five latter piers built upon inverted caissons, and sunk, during to bed rock, at a depth of 45-ft. to 48-ft. below ordinary low water.

The superstructure is of wrought iron, of the form known as the "Pratt Truss," and carries a "through" single line of R.R. track and carriage way combined, at a level of 12 feet above the highest water, or of 80 feet above bed rock.

The spans are as follows:—East shore span, 80-ft. from centre to centre of piers; pivot draw span, 364 feet over all, giving two openings of 160 feet each; three fixed spans, 300 feet centre to centre of piers.

From the above description of the bridge, it is seen that the total width of the natural channel at low water, is only 350 feet; and the whole of this channel is covered by the 364 feet draw-span. The pivot pier being placed exactly in the centre of the low water channel, a clear opening of 160 feet is given, on either side, for the passage of vessels.

It is evident, therefore, that in order to preserve uninterrupted navigation of the river, the low water channel must be controlled, and compelled to run through the draw span; the high water channel must also be watched, and means taken to prevent a cut-off or any serious change taking place. This involves the supervision of the river for some miles above the bridge. Equal care is not required below the bridge, where, only at one point, can any danger be anticipated. This would occur, only in case of the neck of the main "bend," at a distance of 3½ miles below the bridge, being gradually cut away; a calamity to be feared only in the distant future.

The accompanying map shews a portion of the Missouri River, surveyed in connection with the bridge works proper, as well as with the work for the diversion and control of the river in the vicinity of the bridge. The length of the river surveyed was in all, about 13½ miles, comprising one complete "bend," which represents the general character of this river for a great portion of its length. The river at this point runs through a valley of from four to six miles in width, enclosed by ranges of bluffs or rolling, knolly hillsides, of from seventy-five to two hundred feet in height above the river water.

The bluffs on the Missouri bank are composed of stiff clay, while on the Kansas bank, rock crops out at Belmont and Wathena. The clay banks, when excavated and exposed to the weather, stand for a long time with little change; this was instanced in St. Joseph, in 1871–73, where many streets were graded down to a depth of 30 to 40 feet, while the lots, with houses built upon them, were left standing, the only means of access to and from the street, being by stairways placed in a very nearly vertical position in front of each house. The nature of these clay bluffs is such that they are affected but slowly by the action of the flood, except in cases where undermining is caused by the washing out of sand and gravel deposits. In such cases, large slides occur at intervals. The current after striking at the foot of these solid banks, at an acute angle, is deflected gradually, and after following the bank for some distance, is turned from it, and directed into a course tending towards the opposite side of the valley. The "bottoms," or lands situated between the high sides of this valley, are generally formed of sandy alluvial deposit, timbered in part with heavy growth of cotton wood and other trees. In other parts, the later formation of the deposit is indicated by the smaller growth of timber, which gradually diminishes in size, until upon bars of recent formation a short growth of brush, only, is found. In the low ground, however, in front of the eastern portion of the city, and for some distance downwards, along the Missouri shore, the bank is composed of the toughest sort of clay, called "gumbo," in western language. This stands almost vertically where washed by the current, and wears away but slowly.

In sinking pier No. 1 to bed rock at the foot of this bank, sand was struck at a depth of 20 feet below low water, and was found to extend to bed rock, forming a stratum 25 feet in thickness. This accounts for the subsidence of portions of this bank, which occurred during the progress of the work. The great changes in the course of the river occur at times of flood. Cut-offs occur also at times, caused by the wearing of the neck of points formed by the bends of the river. In these cases the old channel remains in the form of a "horse-shoe lake," the ends becoming silted up by wash from the new channel. The frequency with which these horse-shoe lakes are found in following the course of the river demonstrates plainly the changes which have taken place, and which are to be expected to happen in future.

Through these bottoms, at high water, the river cuts its way, varying in width from 1500 to 5500 feet, alternating from bluff to bluff, on opposite sides of the river, describing in its course a succession of curves and reverse curves, removing sand bars, and placing them in new positions, rolling them (as it were) down stream, carrying destruction to any portion of the bottom lands where it strikes with force, and at points where it washes the base or face of hard clay banks wearing them slowly away, at times undermining them, and causing slides of large dimensions.

At low water the discharge is very much reduced (the proportion between high water and low water being about as 11 : 1), and runs in a channel or channels confined for the most part within the high water banks, meandering about and cutting out its course in a variety of curves, forming figures of more minute pattern than at time of high water.

The river is at its lowest stage during the months of November and December. First running ice appears about the middle of November, and the river gorges a few days afterwards. A slight rise frequently takes place in January, and between the middle of February and 15th of March the ice from above usually runs out, with a rise of from six to nine feet. The river continues rising during the months of March, April and May. In June and July the highest water occurs, and lasts as a rule for six or seven weeks. From the end of July until the end of November, the river generally runs out, and reaches its lowest stage about the end of the last named month.

Before making mention of levels or heights it is well to explain the method adopted in their notation. The highest water in the river, on record, was, after much research, established by the sworn testimony of parties, who pointed out marks which they had made, and objects which they had noted in regard to high water of 1844. By connecting these points by levels and comparing their elevations, the correct height was established for the flood of 1844. This level of highest water was called (in the notation upon all the bridge and river works) 100, as being that distance (100 ft.) above an imaginary line which was assumed as a datum for all the work.

TABLE OF HEIGHTS.

| | | |
|---|---|---|
| Highest water on record, 1844, | 100·00 | above datum |
| " " " 1871, | 92·50 | " |
| " " " 1872, | 93·50 | " |
| " " " 1873, | 92·50 | " |
| Ordinary low water, | 80·00 | " |
| Extraordinary " | 78·00 | " |
| Low sand bars, | up to 86·00 | " |
| High " " | 86 to 96 | " |
| General level of "bottoms," Kansas, | 96·00 | for 1880 ft. back |
| " " " " | 100·00 | beyond 1880′ to bluff, with ridges slightly higher. |
| " " " Missouri, | 104·00 | |

The greatest difference between high and low water was 22 feet.

A profile showing the record of water gauge kept at the work at St. Joseph, and also at Leavenworth, Ka., is attached hereto. In order to record the many changes taking place upon the river, notes were taken every month and full surveys were made after all great changes. These notes were plotted upon the original map, in pencil, and tracings made and filed away. By applying any one of these tracings upon the original map, the change is distinctly seen; in the same way, the tracing for any month can be compared with that for any other month, and the various changes noted. All these different surveys, if plotted on the original map in a permanent manner, would form such confusion of lines and colours, that the result would be unintelligible.

The material found in the bed of the river where borings were made, generally consisted of sand, with layers and balls of clay, and some quicksand; and subsequently in sinking the piers of the bridge, an opportunity was afforded for verifying, by sight, the information which had been obtained by boring. In most cases a deposit of boulders, small stones, and gravel was found immediately on top of bed rock. In one case, at a depth of 34 feet below the river bottom, the remains of brick-work, and also a bar of railroad U iron were found, proving that scour had taken place to that depth.

The fall in the water surface of the river was established by careful levels taken at different stages. At stage of 86, in a distance of 4·70 miles, the fall was found to be 4·37 feet, or 0·93 feet per mile, at low water 0·80 feet per mile. During the running of the ice, and at time of highest water, no satisfactory levels could be obtained. The changes were so rapid between the level of 86 and 92, that it was found impossible to get accurate results. The rate of current, as found by experiments with floats, at different stages of the river, varied from $2\frac{1}{2}$ miles to $3\frac{3}{4}$ miles per hour, at stage of 92. The calculated rate of current at stage of 100·0 is $4\frac{1}{3}$ miles per hour.

At times of flood, in places, the current is greatly increased by gorges breaking loose; so much so, that steamers sometimes find it difficult to stem the stream in getting around the bends.

The following table shows the sectional area, velocity and discharge at several stages of the river:—

TABLE OF DISCHARGE.

| Stage of Water. | Sectional Area. | Fall. | | Velocity. | | Discharge per sec. cub. ft. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | Per foot. | Per mile. | Ft. p. sec. | Miles per hour. | | |
| | Sq. feet. | Feet. | Feet. | | | | |
| 78 | 5355 | .0001515 | 0·80 | 3·65 | 2·49 | 19545 | By float. |
| 80 | 6205 | .0001649 | 0·87 | 3·94 | 2·69 | 24448 | Calculation. |
| 86 | 13095 | .0001761 | 0·93 | 3·81 | 2·60 | 49892 | By float. |
| 92 | 21975 | .0001809 | 0·96 | 5·50 | 3·75 | 120863 | By float. |
| 100 | 33175 | .0001860 | 0·98 | 6·36 | 4·34 | 210993 | Calculation. |
| | 7200 | | | 1·0 | 0·68 | 7200 | |
| Gorge. | | | | 9·88 | 6·74 | | |

The nature of the material in the Missouri "bottom," is shewn in the following table, and is all formed by deposits from the river.

| No. of Sample | Description. | Weight. | |
|---|---|---|---|
| | | lbs. per cub ft. | 3-ins. cube lbs. oz. |
| No. 1. | Sand from surface, stratum 18″ thick............ | $61\frac{1}{4}$ | 0 $15\frac{3}{16}$ |
| | Same, shaken down, microscopic grains of sand | 74 | 1 $2\frac{1}{2}$ |
| " 2 | Two feet from surface, 4″ thick. Clay, organic matter and fine sand.............................. | $74\frac{1}{4}$ | 1 $2\frac{1}{16}$ |
| | Same, shaken ...................................... | $81\frac{1}{4}$ | 1 $4\frac{5}{16}$ |
| " 3 | Next stratum, 2″ thick; little organic matter. | ......... | ......... |
| " 4 | Next stratum, 6″ thick; sand nearly as fine as No. 1............................................. | 67 | 1 $0\frac{12}{16}$ |
| | Same, shaken down................................ | $81\frac{1}{4}$ | 1 $3\frac{11}{16}$ |

| No. of Sample | Description. | Weight. | | |
|---|---|---|---|---|
| | | lbs. per. cub. ft. | P.3″ cb lbs. | oz. |
| No. 5 | Stratum, 1″ thick, similar to No. 1……… …… | 64 | 1 | 0 |
| | Same, shaken down …………………………… | $81\frac{1}{4}$ | 1 | $4\frac{5}{16}$ |
| " 8 | Seven feet from surface, clean sand crystals, as fine as in No. 4, some loam …… ………… | 86 | 1 | $5\frac{1}{2}$ |
| | Same, shaken down……………………………… | 97 | 1 | $8\frac{1}{4}$ |
| | Sand from pit on East side; coarse, with small fragments of lignite and gravel……… …… | 97 | 1 | $8\frac{1}{4}$ |
| | Same, shaken down……………………………… | $109\frac{1}{2}$ | 1 | $11\frac{6}{16}$ |
| | Sand from pit East bar ……… ……………… | $103\frac{1}{2}$ | 1 | $7\frac{3}{8}$ |
| | Same, shaken……… ……… …. ……………… | $113\frac{1}{2}$ | 1 | $9\frac{5}{8}$ |
| | Drifting sand from East bar……………… …. | 94 | 1 | $7\frac{1}{2}$ |
| | Same, shaken down……………………………… | 108 | 1 | 11 |

The sediment carried in suspension in the river was examined and was found to consist chiefly of sand in the following quantities, taken from different localities. The amount of water in all cases was a gallon.

| Weights. | | | Weight per cub. In. | | Remarks. |
|---|---|---|---|---|---|
| Filtrate. | Filter. | Sediment. | Loose. | Pressed. | |
| g. mill'g | g. mill'g. | g. mill'g. | g. | g. mill'g. | |
| 47·360 | 15·200 | 32·160 | 22 | 25·970 | Surface of channel. |
| 21·150 | 7·250 | 14·900 | 22 | 25·970 | " |
| 40·600 | 15·25 | 25·350 | 22 | 25·970 | " |
| 43·400 | 7·500 | 35·900 | 22 | 25·970 | Bottom at bridge. |
| | | 108·310= | 27·0775 M'n | Water per | gal. ==$1\underline{^{0426}}$ cub. in. |
| | $1\underline{^{0426}}$ × 6· | 2324=6·49 | 75 Cub. In. | in one cub. | foot of water. |

The discharge of sediment is as follows:

At low water, 78· cub ft. per sec. 73·5 or cub. yds. per 24 h., 235200
" med. " 86· " " 187·32 " " 599424
" high " 100· " " 820·43 " " 2625376

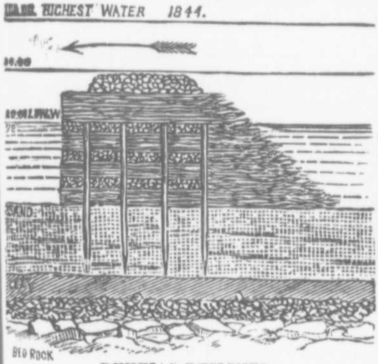
From the above figures it is not difficult to account for the formation of bars in slack water, independent of the shifting of the sand.

The bridge, as well as the river works, were designed by Col. E. D. Mason, engineer in chief, and were carried out under his supervision. The survey was commenced February 1st, 1871, and completed 15th of March following. Upon the accompanying map are shewn the lines of the centres of the low water channels, as located after all great changes. The exact form of the channel and bars, immediately before the commencement of the work (Sept. 27th, 1871), is distinguished by right line shading of the Bars, while the changes effected by these works are shewn by the water lines of the general map which was made from surveys in September and October, 1872.

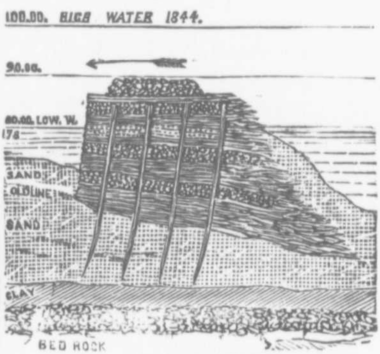
Until the location of the bridge had been made, the chief engineer was unable to decide definitely upon the plan for controlling the river above the bridge. To this subject he gave much of his time; watching the working of the river during the high water, and making experiments upon the sand bars as soon as they began to appear, upon the subsiding of the river. On small water courses he built dykes formed of the smallest brush loaded with sand, and noted minutely the effects produced by the current. In this manner he succeeded in turning the miniature rivers, and in making them run as he willed. Encouraged by his success in these experiments, he determined to apply the same means in undertaking to divert the existing channel from the course which it then followed, along the Kansas shore; and to force it, in course of time, to run along the Eastern shore and follow the high water bank in front of the city of St. Jo, thus securing a permanent and direct approach to the draw span, as located. In adopting this course he was attempting only to force the river to run in an old, natural channel which had been deserted by the river and filled in with sand. Much damage had been done, in previous years, along the frontage of the city, by floods washing away the clay bank; and the city suffered to great extent in loss of valuable buildings. In fact the principal business part of the city had been either destroyed, or was liable to be destroyed, at any time of high water.

To prevent further encroachments of the river, many years ago, works were undertaken for the protection of the bank in front of the city. These proved successful. They consisted of a number of groins built out from shore, for a short distance, and forming an acute angle with the current. At each of these groins the current was slightly deflected, and thus gradually forced to follow the bend of the shore.

From what could be seen of these old works, they appeared to be formed of heavy piles driven near the foot of the slope of bank, the space behind being filled with stone and brush; they were, however, so completely embedded in the sand, that it was impossible to see exactly how they were constructed. This form of protection by groins had been considered with some favour by the chief engineer; but when it was decided to force the current to the east bank it was abandoned and another plan adopted and finally carried out. This comprised the building of two principal dykes: one to act in turning the channel, causing it to cross from the Kansas shore to the Missouri side, there to follow the east bank, and in a straight course, to pass through the draw-span of the bridge; the second to act as a shore protection on the Kansas side, for a short distance above the bridge.



DYKE AS DESIGNED.



DYKE AS BUILT.

When these dykes were designed it was assumed that undermining would take place; and they were proportioned in a manner which was considered would give them sufficient tenacity to hold together, while they conformed to any slope which might be caused by undermining, and without much risk of being overturned. For this reason they were given a wide base, a sloping face and a top load of stone placed so that its centre of gravity was thrown as far back as possible. The base was made 60 ft., the face sloping back so as to give a width of from 24 ft. to 30 ft. on top. The back was carried up vertically. The heights varied: in deepest water the height to top of the brush was 25 ft. The depth of channel at low water is taken at 20-ft. Bed rock was found at a depth of about 45 ft. below low water; upon the bed rock there was a bed of boulders of 5 ft. in thickness; and on top of the boulders, a stratum of clay also of 5 ft. Scour would not take place below the top of the clay. The scour would therefore be restricted to a depth of 15 ft. below the bottom of the channel. When the brush was placed in water less than 20-ft. in depth, and sunk nearly to the bottom, it was considered that scour would take place during the process of sinking; and that the sand would be washed out to, probably, the full depth of the channel. These assumptions were based upon the results of experiments made on a small scale.

Two sketches shewing cross sections of the dykes are hereto attached:—one shewing the position of the dyke, as built and placed upon the bottom without scour, the other shewing the position which the dyke was assumed to take, under a scour of about 15 ft., and which it did, eventually, in most cases, take.

The work upon the dykes was commenced Sept. 27, 1871, the stage of river being ordinary low water. The position of the different dykes is shewn upon the map, numbered in order in which they were commenced; No. 4 was designed to turn the channel. Before commencing to build this dyke it was thought expedient to reduce the current in the channel, across which this dyke was to be built. For this purpose dams were built across two small channels; thus connecting two dry sand bars with the main shore, and excluding a large flow of water.

From the head of the outer of these bars, a dyke, No. 3, was commenced and built downwards and slightly outwards; and, as the work progressed, slowly closed the upper end of the steamboat channel, across which the main dyke, No. 4, was at the same time being built, at a distance below of 2,300 ft. The dams Nos. 1 and 2 being required only for temporary service, were built of small trees and brush, held in place while sinking by small piles driven by hand, and loaded with sand at an elevation of about 2 feet over ordinary low water. Dyke No. 3 was built in the same manner, and was extended, eventually, for a distance of nearly 800 feet, crossing almost entirely the steamboat channel which at this point was 600 feet in width, with rapid current and water from 8 to 12 feet in depth. This dyke, although intended only for temporary purposes, was the means before long, of causing a total change in the low water channel, forcing it out of its course along the Kansas shore and throwing it eastward, forming a deep channel through the centre of the other existing and shallow channel. Dyke No. 4 was commenced shortly after the dams above described, and was carried on at the same time as No. 3. This dyke being intended to act permanently as a means of directing the river, was built in a more solid manner than the structures already described. The form of cross-section of this dyke has been already described. The embankment was formed of alternate courses of trees and brush laid crosswise, and of poles laid lengthwise, so as to break joint. The courses of trees and brush were about 3-ft. 6-ins, and the courses of poles from 1½ to 2 feet in depth. The bottom and top courses were always formed of trees and brush laid crosswise. The trees varied in length from 30 to 60 feet, according to their position in the bank, the whole width being always made with trees of the proper length. They were trimmed by having their branches lopped so as to lie close to the stem; or the branches were cut off entirely for 20 or 30 feet from the butts according to the length of the tree. The loose branches were placed among the tops, and interwoven with them. Over this brush bank was placed a pile of stone 18-ft. in width, and 3 feet in depth, the rear line of the pile being placed 3 feet inwards from the line of the butts of the trees. To hold the brush in position, while being built and sunk to the bottom, stout piles were driven by a floating steam driver, generally to a depth of about 14 feet, and spaced at distances of about 10 feet.

Starting from a point on the Kansas shore, nearly opposite to the centre of the city of St. Joseph, and running downwards, making an angle of about 40 degrees with the centre thread of the stream at high water, this dyke was carried across the steamboat channel, the sand bar island, and the shallow channel beyond, terminating on a sand bar with 2 feet of water on the east side of this second channel. The steamboat channel here is 550 ft. in width with a maximum depth of 20 feet and current of a little less than four miles per hour. Here a mole was built in the same manner as the dykes, to form a finish to the end of the dyke.

It was not considered advisable at this time to extend the dyke any further, and it was determined to await the effect of the next flood, and mark the result. The total length of this dyke is 2,100 feet.

During its construction across the steamboat channel, the area of the water way was steadily contracted, and scour took place in proportion to this contraction. The bottom of the channel was, in this way, scoured to a depth of 25 feet below water. The eastern side of the channel was also scoured from the same cause, to such an extent that the greater part of the lower end of the sand bar island was cut away, as the head of the dyke approached.

About the time when this dyke had been built as far as the island, the change in the channel, previously mentioned as having been caused by dyke No. 3, took place, and at once relieved the pressure upon dyke No. 4, the flow through this channel being now almost stopped, by being turned, at the head of the Island, into the centre of the river

In continuing the dyke across the second channel there was much less difficulty in placing the brush. A few piles had been driven with the intention of forming a temporary breakwater at No. 7: this now was rendered unnecessary, and work upon it was discontinued.

Work upon dyke No. 4 was completed Feb. 16, 1872. The works of "protection" were also commenced, on the Kansas shore, at the same time as the work above described. These consisted of dykes Nos. 5 and 6. No. 5 was merely a small dyke placed at a point 1300 feet above the bridge, to check the scour which was found to be taking place at the time of commencement of No. 6. No. 6, "Weavers Dyke" was commenced on the shore at a point about nine hundred feet above the bridge line, and built for a distance of some nine hundred (900) feet, running downwards and outwards, and striking the current at a more acute angle than in the case of dyke No. 4. The manner in which this dyke was constructed is exactly similar to that of dyke No. 4. This dyke was intended to act more as a protection to the existing bank than as a means of deflecting the river; although it served the latter purpose to a slight extent. The channel at this point was about 850 feet in width with depth of 10 to 15 feet; and the current at low water was 3½ miles per hour. This dyke was completed March 17, 1872, and purpose of great service in protecting the bank, and in saving the piling, and other false works of the bridge below.

A large quantity of stone, for rip-rapping the shore, had been piled along the bank, opposite the rear of this dyke. Nothing was done at this time, on the East bank of the river, in the way of protection. Reliance was placed upon the old works which had been built to protect the city front.

It is well to note, at present, the changes in the low water channel, which had been taking place during the construction of the dykes; during this time the water had been at a low stage, the water at the gauge shewing from 81.5 to 84 feet. At this stage of the river, the greater part of the bars, standing above the level of low water, were visible, and all changes were easily detected.

By the construction of the small dams Nos. 1 and 2, and dyke No. 3, the steamboat channel had been turned entirely out of the course which it had last established along the Kansas shore; and the whole flow of the river was discharged through one channel of 1000 feet in width, with hidden shoals which had rendered it unnavigable. The additional current, caused by the stopping of the principal channel of the river, had the effect of slightly inclining the current of the one remaining channel; and of crowding it from a point some distance above dyke No. 3 upon the western face of what is called here the east bar; scouring out the bottom, and, in a short time, forming a deepwater channel across the river. This current scoured the west shore of this bar, cutting into it and curving to the right as it was gradually deflected in that direction. Then, after cutting out a large portion of this bar, it deserted the east side, and ran as if intending to attack the head of dyke No. 4 as it then existed, following this course until it felt the influence of the lesser current of the water backed up, or retarded, by dyke No. 4; it again curved to the east, and made another attack upon the east sand bar, digging into it, and turning suddenly around the head of dyke No. 4, made in a direct line for dyke No. 5.

On approaching dyke No. 5, and when within about 500 feet, it turned suddenly to the left; and curving on a radius of about 500 feet, for a half circle, reversed suddenly, curved to the right on a radius of 700 feet and described an arc of 120 degrees, passing, on a straight course of about 500 feet, through the spot chosen for the location of the draw span. The channel followed the same curves, with change only caused by the wearing away of the east bar, until the breaking up and running out of the ice on the 21st February, 1872. The works were completed not too soon; the last stone being placed on dyke No. 6 on the 17th of the same month. Up to this date no real injury was done to the works of protection. At dyke No. 6, however, from the constant scouring for a period of two months, the brush had been undermined along the exposed face, and had settled on that side, at places, to the amount of 25 feet; the rear line of the dyke was but little disturbed.

The form of the channel immediately before the "break up" of the river is shewn upon the general map by a heavy dotted line. The ice in the neighborhood of St. Joseph broke up February 21st; and on the 23rd it came down from above with a rush, causing a sudden rise in the river to level of 89. For the few hours during which it remained at this stage, the flow consisted of a succession of gorges, forming and breaking away. The river foamed and hissed. The whole water-way was filled with broken ice grinding along the bottom, and pitching and tossing on the surface. The water itself was not to be seen, as the mass of broken ice, and drift rolled by—forest trees and masses of brush, wreckage of all sorts, whirling around, and forced into the air by the upward action of the heaving ice. A gorge had broken above. On the 24th a gorge occurred, commencing on the east side of the channel, a short distance below the line of dyke No. 4. The channel below this point was very crooked, and retarded the escape of the gorge. The river hurled itself, with great force, against dyke No. 6, and washed along its face, increasing the undermining which had been already done. In a few hours the whole face of the dyke had been undermined; the channel having scoured out to a depth of thirty-four feet. The dyke "turned over"!! It remained, however, as was expected, and now forms a breakwater founded so deep that it is not likely to be disturbed. No. 4 was not assaulted in so violent a manner; and received no injury. No. 3, however, suffered, some two hundred feet at the lower end having been carried away, and deposited near dyke No. 4.

After a few hours the attack on Weavers Dyke seemed to relax; the current did not strike with equal force, nor in so direct a manner; and it gradually changed, so that the dyke was entirely relieved; the gorge ran out; and the river dropped to 84. This relief was caused by the cutting through by the flood of a bend which had occasioned the jamming of the ice and drift.

At the end of April the channel had assumed a tolerably direct course, and followed what was nearly a central course between the high water banks. The river began to rise May 1st, and from this date until September the bars were generally covered. On September 30th the river had reached the stage of ordinary low water, and complete surveys were made on that date and during the following week. From this survey the general map has been drawn. On this plan the action of the river is shewn by centre lines of the channels formed from time, together with the shore lines of the surveys made immediately before the commencement of these works and again in September and October, 1872.

During the time included between these dates, or a little over one year, the low water channel has been turned away from the Kansas shore, and forced to follow the opposite, or Missouri shore, for a distance of 9000 feet. A small channel has also been formed (by the carrying away of a portion of dyke No. 3), from the upper end of the works to the head of dyke No. 4, thence to the head of dyke No. 6; thus forming an island, extending across the whole front of the city, over one mile in length and averaging about 600 feet in width. The principal channel along the east bank varies in width from 500 to 1500 feet.

While these new channels had been scouring out, large deposits of material had been made. A large bar had been formed on the Kansas side, extending from the head of dyke No. 6 to nearly the head of dyke No. 4; thence to dam No. 1. A large quantity of sand has also been placed at the head of the island just referred to, this extends as far up as No. 3 dyke. These changes were of very great extent. A large portion of the east bar was removed by scour during the progress of the works upon the river; but the bulk of work was done during high water.

There was low ground on the east bar at the mouth of Blacksnake creek; on rising over the level of this part of the bar the current rushed in and a channel was commenced; this, as the remainder of the bar was submerged, continued to run along the east bank, eventually cutting out a channel of from 1500 to 500 feet in width. A portion of the east bar was left in place, and now forms the lower end of the island bar in front of the city. The effect of the high water of 1872 was considered very satisfactory. The dykes had done their duty; and the channel had been compelled, after a stubborn resistance, to move 3000 feet to the east; and to follow the Missouri shore.

Under the circumstances then existing, it did not appear necessary that the work should be extended; and it was also considered prudent to await the result of the high water of another year. The work upon the bridge was completed in a few more months; and the staff was discharged in May, 1873. No work was done on the dykes during these months; and the channel continued to run along the Missouri bank.

The changes which were effected in the channel by the action of the current, during the construction of the dykes, and up to date, September 30th, 1872, involved the removal of an enormous quantity of sand; and also the placing of a quantity equal to 5-6ths of that removed. It is natural to suppose that a portion of this deposit was formed with material removed from other parts of the work above; what proportion it is impossible to estimate.

| | | |
|---|---|---|
| Removed from east sand bar : Cub yds. | | 3,050,000 |
| Deposited on west sand bar : | 1,500,000 | |
| " Island shoal | 900,000 | |
| Total deposited in bars | | 2,400,000 |

The total cost of dykes was $58,655.

Cost per cubic yard $\frac{\$58,655}{3,050000} = 1.92$ cents, for material removed.

It is a matter of regret to the writer of these notes, that he is unable to give, from personal experience, any later information about the work which they describe. He has never visited St. Joseph since the year

1873. Information has been received, however, in reply to letters written to persons whose statements can be depended upon.

From these it appears that the low water channel had continued to flow along the east bank of the river; that damage had been done to this bank, a short distance above the bridge, at a point where no rip-rap had been placed, and extending down to the bridge, causing the small shore abutment to slide into the river; that this was stopped by the placing of quantities of rock, by the Kansas City, St. Joseph and C. B. R.R. company, and that a new pier was put in; that a large portion of the town front had to be retained by heavy stone dykes, buttressing the shore; it has since been made secure by the contruction of a second track of the railway, the material of which was mostly rock.

From the above information it would appear, that the fall of the shore abutment was caused by want of care in not protecting the bank above the bridge works. It would also prove that the river has continued to run along the east bank; no reference being made to any injury having been done on the Kansas side of the river. The channel also is said to have run constantly through the draw span, up to the present, a period of fourteen years. The dykes, therefore, seem to have accomplished the end for which they were designed. The protection of the east bank, at the time when these river works were completed, was a thing to be considered. It does not appear to have received attention, until serious injury had been done; and the old works of protection of the city front had proved insufficient to withstand the continual wear, and the more frequently repeated attacks of the river. There is reason, also, to suppose that the works for deflecting the river may have been a means of increasing the effect of floods upon the east bank.

From the drawings accompanying this paper Plate VIII has been prepared.

# DISCUSSION.

**Mr. Henshaw** The works on the Missouri river, described in Mr. Killaly's paper, possess a far deeper interest to engineers than the mere description of the work itself or the progressive results of its construction.

It is one of many experimental efforts made at different points of the Mississippi river and its branches, all of which have a sort of family resemblance.

In spite of many imperfections, these structures, for the most part, have been the result of scientific thought, and they mark a transition state from the iron clad rules of construction, that cramp invention in the old world, to the freedom of thought that is growing in the new. What Ruskin has done for architecture, in sweeping away the five orders of architecture and reducing them to two, and in pointing out the dullness of slavish repetition, however ornate and beautiful in mechanical execution, it is much to be desired that some eminent man may do for engineering in combating the prevailing maxims of what is called correctness of design. His task would of course be a more difficult one, since the range of the application of the laws of science is wider than those of art; but in actual practice, arbitrary instead of scientific rules are altogether too prevalent, and he who steps beyond the lines laid down by authorities is apt to be frowned upon as chimerical if not treated absolutely as a quack.

The subject of construction on sandy or alluvial soils has long engaged the speaker's attention. During a seven years' residence in the north of Europe, he has examined with interest a number of works; but though admiring their massiveness, and the skill shown in their construction, he has always been oppressed by the almost universal sameness of idea implied in their design. Smiles tells us that the first engineer in England was brought over from Holland, and we find that to the present day, when works of the kind we are speaking of are desired, people still go over to Holland to study the antiquated structures of centuries ago, or their copies. Why? Because they are orthodox, the work of the old masters; as if science had not progressed since their time, or as if their knowledge of it left nothing valuable to be discovered. The result has been rather to condense and crystallize old fossiliferous ideas than to expand into new ones.

Hence we find the terms *permanent* and *temporary* often used in an incorrect sense. In engineering, the true meaning of temporary is something to be removed when its work is done; of permanent, that which is always to remain and be kept in repair. But we frequently hear things called temporary because they are slightly built or of perishable materials, while others are called permanent because they are built solidly of the least perishable material, though, as a matter of fact, the former may often outlast the latter. (With all due regard to the gentlemen who designed it, a reference may be made, for example, to our river dyke which is called temporary, but which it would not be a matter of surprise to see reach an age to justify the more imposing title.)

More than all, however, the orthodox idea of a permanent work is one that is built to stand firm, just where it is placed. In other words, man declares war against nature. He builds to oppose, not to accommodate himself to it.

He thrusts out his spurs and outworks against the enemy. He calculates the directions and forces of attack, and provides curves, slopes, and obstructions to repel or weaken the assault; and when these fail, he sits down foiled or to devise fresh means of defence. All this is of course right enough on rocky coasts, where man, if he is to do anything, must imitate the action of the natural defences, but he apparently does not see that on sandy coasts he must change his tactics as nature does hers, and adopt a policy of conciliation; he does not seem to realize that free nature is a wild thing, restlessly flinging out its forces, impelled by laws which are the necessities of its being, which must be satisfied and which can be satisfied if we only know how to do it; in fact, not only satisfied, but amicably enlisted on our side as enormously powerful auxiliaries.

The works described by Mr. Killaly, though crude and experimental in design, and rough in execution, are an immense advance upon old world ideas, and would perhaps have gone further but for the old prejudices still lingering in the designer's mind.

The problem was simply to divert the channel in a direction favorable to a proposed bridge, and keep it there; the difficulties were to establish a stable structure, and prevent a flood while barring the existing channel.

Now the old orthodox way of going to work would of course be to build something solid from the outset, that would stand the rush of the river. The line of the dyke being established, the river would probably be dredged along its slope, and the dyke advanced in a regular manner with apron, etc., complete, the whole to stand finally just as it was built.

But this plan, in view of the enormous movement of sediment by the river, would be a very costly operation, quite beyond the means of ordinary capitalists. What really was done was to build a dyke with the deliberate intention of having its face undermined, but with breadth enough to secure it in its place until the face had sunk upon the undermined bottom and thus form a protection against further erosion, and this its elastic construction enabled it, so far as we know, to do very effectively.

Here we have a case in which nature was trapped, as it were, into taking part in the work.

The transitional condition of this mode of construction is shown, however, by the fact, that the work being done, it reverts to the old principal of attack and resistance.

But the true principles of construction, to which we are slowly tending, will consist in such an alliance with nature as will produce permanency by inducing a stable equilibrium between the opposing forces.

To explain how this may be done would take up far too much time, and is foreign to the object of the present remarks, which are only intended to draw attention to the value of Mr. Killaly's paper, as pointing onward to still higher conceptions of what may be done in carrying out works on sandy soils.

1st December, 1887,

MR. T. C. KEEFER, C.M.G., President, in the Chair.

The following candidates were declared to have been balloted for and duly elected as

### MEMBERS.

| | |
|---|---|
| WILLIAM CARSON. | HENRY HOLGATE. |

### ASSOCIATE MEMBERS.

| | |
|---|---|
| ROBERT FOWLER. | JEAN FRANÇOIS GUAY. |

CECIL BRUNSWICK SMITH, B. A. SC.

### ASSOCIATE.

NEVIL NORTON EVANS.

### STUDENTS.

| | |
|---|---|
| EDGAR SYDNEY MONTGOMERY LOVELACE. | CHARLES DANIEL SARGENT. |
| EDWARD ERNEST STUART MATTICE. | ALLAN WILMOT STRONG. |

## *Paper 10.*

# ON THE NECESSITY OF A SCHOOL OF ARTS FOR THE DOMINION.

BY C. BAILLARGÉ, M.A., M. CAN.SOC. C.E.

During a professional career of now nearly 40 years, and of extremely varied experience, the author has had abundant opportunity of noticing the great and unpardonable ignorance displayed in scores of instances, of the simplest rules of the constructive art.

A paper on this subject would no doubt be more appropriately read before and discussed by a society of architects instead of engineers; but no definite line can well be drawn between the two, and much may be considered common property; for, while the architect often has to be something of an engineer when dealing with foundations built in water, the engineer must also often trench upon the domain of the architect in the erection of bridges and viaducts, and in such architectural structures as manufactories and mills, pump and engine houses for water works and other purposes, light houses, grain and other elevators, stores for dockage purposes, railway station buildings and the like.

Hence no apology need be offered for dealing with this subject in presence of an assemblage of men who, like the members of the Society of Civil Engineers of Canada, must be often called on to design and erect structures in which not only have they to be acquainted with the ordinary and essential rules of construction, but in many cases also of distributive and ornamental architecture. The writer only hopes to say enough to persuade our legislators of the federal and local parliaments of the absolute necessity, at this stage of the growth and progress of Canada, for the creation of one or more schools of art akin to those of Kensington in London, or to those of St. Cyr, Aix and Angers, in France, where the rising generation of engineers and architects may study and make themselves acquainted with the well known rules which should be followed out to prevent disaster and the waste of money, in the construction of works unsuited to the purposes intended.

Is there anything more usual, for instance, with a large number of our would-be architects and builders, than to be totally ignorant of the fact that the strength of a joist or horizontally placed beam is in direct ratio to the square of its depth and in the inverse ratio of its length? Do they even know the meaning of these terms? If they do, would they not in many thousands of existing cases, instead of adding to the breadth of the beam (because it requires no tuition to understand that) have increased its depth by only a fraction of the whole? For, while to double the strength of the beam, its depth remaining the same, the breadth must be doubled, the same increment of resistance is added to it by increasing its depth by only 4 tenths thereof, or little more than a third of its vertical height; to treble the strength, the advantage gained is even more marked, as in such case it suffices to add, not the double of 4 tenths but little over 7 tenths—73 per cent.; and to quadruple the strength, the depth only has to be doubled, so that a 3 ins. × 17 ins joist for instance is as strong as one of 6 ins. × 12 ins. or as two of 3 ins. × 12 ins., while the increased quantity of timber is but 40 per cent. in the one case as against 100 % in the other; and a 3 ins. × 15 ins. joist, with only 25 % more in its cubic contents or board measure, will be 50 % stronger than the 3 ins. × 12 ins. timber. Had this rule been acted on in the past, how many thousands of dollars worth of timber would there not have been saved in the aggregate, and each and every one have benefited thereby.

Of course there is a practical limit to thus adding to the depth of a beam to increase the strength; as, in the case of timber, the deeper beam must be cut from a larger and more expensive log, and if very deep, herring bone bridging or intermediate strutting must be employed to preserve the verticality of the beam and to ensure its lateral stiffness.

The depth of the floors must not be indefinitely increased, the height between floors diminished by so much, or the total elevation of the structure added to in a manner to make it more costly or of ungainly aspect.

Again, how often is it found on entering even new or comparatively new buildings, dwelling houses by the hundreds, stores and factories and even public buildings, that all the floors slant towards the centre of the building, all the doors, more especially in partitions running from front to rear—less so in the narrower direction between the gable ends or party walls,—are on the skew, partly from being forced out of the rectangular, partly from having to be eased off by the joiner from time to time, to cause them to shut and fit their jambs or frames, the furniture of course following suit, with tables on which a round ruler or pencil could not be placed without rolling off, the plastering being cracked and broken from the settlement, and the whole defect rendered doubly sensible and more intolerable to the eye by its being thrust on the spectator in the evidently inclined lines to which the paperings or tapestry were cut to conform to the unhorizontal lines of cornices and skirtings. And all this due to what? to sheer ignorance of the fact that of three points of support, the centre one bears double the weight of either of the others when placed half way between them. Now not only are the division walls of thousands of buildings not stronger than the outer walls, as they should be; but they are on the contrary not half so thick or strong, and worse than all, what is to be found in most tenement houses, but a mere partition of light wooden studs and lath and plaster with sometimes not even a foundation wall in or below the basement floor for this partition to rest on, or if there be one the chances are that it is not on an unyielding foundation. Thus, between the sinking into the soil, the crushing of the superposed horizontal timbers between the tiers of studs due to the weight of the structure and to shrinkage from drying or desiccation, amounting to as much as an inch or more in each story, the settlement alluded to occurs, and either hundreds or thousands have to be expended in rectifying this error of construction, often due to the parsimoniousness and ignorance of the proprietor himself, and in total disregard of the advice of his architect or builder, or the structure remains a crying disgrace and reproach to all concerned in its erection and a source of every day discomfort and torment, as every thing unæsthetical generally is to all people of fine and cultivated feelings.

But the sagging of a floor between the two or four walls has also to be guarded against and for this purpose it often suffices to remember that every joist, as far as possible, or at least every second or alternate one should stretch right through the structure from front to rear, and so rest on all three of the walls, the centre one as well as the two outer; that is, on three points of support. The strength of a joist is thus doubled, and its tendency to sag at the centre of the vacant space reduced by 50 per cent; its stiffness, as already said, being in the inverse ratio of its length; nor must it be forgotten that when no more than two points of support can be had, or the beam is not long enough to reach the full depth, then may its rigidity be increased 25% by thoroughly sealing it at one end in the wall and by not less than 50% when similarly sealed at both ends; not forgetting that whatever weight the beam will bear at its centre, it will bear twice the weight uniformly distributed throughout its length.

Nothing is more difficult than to get a proprietor or even a municipality represented in its city council by illiterate men, to allow an engineer or architect to build a retaining wall of sufficient strength, sufficiently thick at bottom to hold out as it should do for its natural life against the horizontal thrust and overturning tendency of the material behind it, often so liquid—or rather so fluid—when composed of quick sand or of earth diluted with water, that it must be assimilated in stress to that of water pressure for purposes of calculation.

The author has long found out that it is all false economy, and that better be it to design and build any such of a greater rather than a less thickness, than be taunted with and thereafter made to feel keenly the justness of the reproach of not having done so, and see the structure giving way little by little towards the open, first gradually losing its batter, if any, reaching the vertical, and then in course of time leaning forward and finally in from 10 to 20 years threatening destruction, while its natural life should have been at least a hundred years or more if kept in proper repair. But no matter how thick they may be or how well adapted to sustain and resist the thrust, retaining walls will do this, owing to other causes to be guarded against; for example, from the effects of frost when not filled in the rear with permeable material, as they invariably should be, to allow surface or other waters to pass off through weepers below to the street level.

There are other defects to be guarded against, as the bulging out of walls of certain structures, by the stress of vaults and arches when not counteracted either by a proper thickness of wall or by the strengthening thereof by buttresses, or by loading from above by adding to the height, or by applying iron ties to counteract the spreading tendency. Again it is hardly necessary to speak of the very bad effect of the appearance of a corner pier of any building, when as is often the case it is made narrower than the intermediate ones between the openings;

as in an isolated dwelling house or other building, when a narrow passage along the gable of the same throws the door so close to the end as barely to leave more room between it and the angle than the mere thickness of the wall itself, a defect which should not be tolerated. The door should be shifted further from the end even at the expense of widening the passage, and trenching on the room adjoining, or the less objectionable mode should be adopted of encroaching a little on the front portion of the room, and hiding the defect from the inside by an angular or quadrantal projection within the apartment.

There is in human nature an element of æstheticism. Certain proportions seem to be innate in our minds, and to exist there, irrespective of any tuition of the beautiful. They are, so to say, engraven on the retina of the eye and thus rendered indissoluble. Probably this is due to the ratios in the human stature. You can notice this whenever an illiterate man or child says that such and such a thing does not please him, as, for instance, when a building is too heavy, that it looks like a man whose head rests almost on his shoulders without the interposition of a neck.

We all appreciate the true proportions of a human being, man or child or woman. One is said to be too bulky for his height, too short, too stumpy, another too tall and slight. We do not like, we can not bear to see a waist half way down the body, of which the normal height is at say two-thirds from the ground or floor we stand on.

Our clue is taken from this, it is implanted in us by the Creator, and hence it seems that without knowing why, there is scarcely anyone who does not dislike to see a column, for instance, cut or divided through the centre, or an abutting cornice, a plinth course, the head or transom of a door or gateway, the impost of an arched opening, or the top or bottom of a niche come opposite the centre. On the contrary, if any such adjoining feature cuts the column or abuts againts it at just two-thirds the height from base, one feels satisfied that the right proportions are observed.

Why are the fillets in the flutings of a column made just one third the height of shaft. Try them at one-half the height, and somehow or other you will feel not satisfied. Put two such columns side by side, in one of which the flutes are filled in to half, the other to one third the height, and even the untutored eye will select the latter. Have you ever seen a spire, where if the height of angle minarets varies by less than than the two-thirds from the total height of structure, it is pleasing to the eye? No; the pinnacle must be one-third the height of the steeple or thereabouts, and any attempt to alter it materially is destructive of the effect.

In this way also or due to the same sense, the innate æstheticism of our human nature, the fact can be accounted for that a basement floor should be some two-thirds of the joint height of the two stories above it, and an attic story two-thirds only of the story which it crowns; the attic window also—, the writer does not here allude of course to the dormer or so-called attic window in a roof, so much as to what is called in classic architecture an attic, that is the upper portion or story of the front elevation of a building—or the window in a regular attic story is looked for as having to be not one half or one-third the height of the windows in the regular stories below it, but almost invariably some two-thirds thereof, to be agreeable to the eye.

A door must also be in some way proportionate to the human frame when properly attired, having a height from two and a half to three times its width, and its width should never approximate to its height.

A room is not satisfactory, it will please no one, not even those who are incapable of knowing why, or of giving expression to their dislike, unless its length bears a certain proportion to its breadth, as that of 3 to 2 for instance, and, to be agreeable, the height must bear about the same ratio to the breadth, as 10 to 12 ft. for a 15 ft. room, 20 ft. for a 30 ft. room, and so on in proportion.

What would Mansard say if he could witness the many erroneous interpretations of what constitutes the proper proportions of a so called Mansard roof? And in dome construction why depart so widely from the beautiful proportions of the Invalides at Paris?

Try it and vary it as you will, the tower or the steeple must make some approach towards the one-third rule laid down of breadth of portal. Make it much broader and it will not suit, nor can it be much narrower. In the same way as the breadth of spire must conform to that of the church façade, so must the projecting or recessed central portion of any front elevation of a building, that is, the part fronting towards a street, or even on an inner court, hold some relationship, some near approach, to this same ratio of 1 and 2 to 3.

The odd unit is essential in almost every case. Do we not always have an opening, door or window, gateway or the like exactly on the central axis of a building? Is it not natural to do so in all cases, and even in a bridge or viaduct, do we not always seek if possible to have a central span instead of a pier right in the middle of a river or a thoroughfare?

There are defects of space which may be remedied by optical illusion. If a façade be necessarily too low, avoid the too oft repeated horizontal lines of projecting cornices and belt courses, but rather do the contrary and throw it into vertical lines which have the effect of adding materially to the height. The vertical flutings of a column have this effect where any horizontal division of the shaft, any spirally twined ornament around it has the contrary effect.

Nor must we forget to observe the natural in all we do. Not only must a post or column be stout and strong enough to support a structure, but it must appear to be so. When the material for instance is iron, it should be known to be such, and should be painted in such a way as to show its character, instead of being made to look like wood or stone thus creating anxiety and doubt as to the adequacy of its size. How often do we not see this elementary rule of architectural ethics outraged by the disguising of true material under a coat of imitation stone or marble ,where such material reduced to so narrow a breadth would be obviously inadequate to sustain the weight or even to be self supporting.

Gentlemen, we want a school of arts, or more than one, in which our youth may be educated to the necessity of all these observances, and the thousands of dollars lavished in making good the defects of construction alluded to, would ere this have paid for many such institutions and maintained them on a permanent and continuous footing.

As to the sanitary question, made up of drainage, light, ventilation, and heating, we are now pretty well off for Canadian and other periodicals dealing with the subject, and it may be merely remarked, that there seems no reason why some mode should not be devised for adding to our comfort by cooling the inner air in summer in addition to heating it in during cold weather.

For, in the same way that the colder outer air is heated on its way to the interior of a building by being passed over heated pipes, could this outer air, when too warm to suit the human system, be cooled down by passing it over the same pipes then filled with iced water instead of hot, or directly over a bed or stratum of ice ; and how efficient this would prove is evidenced by the fact which many may have often noticed, that when on a warm day a breeze or current of air reaches one in the open air after passing over the ordinary uncovered ice cart—as we have them in Quebec—the decrease in temperature or coolness of the breeze is most marked and agreeable.

The air can be cooled in other ways as it always is in summer during rainy weather or even during the merest shower, by following the same process, imitating nature in an artificial sprinkling kept up during the hotter hours of the day—or better still when it can be affor ded--by artificial rain around the house or opposite a door or window (one or more). Water may be conducted through a pipe under sufficient pressure to roof level, the pipe being perforated along its length like the sprinkler of a watering cart, so that it may distribute its contents over so much of the eaves as to suit the purposes required.

As to fire proofing, the subject is most pertinent, and it is satisfactory to see that a very free use is beginning to be made of iron joists and concrete floors; nor can we reasonably hope for much more than this, with brick partitions instead of wood and lath and plaster ones, as no one will ever consent to dwell or even pass his office hours within a building entirely of stone and brick and iron. No one will put up with any such permanent and continuous discomfort for the sake of an eventuality which may never occur, or not frequently enough to warrant the expense of iron floors, stairs, doors, window sashes and their trimmings, surrounding one with their chilling influences.

Perhaps the most portentous question of all now a days is that of the possibility of escape from a building in case of fire, which has been recently dealt with in a paper by the speaker before the Royal Society of Canada. It is the duty of every one to use his endeavours to compel the Legislature to step in and enforce the erection of fireproof buildings for hotels, theatres, colleges, asylums, manufactories and the like, or at all events to render universal the use of iron joists, with concrete between them, together with brick partition walls, and the provision of some thoroughly practical and efficient mode of escape in case of fire, a social and humanitarian proposition of the first importance.

Gentlemen, at this stage in our country's growth and progress, there is no necessity to go abroad for hints or help. The Dominion is now old enough as to be self sufficient in the building line at least. Montreal can now manufacture almost anything from a needle to an anchor, as the saying is. The several cities and towns in the Dominion have their engineers and architects equal to all and every emergency; and if any one city has not its due proportion of capacity in this respect, it can get it from a sister town of the Dominion.

Is it necessary to allude to aught else than our inland system of water communication? It is not merely equal but superior to anything in the old world. Our Canadian engineers have not been slow to frame their minds, their conceptions and their works on the same vast scale on which our inland waters were presented to them.

It is then time that we should have men educated here in full view of the difficulties of our climate, and whose minds could mature schemes proportionate to the scale of our vast inter-oceanic Dominion.

This can be done, gentlemen, first by a tuition in a school of arts and design, and next by an apprenticeship to a Canadian engineer of high standing in active and varied practice like many of those who have honoured me this evening with their presence.

1st December, 1888.

T. C. KEEFER, C.M.G., President, in the Chair.

## *Paper 11.*

# THE QUEBEC HARBOUR IMPROVEMENTS.

By St. George Boswell, B.A.Sc., M.Can.Soc.C.E.

These improvements consist essentially, in the construction of a wet dock and tidal harbour, on the foreshore, at the mouth of the River St. Charles, and in the construction of a graving or dry dock at St. Joseph, on the Levis side of the St. Lawrence.

The Tidal Harbour and Wet Dock.—The general plan, Plate 12 shows the relative position of what, in the following description, will be designated as the Louise Embankment, the Cross-Wall, and the South Wall, which works, taken as a whole, form the tidal harbour and wet dock.

The Louise Embankment (Plate 12).—This work consists essentially of an embankment 330 feet wide at coping level, formed on the natural foreshore, at the mouth of the River St. Charles, by the deposition of dredged materials between two retaining walls.

The dredged materials forming this embankment were originally intended to have been retained, on the north side, by a stone pitching, having a slope of 1½ to 1. To hold in the toe of this slope, a line of cribwork 6 feet high and 9 feet wide was placed in position along the line of the toe of slope. It was, however, subsequently decided to abandon the pitched slope, principally on account of the danger of damage by ice, and to substitute for it a line of cribwork carried up to coping level.

As the cribwork already placed in position was too narrow to admit of its being carried up to coping level, without some additional support, it was decided to introduce counterforts in the superstructural cribwork, the main crib remaining the same width as the substructure, viz., 9 feet, with a face batter of 1 in 24. The counterforts were 10 feet wide and 15 feet deep, and were placed 30 feet centre to centre.

This cribwork is of the ordinary open kind, the longitudinals and cross-ties being merely placed over each other at right angles, and bolted at their intersection; the cross-ties being notched out 1½ inches to receive the longitudinals. To fill the space in the face of the crib not occupied by longitudinals, and thus form a solid face, what is locally known as an *entremise* filling piece is used. The heads of the cross-ties are dove-tailed with a square shoulder; and the *entremise*, which is 8 or 9 inches thick, is fitted in between them, the two ends of the *entremise* being cut to fit the dove-tails on the cross-ties.

The method of construction is shown in Fig. 3. (Plate 9). All exposed timbers are of white pine, while those under water or buried in the filling are of hemlock. This cribwork was partially filled with large rubble stone to give weight, and has withstood the pressure of the embankment without any change of line. The greater portion of the above mentioned cribwork was built in situ.

The retaining wall on the south face of the embankment, for the first 1,240 feet in length west from the old Ballast wharf, being the quay wall of the tidal harbour, was constructed as shown in Fig. 6, Plate 10.

A trench having a bottom width of 45 feet was first dredged to a depth of 24 feet below low water, for a distance of 1,240 feet. In the trench thus formed, cribwork blocks were then sunk, and filled with concrete backed up with large rubble stone and clayey materials. To complete the tidal harbour quay wall up to coping level, a concrete wall faced with masonry was constructed on this substructure.

The cribwork blocks forming part of the substructure of the tidal harbour wall differ considerably in their design from those generally constructed for ordinary purposes, such as wharf building, &c. They were not, however, intended so much to form a permanent portion of the wall as to act as moulds for the concrete while settling, and they were consequently designed with this object as the chief one to be attained. To construct an efficient concrete wall, it was necessary that there should be as few timbers running through the concrete as practicable, so that the concrete should form as nearly as possible one solid prism or monolith for the entire length of the wall. To accomplish this, the crib blocks were built with as few cross-ties as practicable, the cross-ties being blocked up in the interior of the crib as shown in cross-section Fig. 2; the position of the block and cross-tie being reversed in every successive vertical set of cross-ties, as indicated by the front view of crib Fig. 4. The larger sized blocks were made in two pieces and bolted together; two round rock elm keys, 3 inches in diameter, were driven into the joint horizontally, and parallel to the longitudinals, when the block was in position. Additional strength was given to these cribs by notching out the cross-ties 1½ inches, to receive the blocks and longitudinals,—the block being also notched out to receive the longitudinal—and by the insertion of vertical posts, to which the cross-ties and longitudinals were secured by screw bolts. As in the crib blocks forming the retaining wall, on the north face of the embankment, the spaces in the face of these cribs between the cross-ties are filled by entremises, cut to fit the dove-tailed heads of the cross-ties. These crib blocks were built while afloat; they were 120 feet long, 28 feet high and 32½ feet wide on the bottom, the back of the rib being stepped as shown in Fig. 2, Plate 9.

Before these crib blocks were sunk in position, the bottom of the dredged trench was tested, to ascertain whether or not it was capable, without any previous preparation, of withstanding the weight of the quay wall. This test was made by weighting a stick of timber 12 inches square, standing vertically on end in the trench, and from its settlement, under a known weight, calculating the resistance the bottom was capable of affording.

From the result of this experiment, it was decided that the sand bottom was sufficiently firm to carry the weight of the wall, and would require no preparation beyond levelling. As it was not practicable to level the sand bottom in a depth of 24 feet of water at low tide, with sufficient precision to ensure the crib block settling down uniformly, and to the proper elevation, four rows of weighted timber blocks were sunk and bedded in the sand, on line respectively with the four rows of bottom longitudinals, the top of the blocks being at an exact elevation of 24 feet below low water. The first crib block was sunk on a foundation prepared in the above manner; the process was, however, found to be very slow and uncertain, and was therefore abandoned.

The foundation for the remaining crib blocks was prepared by driving short stub piles, the heads of the piles being at an elevation of 24 feet below low water; this was done by means of a follower, which consisted of a stick of oak 40 feet long and 13 inches square, to one end of which was fastened a socket of ¼ inch iron, the socket projecting about 2 feet beyond the butt of the follower. The stub pile was placed in this socket and slightly wedged. In order to drive the stub piles to a correct elevation, the follower was graduated into feet and inches; when the stub pile had reached the proper elevation, the graduations on the follower corresponded to those on a tide gauge. When the follower was removed after having driven a stub pile, it occasionally slightly drew out the stub pile with it; this, however, very rarely occurred. In this manner the stub piles were easily driven with great accuracy to the proper elevation, and made a good and uniformly level foundation on which to sink the crib blocks.

To ballast one of these crib blocks during construction required 192 cubic yards of large rubble stone; this stone was placed in pockets, formed in the crib block for its reception, between the counterforts. To sink the crib block, and hold it in position until backed up, and filled with concrete, required 96 cubic yards of stone in addition to the above quantity. A cubic yard of the stone used for sinking the cribs weighed 1$\frac{16}{100}$ long tons, so that it took about 334 tons to sink a tidal harbour crib block. As each crib block was sunk, it was backed up with large rubble stone and clayey materials, the backing taking the form shown in Fig. 6, Plate 10.

The front compartments of the crib were then filled with concrete, with the exception of the last two, which were cut off from the remaining compartments by a movableb ulk head. When the next crib block was sunk in position; and before the concreting in it began, this bulk head was removed, and the concreting was then carried on simultaneously in the two crib blocks. The object of this was to prevent a seam in the concrete occurring at the junction of any two cribs. The concrete was retained in rear by a hoarding of 3-inch planks, secured to the crib in the desired form of the back of the wall. This concrete, which formed the substructural wall, was 8¼-feet wide at the top of the crib, viz., at 4 feet above low water, with counterforts 20 feet centre to centre, the counterforts being 3 feet 10 inches deep and 5 feet wide.

On the substructure thus formed, a concrete wall faced with ashlar masonry was built up to coping level, this wall having the same form and dimensions as the concrete wall forming the substructure.

The portion of the south retaining wall, forming the quay wall of the wet dock, is a continuation of the quay wall of the tidal harbour, but is of a different form of construction.

A trench 15 feet deep at low water, and having a bottom width of 25 feet was first excavated in continuation of the tidal harbour, or 24 foot trench, for a distance of 2,310 feet. Crib work blocks, similar to the one shown in Fig. 5, were then sunk in this trench on foundation piles driven to an uniform depth of 10 feet below low water, by means of a follower. These crib blocks were made in lengths of 42 feet, and were 13 feet high and 12½ feet wide on top, or at an elevation of 3 feet above low water; and made up together a distance of 2,310 feet. They were built on ways, as their mode of construction did not permit of their being built while afloat. Along the face of these crib blocks, when sunk, there was driven a row of sheet piles with gauge piles every 7 feet apart centre to centre; the sheet piles were 7½-inches by 12-inches, and were driven to a depth of 21 feet below low water, or 7 feet into the sand bottom. The gauge piles were 15-inches square, and were driven one foot deeper than were the sheet piles. These piles were bolted directly to the crib blocks, the top front longitudinal of the crib acting as an inside wale. The cribs were then filled with concrete, and backed up with clay and rubble stone.

The concrete, while setting, was held in place by 2-inch boarding placed in the crib as shown on plan Fig. 5, Plate 9. The concrete wall was 7 feet 10 inches wide at the top of the crib, or at an elevation of 3 feet above low water, with counterforts every 22 feet, centre to centre, the counterforts being 3 feet 6½ inches deep, and 4½ feet wide.

The space between the bottom of these cribs and the surface of the dredged trench, viz., for a depth of 5 feet, was originally intended to have been filled with clay and large stone. As considerable doubt existed as to the advisibility of founding a wall on a foundation of this description, concrete composed of 9 parts of large stone, 2 parts of broken stone, 5 parts of sand, and 1 part of Portland cement, was finally substituted for the clay and stone. On this substructure, consisting of crib blocks filled with concrete and faced with a line of piles, the superstructure was built. It was composed of a concrete wall faced with masonry, and was similar to the wall forming the superstructure of the tidal harbour, and of the same dimensions.

The concretes in the substructures of the tidal harbour and wet dock walls were originally intended to have been of two kinds, viz., a facing of 4 to 1 concrete about 2 feet in thickness, and a backing of 8 to 1 concrete for the remaining thickness of the wall. The 4 to 1 concrete was to have been composed of 3 measures of sand, 1 measure of broken stone (of 2 inch gauge) and 1 measure of Portland cement. The 8 to 1 concrete was to have been composed of 3 measures of sand, 1 measure of broken stone of 2½ inch gauge, 4 measures of large rubble stone and one measure of Portland cement.

In carrying out the work, however, it was decided to omit the facing of fine or 4 to 1 concrete, and in lieu of it, to enrich the coarse or 8 to 1 concrete, by adding to it an amount of 4 to 1 concrete equivalent to the face concrete omitted. This was done by putting only 4 to 1 concrete into every fifth tremie that was put into the cribs. The above change was made, as it was thought that the benefit to be obtained from having a facing composed of fine concrete did not compensate for the difficulty of keeping the two concretes separated; there was also the practical difficulty with the facing concrete, of putting down so small a body of concrete in a considerable depth of water, and in a confined space, and at the same time preventing the cement from being washed out of the concrete. The result would probably have been that, owing to the wash, the 4 to 1 concrete would have been practically less perfect than the 8 to 1 concrete put down in larger bulk at one time.

The concrete in the superstructure was composed of 2 parts by weight of sand, 1 part by weight of broken stone (2½ inch gauge), 1 part by weight of pebbles, 4 parts by weight of large stones, averaging about ½ cub. foot each, and 1 part by weight of Portland cement.

In both the concretes for the substructure and superstructure, the finer ingredients, viz., the Portland cement, sand, and broken stone or pebbles, were mixed either by hand or machinery ; the large stone being subsequently added.

The concrete in the substructure was placed in position by means of tremies, or skips, similar to the one shown in Fig. 10, Plate 9; these skips held 1 cub. yd. each, and were made of ¼ inch iron. The finer ingredients, or what may be termed the matrix, was mixed with very little water, and allowed to stand for two or three hours before being put into the work; it was then placed in the skip, the due proportion of large rubble stone being at the same time added; when the skip was full and the top covers properly closed it was lowered into the crib, great care being taken that it had fairly reached the bottom, or the concrete previously deposited, before the traps in the bottom were opened and the concrete allowed to escape; so that the concrete when leaving the skip should not pass through the water and so become washed.

The concrete mixing machine consisted of a cubical box of boiler plate iron holding 2⅓ cub. yds.; this box was made to revolve on a diagonal axis or shaft. The sand, broken stone and cement were put into it with the requisite quantity of water; it was then made to revolve four or five times, which was found to be sufficient to thoroughly mix the materials.

THE CROSS WALL, (Plate 13.)—This work is at present completed with the exception of the entrance works, and the closing of an opening, 190 feet wide, left between the Commissioner's wharf and the entrance works, to allow of the passage of vessels into the wet dock, during the construction of the cross-wall.

The cross-wall consists essentially of an embankment, which forms the division wall between the wet dock and tidal harbour, and is composed of dredged materials retained by two parallel quay walls. An entrance from the tidal harbour to the wet dock, closed by a double set of solid timber gates, is left in this embankment; the entrance is to be 66 feet wide at coping level, and will have a depth of 18 feet of water on the sill, at low water spring tides.

It was necessary, in the event of the tide not rising to the same height as the water retained in the wet dock, to provide some means of equalizing the level of the water in the two basins; this is done by placing in the embankment seven sluices, connecting the wet dock with the tidal harbour; the sluices are closed by double faced valves, and have each a cross sectional area af 24 square feet.

The substructure of the retaining wall, on the tidal harbour side of the cross-wall, consists of substantial cribwork blocks, sunk in a trench dredged for their reception to a depth of 26½ feet below low water, and subsequently filled with concrete.

These cribwork blocks differ somewhat from those employed in the construction of the tidal harbour quay wall of the Louise embankment. The face, instead of being composed of longitudinal full timbers and entremise filling pieces, in alternate courses, is made up altogether of full timbers, which are halved on to the dove-tailed heads of the cross ties; the ends of the crib blocks are also built solid to retain the concrete. To retain the concrete, in the rear, 6 inch sheet piles are used, instead of the hoarding of 3 inch planks; these piles are placed in position during the construction of the crib, and are driven six feet into the ground, when the crib is in place. Each crib block thus forms an independent caisson. These crib blocks were sunk on stub piles, driven to the proper elevation by means of a follower, in the same manner as were those placed under the crib blocks of the Louise embankment wall.

There are 36 stub piles under each crib block; the cribs being 140 feet long, 30 feet wide on the bottom, and 28 feet high, with a step of 10 feet in the rear. Two special crib blocks were constructed to form the return walls at the entrance. The one on the north side of the entrance is 152 feet long, 37 feet wide and 32 feet deep; that on the south side, which carries the sluices, being 152 feet long, 55 feet wide and 32 feet deep; 125 stub piles were driven to form the foundation of this last mentioned crib, which, when sunk in position, did not vary more than one inch in level.

In each of the ordinary 140 feet crib blocks there was placed an average of 400 cub. yds. of large rubble stone, which is equivalent to 464 tons weight. In the crib block, on the north side of the entrance, there was placed 844 cub. yds. of rubble stone, and in the crib block on the south side of the entrance, 1104 cub. yds.

The cribwork blocks forming a part of the substructure of the retaining wall, on the wet dock side of the cross-wall, are similar to those on the tidal harbour side, except that they are only 22 feet instead of 28 feet high, and are sunk in a trench dredged to 20½ feet below low water. The top of the cribs or substructure, on both the tidal harbour and wet dock sides of the cross-wall, are thus 1½ feet above low water.

The concrete used for filling the cross-wall cribs, was composed of 4 measures of broken stone (2 inch gauge), 2 measures of sand and 1 measure of Portland cement. No large rubble stone was used in the concrete; this, unless the large stone are put in with great care, is certainly preferable in submarine work, which cannot be readily inspected, as the large stones, when put in too freely, are very apt to become blocked at the cross-ties, and thus cause voids to be formed in the concrete.

The concrete wall at the top of the crib blocks or substructure is 9 feet wide, with counterforts 42 feet centre to centre, 13 feet wide and 7 feet deep.

Before any concrete was put into the cribs forming the substructure of the cross-wall, the sand bottom was covered with a layer of bags filled with concrete; these bags being placed in position by a diver. The concrete in these bags was allowed to become partially set before the bags were put down, as it was found that a bag of unset concrete, placed directly on the sand, did not set, the sand apparently sucking the cement out of the concrete, so that when the bag was taken up and examined, there were almost no traces of cement left; but the sand for some distance round, where the bag had been placed, was found to have absorbed a certain quantity of cement. A number of experiments were made to test this; bags were filled from the same concrete mixture, and some placed directly on the sand bottom, others suspended at different depths in the water, when it was always found that the suspended bags set perfectly, whereas those placed on the sand bottom never did.

From the above result, it would appear that unset concrete laid under water on a sand bottom, is liable to have the cement taken out of it, for the first foot or two up from the sand. It would consequently be a safe precaution, when placing concrete in bulk under water on a sand bottom, to first cover the bottom with some substance that would prevent this action,—tarred canvas would probably answer the purpose—otherwise, the probability is, that between the well set concrete and the comparatively compact sand bottom, there would be a seam or stratum of loose sand and stone, of about 2 feet in thickness.

To form the superstructural portion of the tidal harbour and wet dock retaining walls of the cross-wall embankment, solid masonry walls are built from the level of the top of the cribwork blocks up to coping; these walls are 9 feet wide at the base, with counterforts every 100 feet apart, and have a face batter of 1 in 24.

To construct the entrance works, it was necessary to enclose the site by means of a cofferdam. Two sides of this dam are formed by the two special crib blocks previously mentioned. These cribs are sunk in 30½ feet of water at low tide, and are filled with concrete; the concrete in the return ends of these two cribs joining the concretes in the crib blocks on the tidal harbour and wet dock faces of the cross wall. To form the remaining sides of the coffer-dam, two segmental clay dams are built across the entrance, one on the tidal harbour and the other on the wet dock face, abutting on the two special crib blocks. These dams are each formed of a double row of 12 inch piles, the rows being spaced 10 feet apart, and the space between them filled with clay. The area enclosed is dredged out to 32 feet below low water, and a bottom of concrete, composed of the same materials and in the same proportions as that used in the cribwork blocks, put in over the entire area, for a depth of 12 feet, the sand bottom having been first covered with canvass. When placing concrete in the cross wall crib blocks, a tally was kept of the number of casks of cement used, and of the number of skips of concrete (each containing one cubic yard) put down; the cubical content of the concrete space in each crib was also calculated.

From the above data, the loss of bulk due to mixing the materials, and also the shrinkage of the concrete due to consolidation when placed in the work, can be deduced. Each batch of concrete before mixing, contained 29.32 cubic feet of aggregates, made up of 4.18 cubic feet of cement, 8.40 cubic feet of sand, and 16.74 cubic feet of broken stone (Macadam). To fill the cribs, 23.520 batches, made up as above, were mixed; these batches measured 20901 cubic yards, skip measure, and filled in the cribs a space containing 18476 cubic yards. As each batch contained before mixing 29.32 cubic feet, and as the number of batches mixed was 23520, the materials therefore before mixing aggregated 25541 cubic yards. The concrete formed by mixing the above materials measured, before being placed in the work, 20901 cubic yards; there was consequently a loss of about 18⅕ per cent. in bulk, due to mixing. Of the materials used to form the concrete, 16.74 cubic feet in each batch consisted of broken stone in which the voids amounted to 54 per cent. of the bulk, or to about 9 cubic feet. Had the voids in this stone been filled by the process of mixing, the batch should have lost 9 cubic feet in bulk, or have been reduced from 29.32 to 20.32 cubic feet; by actual measure, however, the batch only lost 18⅕ per cent. in bulk eqnal to 5.34 cubic feet by mixing, or was reduced from 29.32 cubic feet to 23.98 cubic feet. It would follow from this that either voids, equal to 3.66 cubic feet, remain in the broken stone, after mixing, or that the materials have increased in bulk by this amount, during the process of mixing.

In order to ascertain what change in bulk took place when mixing sand and cement together, in the proportions used for the above mentioned concrete, the writer first mixed dry 864 cubic inches of sand with 432 cubic inches of cement, and found that there was no loss of bulk, the mixture measuring 1296 cubic inches. He then remixed the materials, adding a small quantity of water, so that the mixture should be of the same consistency as that used for concrete placed under water, and then found that the mixture measured 1477 cubic inches, having increased in bulk by 181 cubic inches or about 14 per cent. Allowing for this increase in bulk, a batch when mixed would be composed somewhat as follows:—

| | | cub. ft. | |
|---|---|---|---|
| Original bulk of materials | | = 29.32 | |
| Loss due to mixing $18\frac{1}{5}$ per cent | | = 5.34 | 23.98 |
| Bulk of materials when mixed | | | |
| Made up as below: | | | |
| Broken stone | | 16.74 | |
| Original bulk of sand | = 8.40 | | |
| do do of cement | = 4.18 | | |
| | 12.58 | | |
| Gain in bulk 14 per cent | 1.76 | | |
| Total sand and cement | | 14.34 | |
| Total bulk of ingredients | | | 31.08 |
| Lost in voids of stone | | | 7.10 |

As the total voids in the stone amount to 9 cubic feet, there would thus remain 1.90 cubic feet of voids that have not been filled by the process of mixing.

The above result would only be obtained when a small quantity of water was used for mixing. When sufficient water is added to make the cement and sand into a thick mortar, such as would be used for masonry, the bulk is then diminished, the loss being about equal to the bulk of the cement used.

The reason of this is probably that when a small quantity of water is used, the cement in a liquid form coats the particles of sand, thus increasing their size, but is not sufficiently fluid to fill the voids in the sand; when more water is added, the liquid cement is then sufficiently fluid to run into and fill the voids in the sand, the coating over each particle of sand at the same time being reduced in thickness by the loss of the cement taken to fill the voids.

When placing the concrete in the crib blocks, it required 20901 cubic yards to fill a space in the cribs having a cubical capacity of 18476 cubic yards; the shrinkage of the concrete therefore, due to consolidation in the work, amounted to about $11\frac{1}{2}$ per cent. A batch containing originally 29.32 cubic feet of materials, would thus be reduced in bulk $18\frac{1}{5}$ per cent. or to 23.98 cubic feet, by the process of mixing. It would again be reduced from 23.98 cubic feet to 21.20, or by $11\frac{1}{2}$ per cent. due to consolidation in the work, this latter loss of 2.78 cubic feet ,being equal to the voids remaining unfilled in the stone after mixing, viz., 1.90 cubic feet, and one half the gain in bulk of the sand and cement during mixing, viz., 0.88 cubic feet. A block of concrete containing in place 21.20 cubic feet, and composed of 4 measures of stone, 2 measures of sand, and one measure of cement, would consequently be made up of:

| | | |
|---|---|---|
| Broken stone | 16.74 | cubic feet. |
| Sand and cement in voids | 9.00 | " |
| Excess of sand and cement | 4.46 | " |
| | ——— | " |
| Bulk of ingredients | 30.20 | cubic feet. |

As a correct answer to the question, so often asked, to what extent does frost injure concrete? and how long is it probable that a concrete wall, exposed to the action of frost will be able to endure, without material injury? is of the greatest importance in a climate such as that of Canada. It may be well to state that in the year 1879, blocks of concrete each 6 inches square, composed of different proportions of cement, sand, and pebbles, were made, for experimental purposes, in connection with the tests of Portland cement to be used on the Quebec Harbour works. These blocks have remained out in the open air since then, and are now, after eight years of exposure to all kinds of weather, in as good condition as when made, the frost not having injured them in the slightest degree. Concrete walls, constructed in connection with the harbour works, and left exposed to the weather for five years, received no injury. The concrete composing these walls being more or less porous, it would seem probable that water entering the pores and freezing would injure the concrete, and in time cause it to disintegrate. This would probably be the result were all the pores full of water. When, however, as actually happens, the concrete is not saturated, but has only a small proportion of the pores filled with water, the water when freezing has room to expand through the unfilled pores, in every direction, the concrete for this reason escaping injury.

THE SOUTH WALL.—Work on this portion of the harbour improvements was only begun this spring, it would therefore be premature to enter into a detailed description of this work. A brief description is, however, necessary, to enable the entire scheme of harbour improvements at Quebec to be fully understood. This work will form the third side of the wet dock, the Louise Embankment and the Cross Wall forming the remaining two sides; it will join the Louise Embankment at its western and the Cross Wall at its southern end, and will consist essentially of a water-tight wall and intercepting sewer combined. The necessity of a sewer has arisen from the fact that a large proportion of the city sewage is at present discharged into the St. Charles River, in that part of its channel now about to be enclosed in the wet dock; it has therefore become necessary to divert this sewage, which will now be discharged into deep water in the River St. Lawrence. The sewer will have a cross sectional area of 41 square feet, and a grade of 1¼ in 1000. At the upper or western end, a connection will be made with the wet dock, to enable the sewer to be flushed out when desirable. The general design of this work will be seen on referring to Plate 12.

On the completion of the Louise Docks, there will be a depth of 30 feet of water in the inner or wet dock basin, except just along the face of the Louise Embankment quay wall, where the depth will be 25 feet. In the outer or tidal basin, the depth of water at low spring tides is at present 25 feet.

In connection with these works, there has been removed up to date, by dredging, a total of 2,104,014 cubic yards of material; of this amount 740,800 cubic yards are place measure, the balance being scow measure.

GRAVING DOCK (Plate 11).—The general plan Fig. 13 gives the principal horizontal dimensions of this work, the longitudinal section Fig. 14, the elevation of the inverts, bottom of dock, &c. All these dimensions are the same as those originally contemplated, with the exception that one foot has been added to the depth of the invert below low water, and that the length of the dock has been reduced by 65 feet. This latter change was rendered necessary by the difficulties met with during the construction of the coffer dam. The original coffer dam consisted of:

1st. The coffer dam proper, which was a segmental dam closing the entrance to the dock and abutting on the wing walls; this dam was composed of a double row of full timber piles, the space between the two rows of piles being dredged out to 10 feet below low water, and then filled with clay puddle.

2nd. The wing walls.—The substructure of these walls was composed of 6 to 1 concrete, formed in the proportion of 1 part of sand, 5 parts of broken stone (macadam) and one part of Portland cement. This concrete was retained by a double row of 11 inch square piles, spaced 14 feet apart and driven to 18 feet below low water; the space between the two rows of piles being dredged to a depth of 10 feet below low water, before being filled with concrete. The superstructure, which begins at 2 feet above low water, consists of a masonry wall backed with concrete composed of two measures of broken stone, two measures of sand, four measures of large stones, and one measure of Portland cement.

3rd. A timber wharf, known as the government wharf. The dock side of this wharf was sheet piled, and a bank of clay deposited along the face of the piles.

When an attempt was made to pump out the area enclosed by this dam, it was found that the water entered so freely through and under the wing walls, and through the government wharf, that the pump was unable to control the leakage. It was then decided to construct two concrete walls inside the wing walls, in continuation of the clay dam, and to put in a concrete apron or bottom 12 feet in thickness over the entire area inside the dam; the apron to extend in shore until the rock was met with. In carrying out this work, considerable difficulties had to be contended with, as the area inside the cofferdam, which had to be dredged out to a depth of 21 feet below low water, was so confined that there was no room for a suitable dredge. The rock when met with in shore at this depth had to be cleaned off; this it was impossible to do with a dredge, the surface of the rock being so irregular that the dipper of the dredge could not get into the crevices and corrugations of the rock, to clear out the materials which consisted of sand and sawdust. It was expected, however, that by making the first layer of concrete rich in cement, and by stirring up the soft bottom, that the sand and sawdust would become impregnated with cement, and so form a sufficiently hard concrete or mortar to make a water-tight joint with the rock. In some cases where it was impossible, with the appliances at hand, to clean off the rock, pure cement was put down and stirred up with the materials lying on the rock; it was in this manner as it were, attempted to mix concrete under water.

The cofferdam thus formed was capable of withstanding a head of water of about 9 feet, and it was unwatered to this extend during the construction of one of the culverts; when, however, it was attempted to unwater it completely, several blows through the concrete bottom occurred. At this junction, the control of the work passed into the hands of the Chief Engineer of Public Works. It was then decided to abandon the cofferdams already constructed, and to shorten the dock so as to bring the entrance works on to the solid rock; as it was considered that, even had it been possible to remedy the defects in the coffer dam already constructed, it would not be advisable to construct the entrance works on the concrete apron or floor, as was originally intended, as owing to the nature of the blows which took place, and which carried in with them large quantities of sand and sawdust, it was apparent that the concrete apron had been undermined, and would be consequently unsafe to build upon; a third dam forming two sides of a square, and shutting out the blow holes, was therefore constructed, Fig. 13. This dam proved successful; there were, however, several occasions after its completion, on which the works were flooded;

the water entering in great quantities through fissures in the rock, during the excavation for the caisson recess.

The graving dock, with the exception of the wing walls, is founded entirely on rock. The rock in the body of the dock was excavated to a depth of 7 feet below the level of the top surface of the finished floor. Arterial drains were then placed in channels, cut for their reception in the rock bottom; these drains were made of perforated rock elm planks 2 inches thick, and were 4 and 6 inches square inside. When in place they were imbedded in porous concrete, composed of 5 parts of clean pebbles, and 1 part of Portland cement, the porous concrete being made by washing the pebbles in a thick cement grout. Feeders to these drains were carried up behind the side walls, so that the whole of the walls and bottom were thoroughly drained. The arterial drains are carried to a well in the floor of the dock, which communicates with the pump wells. The rock bottom was covered with a bed of concrete five feet in thickness, on which the masonry paving was laid. The side walls are of ashlar masonry backed up with concrete, and are built up in altars as shown in cross-section Fig. 16, the face batter of the walls being 1 in 24. The concrete used for backing up the side walls, and as a foundation for the floor paving, was composed of 3 parts of broken stone, 3 parts of sand, 6 parts of large stone, each not weighing less than 40 pounds, and one part of Portland cement. The large stones used were taken from the excavations, and were from one half a cubic foot up to one or one and one-half cubic yards in size; these large stones were carefully bedded in the fine concrete, so that the concrete was virtually rubble masonry laid in Portland cement.

For access to the dock floor, a stair and timber slide are placed at each corner of the body of the dock. The dock is closed by an iron caisson which travels on two parallel sets of cast-iron rollers, placed in the floors of the caisson berth and recess; it is drawn back into the recess by two endless chains working round sheaves on a shaft, connected by worm gear with the auxiliary pumping engine. To make the water-tight joint, a meeting face 12 inches wide, projecting $\frac{3}{4}$ of an inch beyond the face of the stone, is cut on the granite quoins of the inner and outer inverts; the surface of this meeting face is rubbed down and polished after the stones are in place, until the surface is every where in a vertical plane at right angles to the centre line of the dock. To correspond with the meeting faces on the inner and outer invert quoins, a teak wood face is fastened to the sides of the caisson, and is dressed down until, when the caisson is resting on the rollers in the caisson berth, the surface is in a vertical plane at right angles to the centre line of the dock. The pressure of the water brings the two meeting faces together, which thus form a water-tight joint.

The caisson is divided horizontally into two compartments by a water-tight deck. The permanent ballast consisting of concrete is put into the lower compartment, sufficient being put in to prevent the caisson from floating, before the tide water has reached the level of the water-tight deck. The upper compartment is used for water ballast, the use of which is to counteract the floatation due to the rise of tide, the water being allowed to rise and fall in the caisson above the water-tight deck with the rise and fall of the tide outside.

The water ballast is regulated by means of two sluices, which pass through the caisson immediately beneath the water-tight deck, valves being placed in the sluices near the face of the caisson. A connection is made on the centre line of the caisson, between these sluices and the upper compartment, through the water-tight deck, and a pendulum valve is suspended in the sluice at this point. To allow the tide water to rise in the caisson, the valves in the two sluices, near the face of the caisson, are opened; the water then enters the sluices and presses against the pendulum valves, thereby closing the passage through the sluices. As the tide rises the water is forced up through the openings in the water-tight dock into the upper compartment.

The plan Fig. 13 shews the position and size of the culverts used for flooding the dock, and for carrying oft the water discharged by the pumps, the arrows marking the course taken by the water during the operation of pumping out. These culverts are circular and are constructed of masonry.

It will be observed that one culvert passes into the caisson recess and is continued again on the other side of the dock, where it passes from the caisson berth out through the wing wall. The use of this culvert is to afford a means of washing off any deposit that may accumulate on the rollers. No occasion to use it for this purpose has, however, occurred at the Quebec Dock up to the present.

For pumping out the dock two main pumps are provided, having brass barrels 4 feet in diameter, with a stroke of 5 feet. These pump are capable of discharging 12,000 gallons per minute, with a mean lift of 21 feet, and are worked by gearing from the main engine shaft. The main engines are of the condensing horizontal description, with cylinders 27 inches in diameter, and 3 feet stroke.

In addition to the main engines, an auxiliary engine is provided for working the drainage pumps and the caisson hauling machinery. To operate the caisson hauling machinery it must do work equivalent to lifting 45 tons 80 feet vertically in 9 minutes.

The drainage pumps are two in number, and have a stroke of 2½ ft. the barrel being 10 inches in diameter; they are capable of raising 600 gallons 50 feet in one minute.

The following is the general specification for the Portland cement used on these works:—

"The cement to be used throughout the works is to be of Portland, of the best quality, finely ground, and must pass through a sieve of 2500 meshes to the square inch, without leaving more than 20 per cent. of its bulk as residue, or through a sieve of 1600 meshes to the square inch without leaving more than 10 per cent. of its bulk as residue; and must weigh not less than 112 pounds to the imperial striked bushel, or 87¼ pounds per cubic foot. It shall be deposited upon the works at least one month before it is required for use, and at least two tests shall be made; one at the time of the delivery of the cement, and another on the tenth day after delivery. These tests are to be made from samples taken from every twenty-fifth bushel. After having been mixed and cast in moulds as directed, they shall remain in the open air for twelve hours, and then be immersed in water for seven clear days, at the end of which time, if every five samples do not bear an average tensile strain or dead weight of 1000 lbs. avoirdupois to a section of 1½ inches by 1½ inches, the cement shall be forthwith rejected, etc. The minimum test must not be less than 750 lbs."

The test quoted above was made in the following manner:

A cubic foot of the cement to be tested was first weighed; to do this the cement was made to fall from a fixed height into the measuring box through a canvas funnel, so that it should always be of the same density when weighed.

It was then sifted through a 50 x 50 sieve, twenty pounds weight being taken for this purpose; and the residue weighed. Sufficient cement to make three bricquets, was then taken from the sample, and mixed with a small quantity of water; the proportion generally being 75 ounces of cement to 16 or 17 ounces of water. It was then put into moulds, a small punner being used to consolidate it, and insure the mould being properly filled. The bricquets thus formed Fig. 17 were then allowed to set for 24 hours in the air, after which they were immersed in water for 7 clear days, and then taken out and subjected to a tensile strain, in an Adie testing machine; the section broken having a sectional area of 2¼ square inches. A great number of cement tests have been made in the above described manner, and the results recorded in a book kept for that purpose. Among these results, the following may be of interest. On several occasions the temperature of the water used for making the bricquets was 33 and 34 degrees Fahrenheit, the temperature of the air at the same time being 32 degrees, and that of the cement 35 degrees. The bricquets made under these conditions stood as high a tensile strain as did those made at ordinary temperatures, the results varying from 1300 to 1000 pounds on a section of 2¼ square inches.

In another instance, bricquets were made with boiling water, but in this case only stood a strain of 500 pounds to the same cross section. Bricquets have also been made with water, in which a large quantity of blue clay had been dissolved, and were found to stand as high a tensile strain as did those made with clear water.

It is now pretty generally admitted that the usual 7 days test of cement, gauged pure, is not sufficient to enable a true estimate of its value to be arrived at; for the reason that coarse cement will, as a rule, stand a greater tensile strain at the end of 7 days than will finely ground cement; whereas when mixed with sand, the finely ground cement will stand the greater strain of the two. To ascertain the true value of a Portland cement, it should therefore be tested by mixing it with different proportions of sand. The objection to this test, however, is that it requires considerable time, as the bricquets should be allowed to harden for about a month before being tested.

To form a pretty accurate idea of the quality of a cement, when there is no means of having it thoroughly tested, it should be subjected to the following partial tests:—

1st. For fineness—For ordinary purposes the cement should pass through a 50 x 50 sieve, without leaving more than from 10 to 12 per cent. residue.

2nd. For weight and specific gravity—The weight, to be in harmony with the fineness specified above, should range between 112 and 115 lbs. to the imperial striked bushel, the bushel measure being filled through a canvas funnel, held about 7 or 8 inches above the measuring box; this would correspond to a specific gravity of from 3·04 to 3·10.

3rd. For a tendency to blow,—which indicates that the cement contains lime in excess, or has not been sufficiently burned. This defect may in some cases be rectified by air slacking the cement.

Thin flat cakes should be made of the cement and allowed to set on a glass plate; when they have become hard, they should be immersed in water; if they then crack at the *outer edges*, the sample of cement should be spread out to cool for some days, after which fresh cakes should be made in a similar manner; if these again, on being placed under water, crack at the outer edges, the cement contains an excess of lime, and is unsafe for use.

Another means of detecting the same defect in a cement, is to fill a test tube with a paste of pure cement; when the cement has set place the tube in water, it will then in a day or two either be cracked or shattered in pieces by the hardening of the cement. In the latter case the great expansion indicates, as before, an excess of lime or underburning.

Cement, which by the makers is claimed to be equal to true Portland cement, is now being manufactured from a mixture of iron slag and slacked lime; its specific gravity is less than that of Portland cement, and the colour of a mauve tint. A cake made from this cement when broken is of a deep indigo colour.

Mr. D. L. Collins, of Messrs. Gibbs & Co., has recently published a pamphlet on Portland cement, from which the following tests for detecting the presence of slag cement is extracted.

"To a gill of water is added about a drachm and a half (80 drops) of sulphuric acid. Into this, 25 grains of the cement is dropped and quickly stirred, so as to prevent any setting; and then immediately, and whilst still stirring, Condy's fluid is allowed to fall in drop by drop until the red colour remains permanent.

A good genuine cement will require only 10 to 15 drops of the fluid (certainly not more than 20), whilst an adulterated cement will take considerably more (say 30 to 60), and a cement made from slag only, probably over 200 drops.

Mr. H. B. Yardley, analytical chemist, has also formulated the following as a simple test for the same purpose, viz., to place upon a clean silver coin a thin layer of the suspected cement, dropping thereon a small quantity of dilute sulphuric acid (1 acid to 7 water), and afterwards rinsing with water. If the cement is genuine, the treatment with acid will only slightly affect the colour of the silver; but if slag is present in any notable proportion, a dark brown stain will be produced upon the coin."

The following table shows the comparative value after one month's hardening of several brands of Portland and Canadian cements.

| BRAND. | Number of Bricquets. | Average tensile stress in lbs. on 2¼ sq. in. | Weight of one cub. foot. | No. of days in air. | No. of days in water. | Sieve 40×40 | | Parts of cement. | Parts of sand. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | lbs. sifted. | lbs. residue. | | |
| *English.* Portland. | | | | | | | | | |
| E. | 3 | 1514 | 88 | 1 | 29 | 20 | 2 | 1 | 0 |
| " | 3 | 912 | 88 | 1 | 29 | 20 | 2 | 1 | 1 |
| " | 3 | 465 | 88 | 1 | 29 | 20 | 2 | 1 | 2 |
| " | 3 | 378 | 88 | 1 | 29 | 20 | 2 | 1 | 3 |

| Brand. | Number of Bricquets. | Average tensile stress in lbs. on $2\frac{1}{4}$ sq. in. | Weight of one cub. foot. | No. of days in air. | No. of days in water. | Sieve 40×40 | | Parts of cement | Parts of sand. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | lbs. sifted. | lbs. residue. | | |
| *German.* Portland. | | | | | | | | | |
| A. | 3 | 1602 | 84 | 1 | 29 | 20 | $1\frac{1}{2}$ | 1 | 0 |
| " | 3 | 970 | 84 | 1 | 29 | 20 | $1\frac{1}{2}$ | 1 | 1 |
| " | 3 | 706 | 84 | 1 | 29 | 20 | $1\frac{1}{2}$ | 1 | 2 |
| " | 3 | 367 | 84 | 1 | 29 | 20 | $1\frac{1}{2}$ | 1 | 3 |
| *Belgian.* Portland. | | | | | | | | | |
| J. | 3 | 988 | 84 | 1 | 29 | 20 | $\frac{1}{2}$ | 1 | 0 |
| " | 3 | 892 | 84 | 1 | 29 | 20 | $\frac{1}{2}$ | 1 | 1 |
| " | 3 | 696 | 84 | 1 | 29 | 20 | $\frac{1}{2}$ | 1 | 2 |
| " | 3 | 402 | 84 | 1 | 29 | 20 | $\frac{1}{2}$ | 1 | 3 |
| *Canadian.* Portland. | | | | | | | | | |
| G. | 3 | 616 | 54 | 1 | 29 | 20 | $2\frac{1}{1}\frac{1}{6}$ | 1 | 0 |
| " | 3 | 150 | 54 | 1 | 29 | 20 | " | 1 | 1 |
| " | 3 | 000 | 54 | 1 | 29 | 20 | " | 1 | 2 |
| W. | 3 | 555 | 58 | 1 | 29 | 20 | $\frac{4}{1}{}^{9}$ | 1 | 0 |
| " | 3 | 403 | 58 | 1 | 29 | 20 | " | 1 | 1 |
| " | 3 | 000 | 58 | 1 | 29 | 20 | " | 1 | 2 |

From the drawings accompanying this Paper, Plates 9, 10, 11, 12 and 13 have been prepared.

## DISCUSSION.

Mr. Keating.

Mr. Boswell's paper must prove one of more than ordinary interest to most Canadian Engineers, and he is deserving of special thanks for the pains he has taken in its preparation, and for describing minutely some of the most important features of the works.

As Portland cement concrete entered largely into their construction, it was to be expected that considerable space would be devoted to describing the methods pursued in its preparation, and the various proportions of aggregates adopted for the different classes of work. Some of these proportions appear peculiar and capable of improvement.

After hearing the description of the concrete used in the substructure of the wing walls of the dry dock, it seems difficult to imagine how any other result than the failure which was experienced could have been expected, as the mass would necessarily be of a highly porous nature. This concrete we are told was composed of 1 part cement, 1 part sand, and 5 parts broken stone, extending from 10 feet below to 2 feet above low water level, and yet it appears to have been regarded as sufficient to form a portion of the original cofferdam intended to exclude the water from the main body of the work while in progress. Concrete made in such proportions would not be water-tight under the most favorable circumstances, but when deposited below water and on a sandy bottom, its worthlessness for cofferdam purposes one would think ought to have been anticipated.

Mr. Boswell's notes on the shrinkage or loss of bulk in concrete are interesting and practical. As he does not say that punning was practiced it may be inferred that it was not, but that the material was simply shovelled or dumped into place and allowed to consolidate itself. He shows that it required 25,541 cubic yards of dry material to produce 18,476 cubic yards of concrete in place in the cross wall-cribs, and he states that the loss due to mixing was 18.2 per cent. The shrinkage due to consolidation was therefore 9.5 per cent., or the total loss or shrinkage due to all causes 27.7 per cent. of the original bulk, without taking into account the quantity of water used.

In order to obtain one cubic yard of concrete of the proportions stated, viz.: 1 part cement to 2 parts sand and 4 parts broken stone such as ordinary road metal, it would thus appear to be necessary to provide

| | | |
|---|---|---|
| | 5.33 | cubic feet of cement. |
| | 10.67 | " " " sand. |
| | 21.34 | " " " broken stone. |
| Total...... | 37.34 | " " " dry materials. |

Now, as a matter of fact, large as this allowance may appear, it is not sufficient to produce one cubic yard of thoroughly consolidated concrete, and had the material been rammed very different results would have been obtained. There must still have been voids in the finished concrete described to the extent of nearly 3¼ cubic feet to the cubic yard. In other words the total loss or shrinkage (as it may for convenience be termed) in the formation of a thoroughly consolidated concrete, is about 50 per cent. of the original bulk of the dry materials. This is the result which the speaker has arrived at after repeated careful experiments with concrete rammed into moulds for special purposes. With some materials the actual loss was found to be greater, but the general allowance of 50 per cent. appears, as a rule, near enough for all practical purposes. The subject is one of considerable importance to contractors and others, who are likely to be concerned in the construction of large concrete works.

Probably there must have been good reasons why no mention is made in the paper under discussion of prices paid for different items of the work and of the total ultimate cost, but as these are matters of very considerable interest and importance they would appear to be deserving of some attention. The latter in fact is of the first importance, as an undertaking may prove so expensive that it become a positive burden to the community, corporation or company who are expected to furnish the funds instead of a benefit as might have been at first anticipated. It is not to be inferred that this is the case in the present instance, although it is well known that the works have cost, at least in the case of the dry dock, vastly more than was expected at the commencement, and somewhere about double the original estimate.

It seems that the dry dock was commenced in 1877, and by the terms of the contract was to have been completed in 1882.

From the official reports of the Quebec Harbor Commissions it appears the original contracts were as follows, viz.:

| | |
|---|---|
| For the Graving Dock Engine and boiler houses | $330,953.89 |
| " Caisson for same | 29,221.51 |
| " Pumping Machinery for same | 32,000.00 |
| " Boilers (3) | 4,500.00 |
| " Keel Blocks (127) | 5,588.00 |
| Total | $402,263.40 |

There were extras or additions to the contracts, owing, it is to be presumed, to the serious difficulties encountered in carrying out the works, so that by the close of 1885 about $720,000 had been expended. It would be highly interesting and instructive to know how all these extras were made up, what they were for, and what the total cost of the work amounted to at completion.

Some features of the work as described seem extraordinary and novel. For example, the experiment of mixing concrete under water would appear to possess no other merit than that of novelty, and is not likely to be often repeated elsewhere.

There is also another feature which it would be interesting to have more fully explained. The graving dock it is stated is founded entirely on solid rock, and yet this rock was excavated to a depth of seven feet below the finished level of the floor, and the space filled in again with concrete which could not reasonably be expected to be as solid, or at least any more solid, than the material removed. The procedure would therefore appear to be not only unnecessary but extravagant.

Mr. Evans. With reference to Mr. St. George Boswell's paper on the Quebec Harbour Improvements, Mr. E. A. Evans has read with interest the valuable information contained therein, but desires to take exception to "the statement that a bag of unset concrete, placed directly on the sand, "did not set, the sand apparently sucking the cement out of the "concrete, so that when the bag was taken up and examined, there "were almost no traces of cement left, but the sand for some distance "round, where the bag had been placed, was found to have absorbed "a certain quantity of cement." Mr. Evans fails to see how sand at the bottom of a river, which must already have absorbed all the moisture that it possibly can, and therefore have lost all power of suction, could suck the cement out of the concrete, and consequently considers that some other cause must be looked for, to account for this unusual occurrence (perhaps due to the velocity of the river). To be further convinced he has, since reading the papers, made three separate and distinct experiments on the Coulonge River, as follows:

No. 1. Concrete composed of 2 of sand, 1 of Portland cement, and as much broken stone as was required to fill all voids. After being placed in bags, allowed one hour before immersion, were placed on sand at bottom of River and one bag suspended in the River.

No. 2. Concrete composed as in No. 1, but bags immersed immediately after mixing in the same manner as No. 1.

No. 3. Concrete composed of 4 of sand, 1 of Portland cement, and as much broken stone as was necessary to fill all voids, bags immersed immediately after mixing in the same manner as No. 1.

The bags of concrete were permitted to remain in the River 7 days, at the end of which period they were taken out with the following results:—

Nos. 1 and 2. The concrete was firmly set, but the cement had not had sufficient time to be perfectly hardened.

No. 3. Same as Nos. 1 and 2, with the exception that the concrete was broken through at the part where rope was placed around bags for the purpose of hauling them out. (This would no doubt be due to the proportions of sand to cement, and to the shortness of time allowed for setting.)

In each of these experiments it was impossible to detect the difference between the bags suspended in the water and those placed on the sand bottom of the River, and there was no apparent loss of cement. It would perhaps be as well to mention that the greatest surface velocity at high water is only about 2 miles per hour, so that the velocity of the current is not likely to have had any effect on their experiments.

Mr. Evans has for some time tested cement for an excess of lime by the method mentioned by Mr. Boswell, viz., by making thin flat cakes, and when sufficiently hardened immersing them in water. He considers the method not only good, but very necessary to a satisfactory test as to quality.

Mr. Irwin.

It seems to the speaker that some of the criticisms on the experiments made in Quebec as to the effect of sand in the bed of a River on bags of concrete deposited thereon are hardly fair.

One member declares that he cannot accept the experiments as reliable, and says that the cement used must have been very bad; yet so far as the speaker can remember he gives no reason for the conclusion he arrives at.

Another member states that he cannot understand the result of the said experiments, and, as his reason, gives an account of some tests made by himself and of a somewhat similar character.

Now a bare statement that one cannot accept any experiments except they be made in person, or to confess inability to understand them, can scarcely be called a proof of the want of reliability of said experiments; and in any case the tests made by Mr. Evans, were carried out under totally different conditions from those at Quebec, the water was different, the current was not the same, the cement was by another maker and the sand on the bed of the River was certainly of a very different character.

Whether the members above referred to on the one hand refuse to accept, or on the other hand fail to understand the experiments referred to by Mr. Boswell, the following *facts* remain:

*First.*--That bags of concrete, similar in every way to those deposited on the bed of the River, when suspended freely in the water, set very well.

*Second.*—That placing tarred canvas under the bags of the same kind of concrete when they were laid on the bed of the River; and

*Third.*—That when the concrete was deposited in bags on the sand of the bed of the River, a considerable portion of the cement found its way into the sand below.

As these experiments seem to have been honestly made, I do not think that any of the statements made or tests carried out with a view of disproving them should be given too much weight.

Mr. Evans says that he cannot understand how sand saturated with water could have any power to absorb cement from a bag of cement deposited on it; however, as already remarked, inability to understand a subject is no argument against it, the cement may have been slow in setting, and supposing that to have been the case it is quite possible to imagine that a heavy bag of concrete, laid on the bed of the River, would press the surplus water out of the sand immediately below it, and leave it in such a condition as to have a certain capacity for absorbing some of the cement above it, possibly by some sort of capillary attraction. While speaking of cement, the speaker would be glad to know if any member can give information as to the composition of the sediment, called by the French "laitance," which rises on the top of concrete when laid under water, also if any means have been taken to prevent its rising.

It seems that, in the case of concrete laid in sea water, this "laitance" sometimes becomes almost like a thin jelly. Could this be any part of the "soluble silica" which might be prevented from combining to form silicates through some of the salts in the sea water?

Recently in the case of certain concrete set in fresh water, this sediment was analysed and found to consist of lime and magnesia. Possibly if a little neat cement were spread ever the surface of the concrete through a rubber tube it would set with the sediment, as the concrete may have contained an excess of lime and magnesia. Some experiments might be made with a view of finding out the cause and means of prevention of this sediment.

A member has just stated that a very small amount of impurity in the cement was sufficient to make large blocks of concrete break in pieces on being lifted—It seems hardly possible that the small amount of impurity "*per se*" could have been the cause of the breakage—it probably acted by preventing the "soluble silica" from combining; just as in the case of chemical experiments a very small amount of impurity will often prevent a reaction from taking place.

With regard to concrete used in winter the speaker has recently seen the result of experiments made in Germany on the effect of mixing salt with the water. It was found that concrete made when eight per cent. of salt was added to the water was very much stronger than that made with pure water when the weather was very cold. Unfortunately no mention was made of the strength of similar concrete made at a higher temperature. The salt seems to have kept the water from freezing longer and to have thus given the cement longer time to set.

As to the tests made of the bearing power of the sand on which the cribs of concrete were to be placed—a twelve inch pile was far too small, as the sand would yield under it by being displaced laterally — however, the experiments, if they gave incorrect results, would err on the safe side.

**Mr. Henshaw.**

The speaker has not had an opportunity of visiting the works treated of in Mr. Boswell's paper, nor of conversing with any one connected with them. He has had only the paper to go by, and he hopes that much of the severe criticism he is about to utter may be found to have been made under a misapprehension of its statements; yet, the paper seems plainly written and with a frankness very creditable to its author.

The paper is a very instructive one, but not in the usual sense of the term; for it gives a description of things to be avoided, rather than to be followed. In short, it describes a work in which there is not, so far as the original design is concerned, one single solitary feature to be commended, and from which the only satisfaction to be derived by us is the fact that its designer was not a Canadian. It is not intended to include in this condemnation the gentleman who had charge of the work. He appears to have faithfully followed his instructions. The fault is clearly in the design itself, which exhibits an ignorance of practical hydrography that is appalling.

Taking the wet dock or Louise Basin, the walls enclosing it are found to be of different depths, so that the foundation of one wall at least is much higher than the bottom of the basin. Now, there might be good reasons for this if it was shewn that the bottom was solid at the depth given. The actual fact, however, appears to be that it was nothing more than sand, and not only that, but the depth of the sand and the character of its layers seem never to have been ascertained.

The veriest tyro knows that the amount, position, and shape of a sand deposit depends upon the currents which bring it to the spot, and that these depend upon the natural conditions of the river bottom, and the shores which confine it; and, finally, that any obstructions to or alterations in these will produce corresponding alterations in the currents, and consequently in the shape, position and quantity of the deposits. As the changes thus produced are subtle and difficult to predict, it is customary, in fact imperative, so to secure the foundations that they cannot be undermined. If, therefore, the walls cannot be carried down to a firm bottom, they should be built upon piles driven to the solid. In certain places, it is true, where the area outside the walls is valueless, spurs may be thrown out to trap the sand and make that part an area of deposit instead of erosion; but in a tidal river with an enclosed basin, the rising and falling tides will produce a head between the river and the basin, tending to set up currents beneath the foundation that will gradually undermine the wall wherever they can most easily work through.

Now, how were these walls founded? Having experimentally discovered the bearing power of a blunt pile upon the sand, a sufficient number of short or stub piles were driven by a follower until their heads were all on a level, and cribs were then sunk upon them. That their *actual* individual bearing power was quite ignored, and the experimental test alone relied upon, is shewn by the fact that some, if not many, were so loosely driven as to be pulled out on withdrawing the follower. And this was to be the foundation of a great and important work.

The puerility of such a design is shewn from the treatment of sand at the bottom of a river as if it was high and dry. Its author appears to see no difference between the weight and tenacity of dry sand, and sand only saturated, but diminished in gravity by the weight of the water displaced by it. The mere fact that the pile could easily be driven into the sand which was supposed able to support it, might have suggested that the seismic shocks, however slight they might be, to which the locality is subject, would tend to sink it further, when the weight of the wall was on it. It is much to be feared that though subsequent counsels prevailed, and the space between the bottom of the cribs and the sand was filled with concrete, the danger has not yet disappeared. At least it should be more clearly explained how this filling was done, whether after the cribs were sunk or before.

The character, too, of the concrete itself appears questionable, both in the composition of the cement and in the broken stone used.

With regard to the first, it is the speaker's firm opinion that no first class work can be obtained from mixtures of quick lime and cement; that a cement found to swell or heat should at once be rejected. He is well aware that a so-called hydraulic lime is much used in England for concrete, but his experience of it is that it is perfect trash, and that where favourable results have been claimed for it, still more favourable results would have been reached by the use of good common quick lime alone.

Quick lime requires a long time to slack, and if mixed with cement cannot be slacked before the strength of the cement is greatly exhausted if not destroyed.

With regard to the broken stone, the use of large stones thrust among the smaller is very objectionable. In any given concrete mixture, the strength of the mass is in direct proportion to its homogeneity, and therefore great care should be taken in that respect.

Another remarkable point is the peculiar use made of bags of concrete, which are usually applied along the bases of sheet piling to make it tight, but which appear here to have been laid over the entire bottom. The extraordinary part, however, is that instead of being used so as to conform to irregularities which are really their only *raison d'être*, they were allowed to set partially before being placed, thus becoming as useless for such a purpose as so many rotten stones. The reason given for this is still more extraordinary, namely, that it was found that the sand at the bottom sucked the cement through the bags out of the concrete. This remarkable supposition was supported, it appears, by the experiment of laying one bag on the sand, and suspending another free in the water. In the first of these the cement was found to have disappeared, and in the other firmly set in the concrete. Now the speaker has no hesitation in expressing his disbelief in the author's conclusions regarding this experiment, and if the latter will not only pardon but follow the advice of an old engineer, he will be very careful in future not to jump at conclusions, especially in so unprecedented a case, without far more exhaustive experiment than appears to have been undertaken here. He will probably yet find in the experiment described that, owing to the condition of the bag, or the coarseness of the macadam, or the poorness of the cement, or all together, the cement was in the one case lost in the filling and not in the other.

The concrete appears to have been of the same coarse character as that used elsewhere, but the speaker's practice has been to use only fine gravel when placed in bags, and either to use old flour bags, or bags the interiors of which have been dredged over with wheat flour. That saturated sand at the bottom of a river could have any power of suction is simply incredible.

It is always an unpleasant and invidious task to find fault with the work of a brother engineer. It is far more pleasant to dwell upon the excellencies than the defects of a work; but there are cases in which it becomes the duty of the older engineers to speak out plainly, lest the younger members be led by their silence into receiving false principles of construction as sound.

**Mr. MacPherson.** This interesting paper has given a large amount of information concerning what has certainly proved a gigantic undertaking, but it would be difficult fairly to criticise its merits, as an undertaking, without having thoroughly examined the location and the plans in detail; in reading over the paper, however there are points in the details of the work which strike one at once as admitting of explanation or further information.

For example, after testing the foundations for the quay wall of the tidal harbor, by means of a 12ins. ×12ins. timber standing upright and weighted, it was decided the resistance was sufficient; now it is not told what the minimum resistance was found to be, per square foot, nor what the maximum weight is, which the finished structure brings upon such an end. The author will doubtless be good enough to inform us on this point.

The top of cribwork in the substructure is stated to be 1½ above low water, why was it built so? Does the fact, that the timbers never really get dry, prevent them from rotting, just as if continually under water.

The work of constructing a coffer-dam for the graving dock seems to have been largely, if not entirely, experimental, as after the failure of the original dam, extra concrete walls were built inside the wing walls, and a layer of concrete 12 feet deep was placed over the whole area of basin inside the dam, this should have been successful if properly carried out, but for a second time the coffer-dam failed and the reason seems obvious. It was a novel idea, this attempt to mix pure cement, under water, with mud and sawdust, in the hope that it would form concrete.

This plan, if successful, might have revolutionized the old, slow but safe methods for foundations under water, where soft material overlies rock; unfortunately it was not successful, for 12 feet in depth of this unique mixture, it seems a libel to call it concrete, would not resist a head of over 9 feet of water, and again this huge experiment in coffer-dams was abandoned.

The third one was successful, but the gaving dock was shortened 65 feet. It would be interesting to know what were the conditions governing its original length, and how these conditions were affected by the shortened dock.

Could the author give comparative figures as to what was the total cost of the two coffer-dams which failed, and what would have been the additional cost to have kept to the original length of dock by going further inshore.

**Mr. Bovey.** Mr. Boswell's paper is one full of interest and of valuable information. There are many points connected with the design and construction of the harbour works at Quebec of a novel and unique character, and of extremely doubtful pratice. What might almost be considered a dangerous experiment, is the method adopted in building the river wall. Long timber stringers of large scantling run at short intervals right through the wall from front to back. In the settling of the concrete, voids will be left immediately below these stringers—and this has been found to have always occurred in concrete stuctures interlaced with timbers—and channels will then be formed through which the water will have a free passage to the river. Whether the leakage will be so large as seriously to diminish the depth of the water in the dock, experience only will shew, but it certainly promises to be considerable.

The experiment of the concrete bags referred to by Mr. Boswell is, on the face of it somewhat extraordinary, and perhaps it might be well to assume that the bags were extremely porous.

The statements respecting the laying of concrete in cold weather are also of much interest. There now seems to be a general unanimity of opinion as to the practicability of doing this successfully, *providing due care is exercised.* As far back as 1875 Mr. Chanute used both masonry and concrete in the Kansas city bridge, when the thermometer was very low. The water and sand were artificially heated, the result being that settling took place before the mass was cool enough to freeze. Mr. T. C. Clarke notes the fact, in connection with the Quincy Bridge, that some of the masonry was laid in place when the thermometer was as low as 16° F., care having been taken to heat the water and sand, and to clean out the frost from the stones, by holding them over a charcoal brazier. Subsequent examinations have shewn no appreciable difference in the quality of the portions built during the summer and winter. Again, in building the New York wall, the sand and broken stone were heated, and the work was carried on during the winter with most satisfactory results. On one occasion the thermometer fell to 11° F., in the atmostphere and 32° F. in the water, but without detriment to the concrete.

Mr. Boswell has given various data respecting the change in bulk of the concrete materials before and after mixing, and the following might be of some interest, as they relate to a similar class of structure, viz. No. 1 Graving Dock Liverpool, Eng.

In 29,380 cubic yards of concrete, the proportions of material were—burrs 29,043 cubic yards, sand 14,615, Portland cement 3,477, equivalent to 1 of cement, to 3·66 of sand, to 5 of stone in finished work

In Guernsey Mr. LeMesurier found that 1 cubic foot of cement, and 4 cubic feet of sand, when mixed with 1 cubic foot of water=when ready for use, 4 cubic feet, and that 1 cubic foot of cement and 5 cubic feet of sand when mixed with 1 cubic foot of water=when ready for use, 5 cubic feet.

While in Liverpool 2361 cubic inches of Portland cement when mixed with 1287 cubic inches of water=2350 cubic inches.

It is very true, as Mr. Boswell says, that the strength of concrete depends very greatly on the irregular size of the stones. The following experiments, carried out by Mr. Le Mesurier, of the Mersey Docks, shew this in a very marked manner.

All the blocks tested were 12×12 in. face, × 6 in. depth, and they were crushed after a space of 2 months.

The average crushing stress per sq. in. of 2 blocks made of fine river sand, $\frac{1}{11}$th of the whole being cement, was 48·2 lbs. per sq. in.

The average crushing stress per sq. in of 2 blocks made of sandstone broken to a uniform size to pass through a 2 inch ring, $\frac{1}{11}$th of the whole being cement, and the cement in the proportion of 6½ to 1, was 208·4 lbs. per sq. inch.

The average crushing stress per sq. in of 2 blocks made of large and small sandstone as broken by Blake's crusher, viz., 231 lbs. of stones under 6 in. × 13 in. × 3 in., 100 lbs. of stones under 3 in. cube, 41 lbs. of stones from siftings and 32 lbs. of sand from sandstone, with $\frac{1}{11}$th cement and sand in the proportion of 1 to 4, was 324 lbs. per sq. in.

The strengths were thus in the ratio of 1 : 4·2 : 6·5. On the New York River wall the crushing strength of concrete (1 of cement 2½ sand, 6 of broken stone), varied from 944 to 1660 lbs. and averaged 1302 lbs. per sq. in. after setting 6 months.

Mr. Boswell.

Mr. Henshaw, when condemning the general design of the Quebec Harbour works, states, as one reason for doing so, that in the Louise Basin the foundation of one wall, at least, is higher than the bottom of the basin; this is not, however, the case, and Mr. Boswell regrets that his description of the works should have been so ambiguous as to have led Mr. Henshaw to suppose so. The least depth of the foundations in the outer or tidal basin is 24 feet below low water, the bottom of the basin being dredged to the same depth. In the inner or wet dock basin, the least depth of the foundations is 10 feet below low water, the bottom of the basin, in proximity to this wall, being dredged to the same depth. This, if not clearly stated in the paper, is shown to be the case on the drawings.

Mr. Henshaw has misunderstood the use of the stub piles. They formed no part of the original design, but were merely used as a ready means of preparing a level foundation on which to sink the cribs; the first crib block was, in fact, as stated in the paper, sunk on sleepers; it was only when this method was found to be cumbersome that the stub pile system was adopted. These piles were in no instance intended to act as bearing or foundation piles; the crib blocks which rest on them "were not intended so much to form a permanent portion of the wall, as to act as moulds for the concrete while setting;" the wall, which consists of concrete, does not depend for support upon the cribs or stub piles, but upon the sand bottom, and as far as the stability of the wall goes, the stub piles might have been omitted.

Mr. Henshaw supposes that many of these stub piles were withdrawn by the removal of the follower; this is, however, a gratuitous assumption, as "it very rarely occurred." Mr. Boswell agrees with Mr. Henshaw when he condemns a mixture of quick-lime and cement; Mr. Henshaw is, however, mistaken, when he supposes such a mixture to have been employed on the Quebec Harbour Works, as no mixture of the kind was used; he does not, however, agree with him, when he condemns the use of stones of different sizes in a concrete structure; when the work can be inspected, and the large stone carefully bedded in the matrix, there is no more objection to their being used in concrete than there would be in masonry.

The experiment with bags of concrete filled from the same mixture was made on several different occasions, with always the same result, which was that in the bag suspended in the water the concrete set perfectly, while the concrete in the bag placed on the sand bottom did not set at all. Mr. Boswell would prefer providing against such a contingency, when placing concrete in a plastic state under water on a sand bottom, than to trusting to an opinion or theory as to the impossibility of such action taking place, until shown to be correct by some more tangible evidence than has so far been produced.

The difference between the results of the experiments, with bags of concrete, made by Mr. Evans, and those obtained at Quebec, may, as clearly pointed out by Mr. Irwin, be due to a variety of causes. For instance, the cement used by Mr. Evans may have been quick setting, so that the concrete might have had time to set, before the process could be checked, by the contact of the concrete with the sand bottom. Mr. Bovey supposes the bags used to have been porous, this they were, at they were old flour bags; but they were no more porous in one nstance than in another, the same quality of bag being used in all cases. When placing concrete in a plastic state under water, Mr. Boswell knows of no means of avoiding the formation of the laitance referred to by Mr. Irwin. The formation of this substance is, no doubt, a great objection to the use of plastic concrete, the quantity of laitance deposited being an indication of the amount of wash that has taken place in the concrete. No matter how carefully the concrete may be put down, a certain amount of laitance is sure to be deposited, which not only weakens the concrete by an actual loss of cement, but also, unless removed, will form seams in the concrete. Mr. Boswell has seen considerable quantities of laitance formed by the wash caused by the tide rising over concrete, that had been placed in position from one half to one hour before the water reached it. Any remedy, which would prevent the formation of laitance, would undoubtedly add greatly to the value of Portland Cement concrete as a building material.

Mr. Boswell regrets that he is unable to give Mr. Macpherson any details of the experiment made with a 12 in. ×12 in. pile for testing the bearing power of the sand foundation, as it was made under the personal supervision of the then resident engineer, acting, he believes, on instructions from the chief engineers. The conclusion arrived at, however, was that the sand bottom was capable of supporting the weight of the walls without the intervention of foundation piles or other accessories. The reason the tops of the cribs or substructure were above low water, was to avoid setting masonry under water. The top timbers of the cribs are not exposed to the air for a sufficient length of time, to permit of their becoming dry.

The 12 feet concrete apron, forming part of the second coffer-dam at the Graving Dock, was put down with skips, in the ordinary manner; it was only at the junction of this apron with the inclined surface of the rock, and when pickets of sand were found, which the dredge could not remove, that the expedient of putting down pure cement was adopted. Mr. Boswell would certainly not recommend this method of getting over a difficulty.

Mr. Boswell does not agree with Mr. Keating in considering the failure of the first coffer-dam at the Graving Deck, to be due altogether to the quality of the concrete in the wing walls; but more to the character of the sand foundation and the very probable existence of a seam of poor concrete immediately over this sand bottom. The concrete, of which the walls and bottom of the coffer-dam for the entrance works of the cross wall are made, is of very nearly the same composition. This dam has been successfully unwatered, and has stood a head of 40 feet. As stated by Mr. Bovey, the timbers running through the concrete are very apt to form channels for the passage of water; this objection is, however, overcome to a great extent by the solid timbers facing the crib blocks, which prevents the passage of water to any large extent. This may be observed at the cofferdam for the cross wall entrance, where comparatively few of the timbers running through the concrete, lead in water, and this with a head of water of about 40 feet, whereas, on the completion of the inner basin, the head will not exceed 15 or 16 feet.

Mr. Keating has not stated the proportions of the aggregates in the concetre, in which he found the shrinkage to amount to 50 per cent.

The results given in the paper are based on careful measurements made when placing concrete under water; the concrete was not, as a matter of course, punned, as this would only have had the effect of stirring up the concrete, and thereby causing the cement to be washed out. That under ordinary circumstances the shrinkage can possibly amount to 50 per cent., when the aggregates used are in the proportion of 4 parts of broken stone, 2 parts of sand, and one part of cement, seems to Mr. Boswell unlikely, as the shrinkage would then have to extend to the stone; for instance, to make one cubic yd. of concrete in place, with a 50 per cent. shrinkage, would require :—

| | | |
|---|---|---|
| Cement | 7·7 | cub. ft. |
| Sand | 15·4 | " |
| Broken stone | 30·9 | " |
| Total aggregates | 54·0 | |

These aggregates, when mixed and placed as concrete in the work would, according to Mr. Keating, only make one cub. yd.; to do this it would be necessary, after the disappearing of the sand and cement, that the stone, which alone amounts to 30·9 cub. feet, should shrink 3·9 cubic feet, or from 30·9 to 27 cub. feet.

In the very interesting record of experimental facts regarding the shrinkage of concrete and cement mortar, given by Mr. Bovey, the results agree very closely with those mentioned in the paper, with the exception that the shrinkage of the concrete is greater than occurred at Quebec; this is probably due to the difference in the character of the aggregates.

The conclusion to be arrived at by comparing these two records of the shrinkage of concrete, when used in any considerable quantity is that, in providing the aggregates, a loss of from 30 to 35 per cent. must be allowed for. Mr. Boswell's principal reason for not mentioning the cost of the different works was that this information may be obtained by referring to the annual reports of the Quebec Harbour Commissioners.

# OBITUARY.

T. W. **Harrington** was a son of the late Mr. Michael Harrington, for many years a clerk in the Quarter-Master General's Department at Kingston.

He was born in Quebec in 1829. Shortly afterwards the family moved to Kingston where he was educated at the Midland Grammar School, studied medicine for a short period with the late Dr. Sampson, and temporarily filled the position of junior clerk in the same office with his father. In 1850, he resigned this post and joined one of the parties engaged in making the preliminary surveys for the Montreal and Kingston Railway, of which the present President of the Society, Mr. T. C. Keefer, was the Chief Engineer. He obtained this position on the recommendation of Colonel Baron de Rottenburg. He was subsequently employed under Mr. Keefer on the construction of the Montreal Water Works, where his ability and integrity became apparent in the satisfactory manner in which he performed his duties as assistant in charge of the Aqueduct, obtaining considerable practical experience in the profession. Shortly after the completion of these works, in 1856, Mr. Keefer again employed him as assistant on the Hamilton Water Works, and here amongst other duties he superintended the construction of the large reservoir on the Mountain, the laying of the principal mains, etc., to the entire satisfaction of his chief.

He was for many years first assistant in the office of the late Mr. Sippell, Superintending Engineer of the Lachine and Ottawa Canal, and under Mr. Sippell's successor continued to occupy this position until his death, on the 26th October last. He had been suffering for the past two or three years from a painful disease, so that his decease although rather sudden was not unexpected.

Mr. Harrington was of an amiable and kindly disposition, and made many warm friends amongst all classes with whom he was brought into contact. He possessed, under a simple and unpretending exterior, a large amount of common sense coupled with considerable executive ability and extensive information. He was faithful and truthful, and it was certain that any work or business entrusted to his charge would be ably and honestly carried out.

It is well known that the value of his services were fully recognized by the Chief Engineer of Canals, with whom he was deservedly a favorite employé.

Mr. Harrington was, it will be seen, amongst the number of those who joined the ranks of the engineering profession over 35 years ago, when the first important move was made towards the construction of the trunk lines of railway; and at a time when the public works of Canada were on a comparatively restricted scale. He contributed his share of diligent and faithful work towards establishing the present advanced condition of affairs, and leaves an example which, in many respects, may with profit be followed by his younger professional brethren.

# INDEX TO THE TRANSACTIONS.

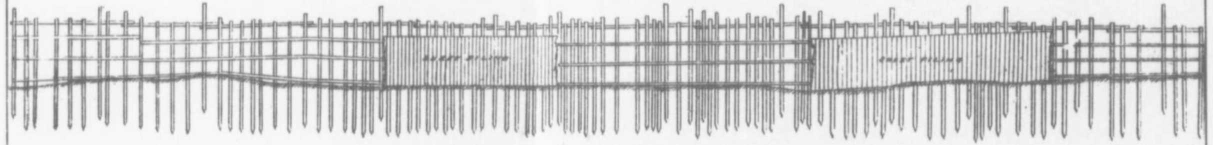
1887—October to December.

5

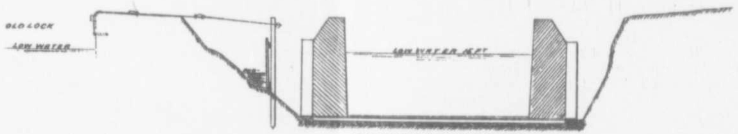
PLATE 5

## RAPIDE PLAT CANAL

DAM TO PROTECT SOUTH BANK OF LOCK-PIT

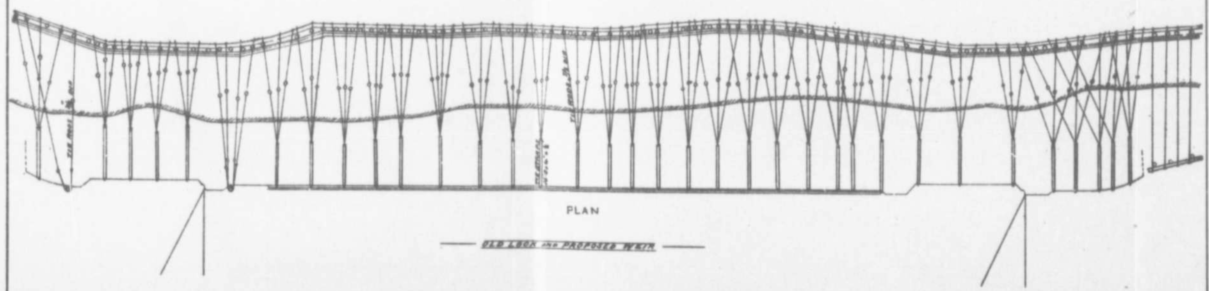


LONGL SECTION



GENL CROSS-SECTION

CENTRE LINE OF GUARD LOCK



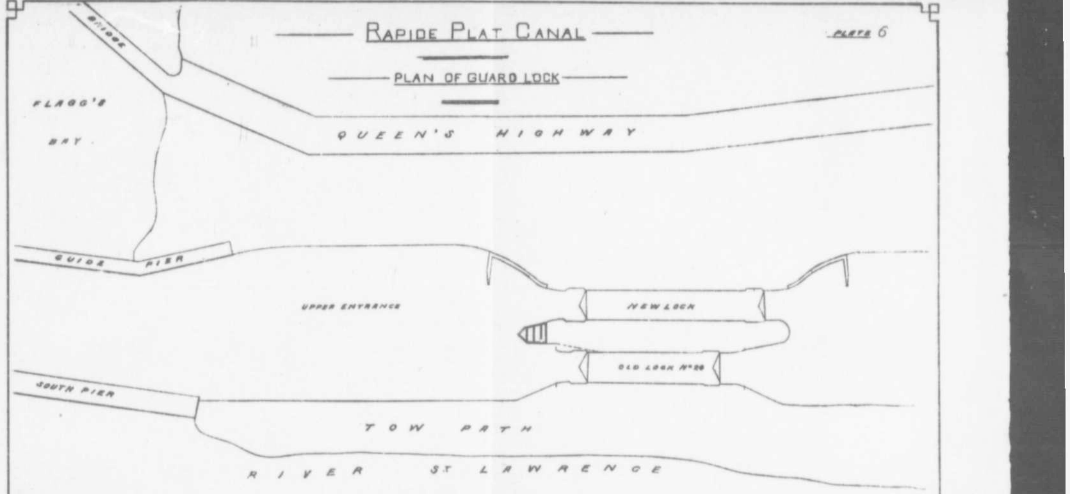
PLAN

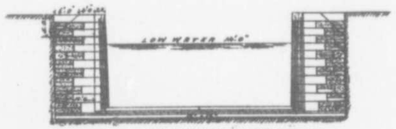
OLD LOCK AND PROPOSED WEIR

PLATE 6

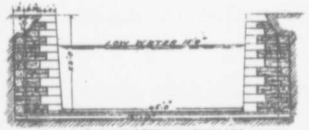
## RAPIDE PLAT CANAL

PLAN OF GUARD LOCK



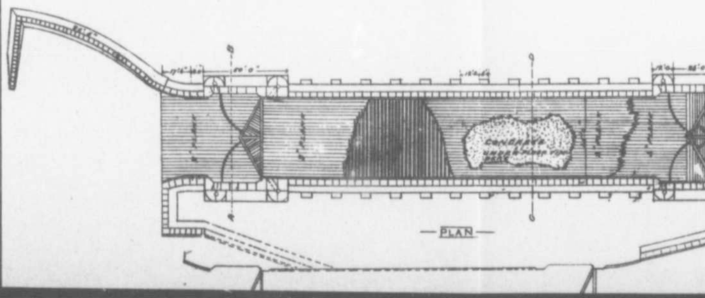


SECTION THROUGH A.B.



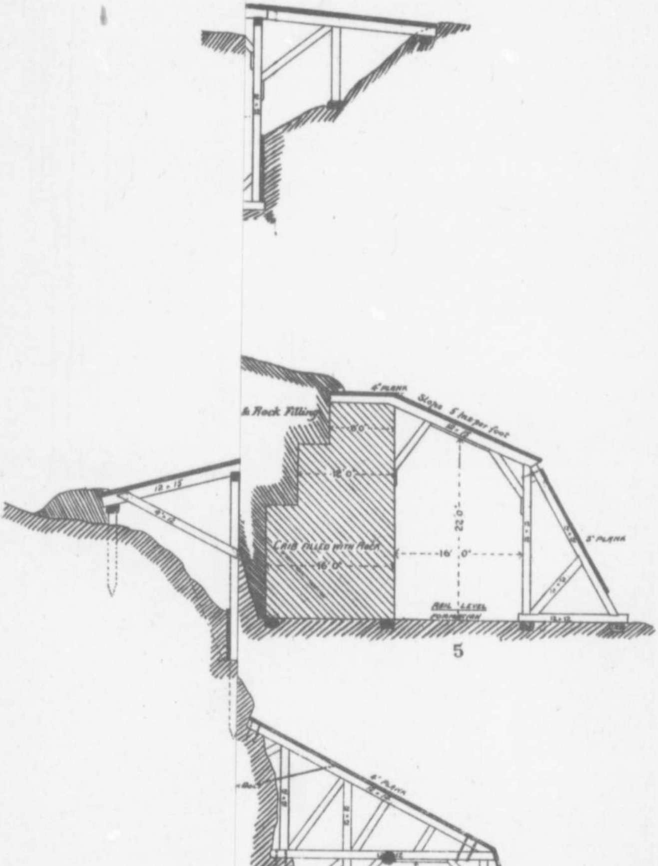
SECTION THROUGH CHAMBER ON LINE C.D.

LONGL SECTION



PLAN

## Plate VII.


4" PLANK
Slope 5 Ins per foot
12x12
& Rock Filling
8'0"
12'0"
CRIB FILLED WITH ROCK
16'0"
22'0"
16'0"
5" PLANK
8x8
RAIL LEVEL
FORMATION
12x12
12 x 15
4x12
Bolt
4" PLANK
12x12
8x8
22'0"
16'0"
RAIL LEVEL
FORMATION

5

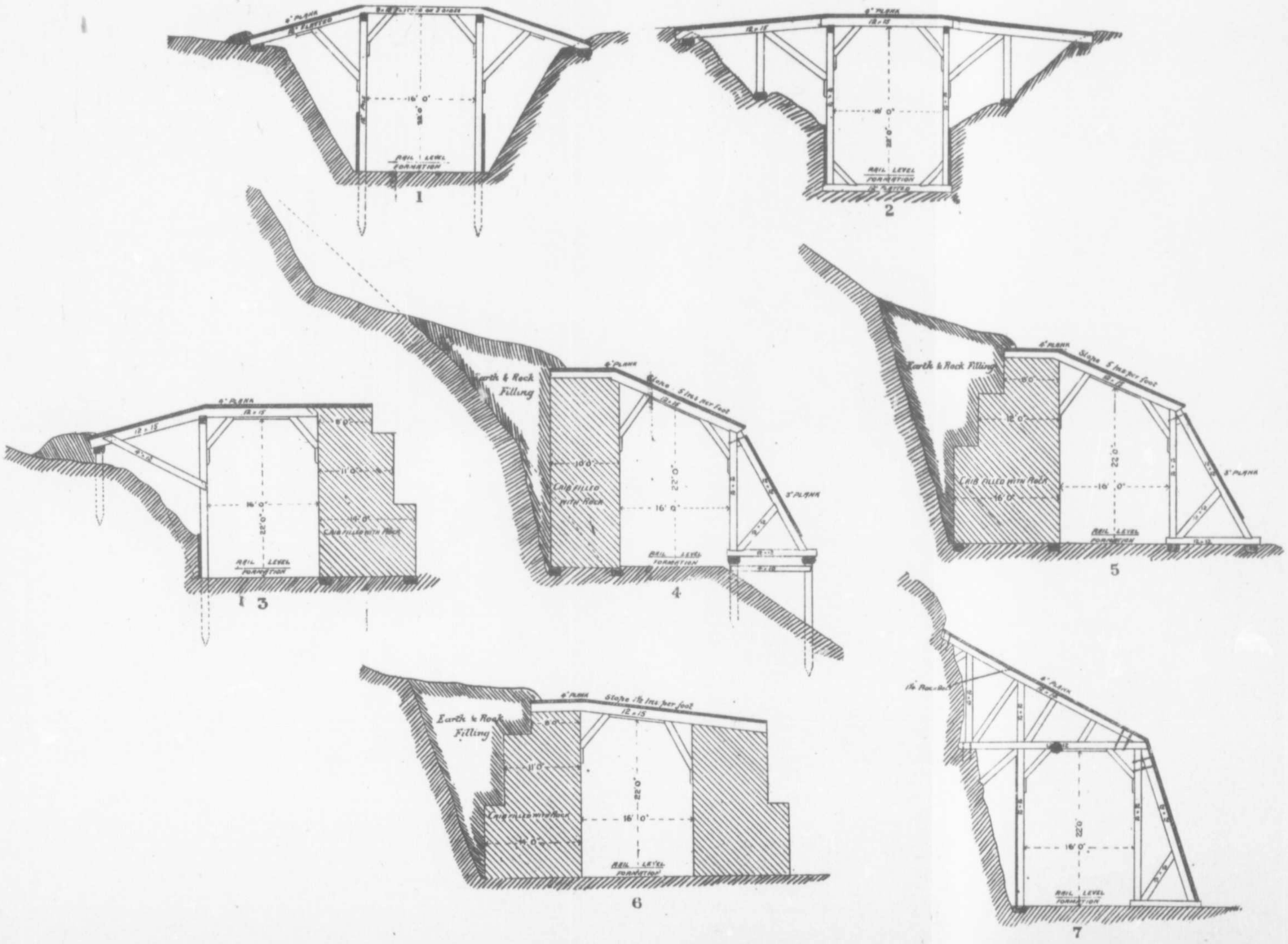
7

Plate VII.

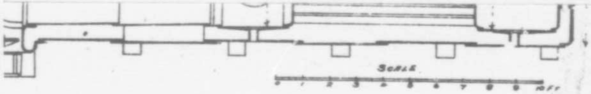
C. P. R.

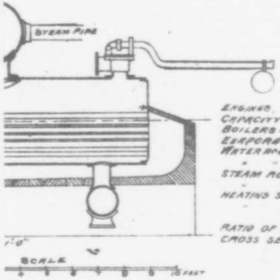
Pacific Division · Selkirk Section

Snowshedwork: 1886



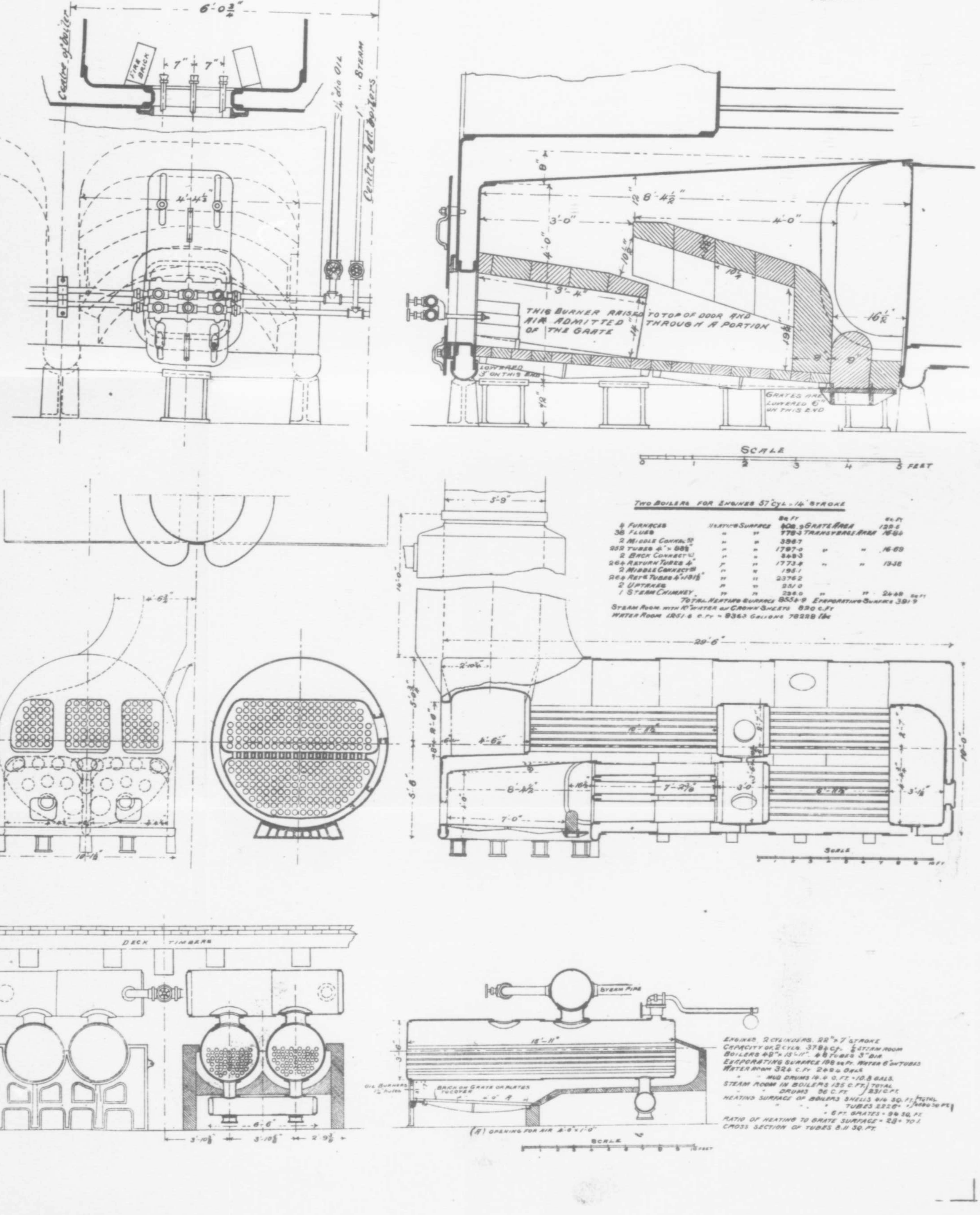
*Systems of Snowsheds built in 1886.*





ENGINES, 2 CYLINDERS, 22" × 7' STROKE
CAPACITY OF 2 CYLS. 37.84 C.FT. = 1/6 STEAM ROOM
BOILERS 49" × 15'-11". 48 TUBES 3" DIA.
EVAPORATING SURFACE 198 SQ. FT. WATER 6" ON TUBES
WATER ROOM 324 C. FT. 2424 GALS
" " MUD DRUMS 14.4 C. FT. = 10.8 GALS.
STEAM ROOM IN BOILERS 135 C. FT. } TOTAL
" " DRUMS 96 C. FT. } 231 C. FT.
HEATING SURFACE OF BOILERS SHELLS 414 SQ. FT. } TOTAL
" " " " TUBES 2226 " } 2640 SQ FT
" 6 FT. GRATES = 96 SQ. FT.
RATIO OF HEATING TO GRATE SURFACE = 28 + TO 1.
CROSS SECTION OF TUBES 8.11 SQ. FT.

PLATE 7A.



TWO BOILERS FOR ENGINES 57" CYL. – 14' STROKE

| | | Sq. Ft. | | Sq. Ft. |
|---|---|---|---|---|
| 4 Furnaces | Heating Surface | 408.9 | Grate Area | 129.6 |
| 38 Flues | " " | 778.3 | Transverse Area | 16.64 |
| 2 Middle Connec.ns | " " | 396.7 | | |
| 252 Tubes 4" × 88½" | " " | 1797.0 | " " | 16.69 |
| 2 Back Connect.ns | " " | 349.3 | | |
| 264 Return Tubes 4" | " " | 1773.4 | " " | 13.38 |
| 2 Middle Connect.ns | " " | 195.1 | | |
| 264 Ret.n Tubes 4" × 131½" | " " | 2376.2 | | |
| 2 Uptakes | " " | 251.0 | | |
| 1 Steam Chimney | " " | 236.0 | " " | 24.48 Sq. Ft. |

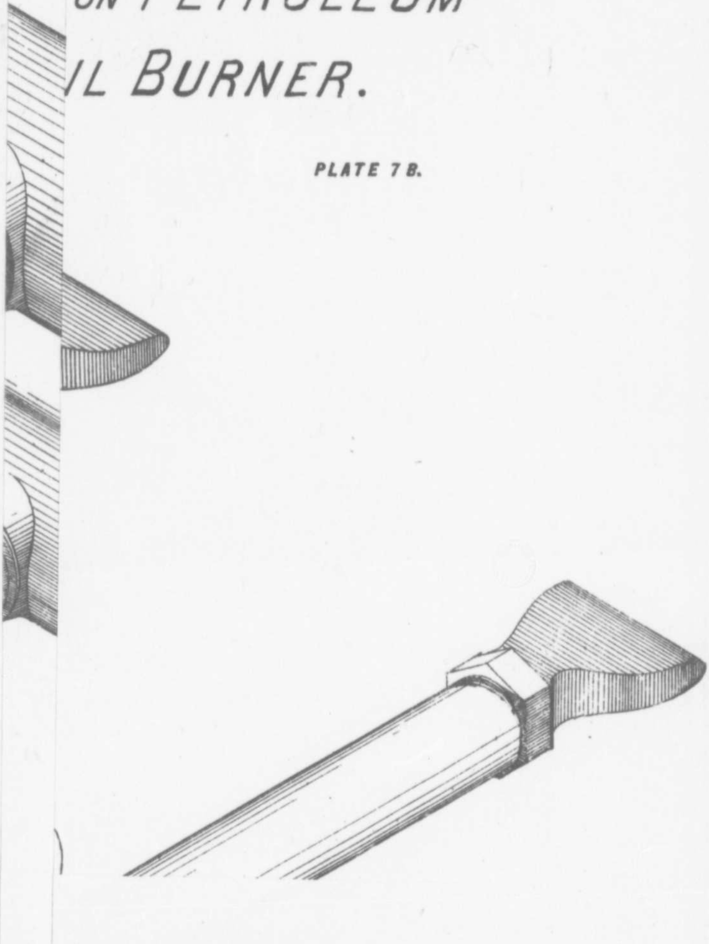
Total Heating Surface 8554.9 Evaporating Surface 391.9
Steam Room with 10" Water on Crown Sheets 820 c. ft
Water Room 1251.6 c. ft = 9362 Gallons 78228 lbs

Engines, 2 Cylinders, 22" × 7' stroke
Capacity of 2 cyls. 37.84 c.ft. ⅙ steam room
Boilers 48" × 15'-11". 46 tubes 3" dia.
Evaporating surface 198 sq. ft. Water 6" on tubes
Water room 324 c. ft 2424 gals.
" " mud drums 14.4 c. ft. = 10.8 gals.
Steam room in boilers 135 c. ft. } total
" " drums 96 c. ft. } 231 c. ft.
Heating surface of boilers shells 414 sq. ft. } total
" " " tubes 2226 " } 2640 sq. ft.
" 6 ft. grates = 94 sq. ft.
Ratio of heating to grate surface = 28 + to 1.
Cross section of tubes 8.11 sq. ft.

THE BURLAND LITH. CO. MONTREAL.

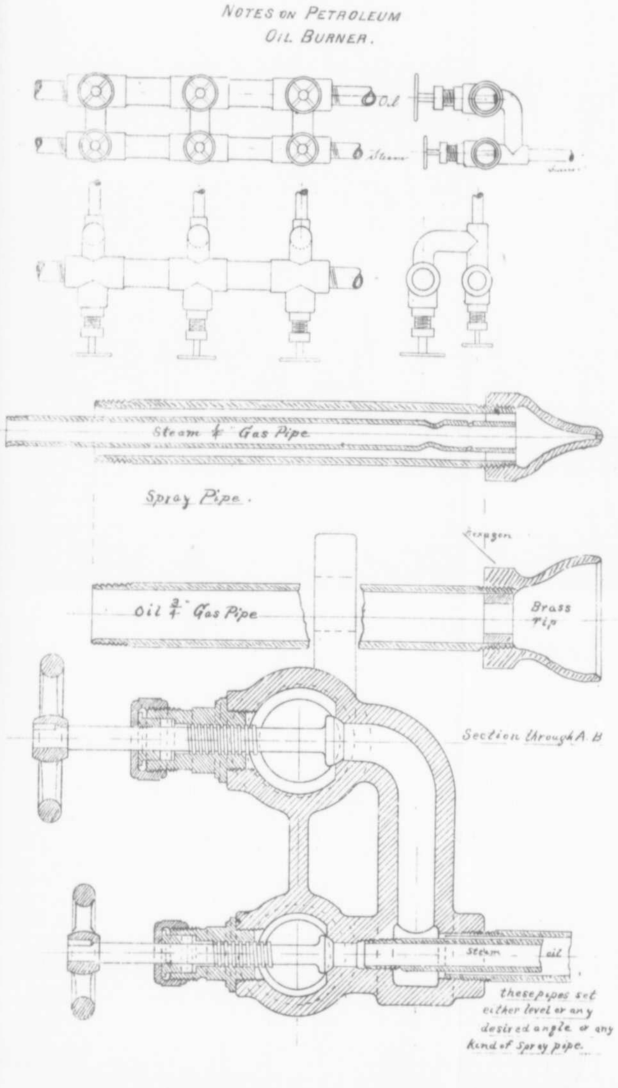
# ON PETROLEUM
# IL BURNER.

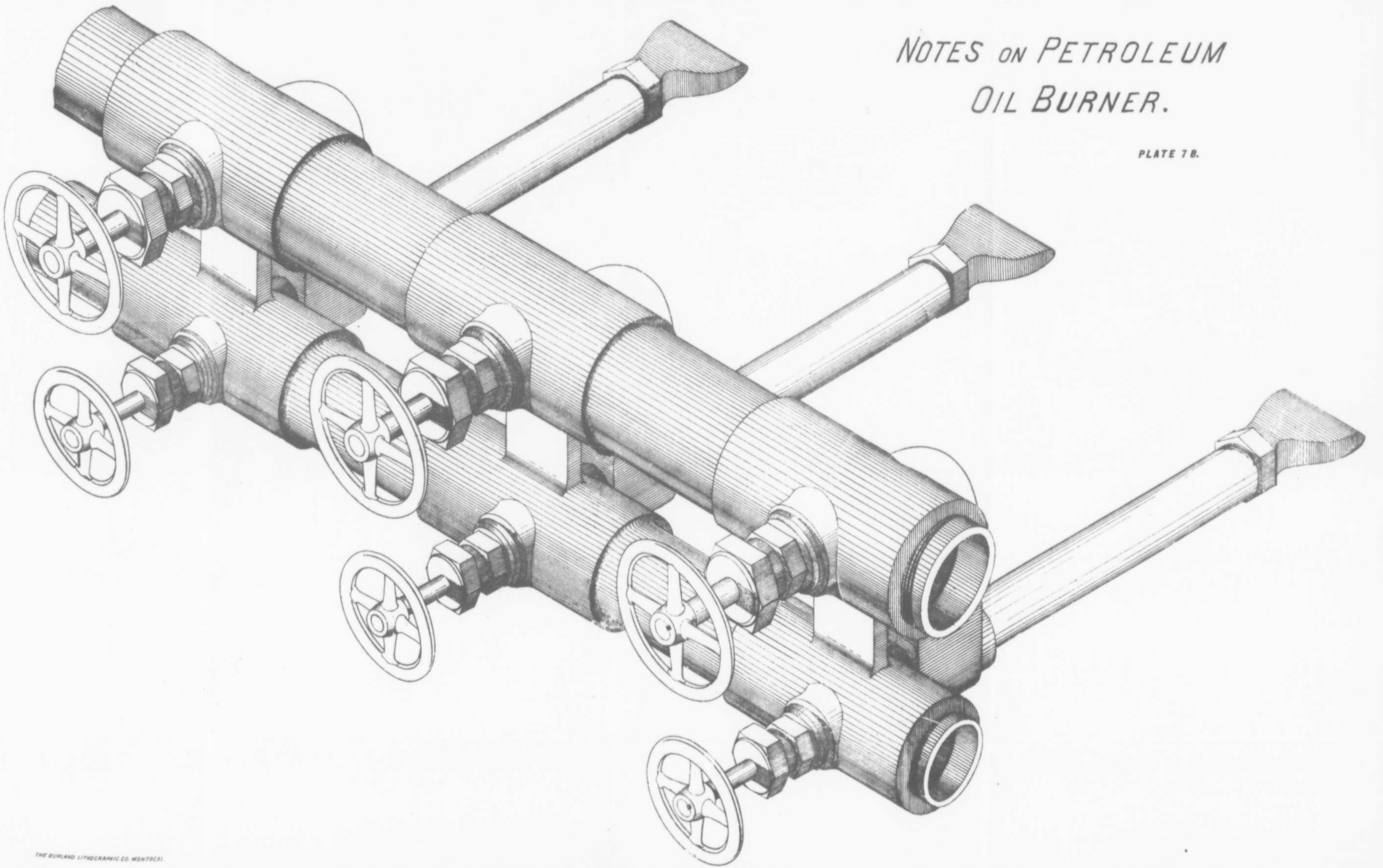
PLATE 7 B.



# NOTES ON PETROLEUM OIL BURNER.

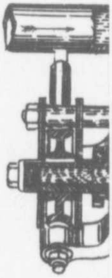
PLATE 78.



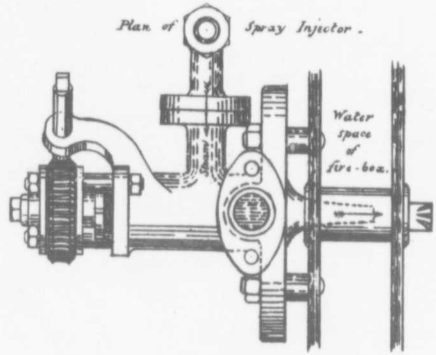


THE BURLAND LITHOGRAPHIC CO. MONTREAL

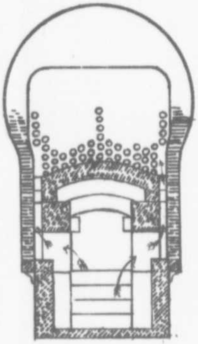
Scale 1/4th



Scale 1/4

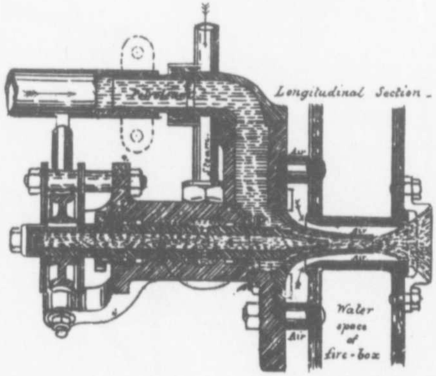


Plan of Spray Injector.

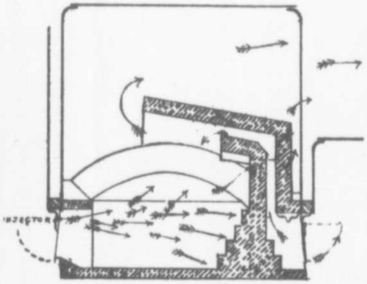


Scale 1/8th 0 1 2 3 4 5 6 7 8 9 10 11 12 Ins

Ins 12 6 0 1 2 3 4 5 6 Feet



Longitudinal Section.



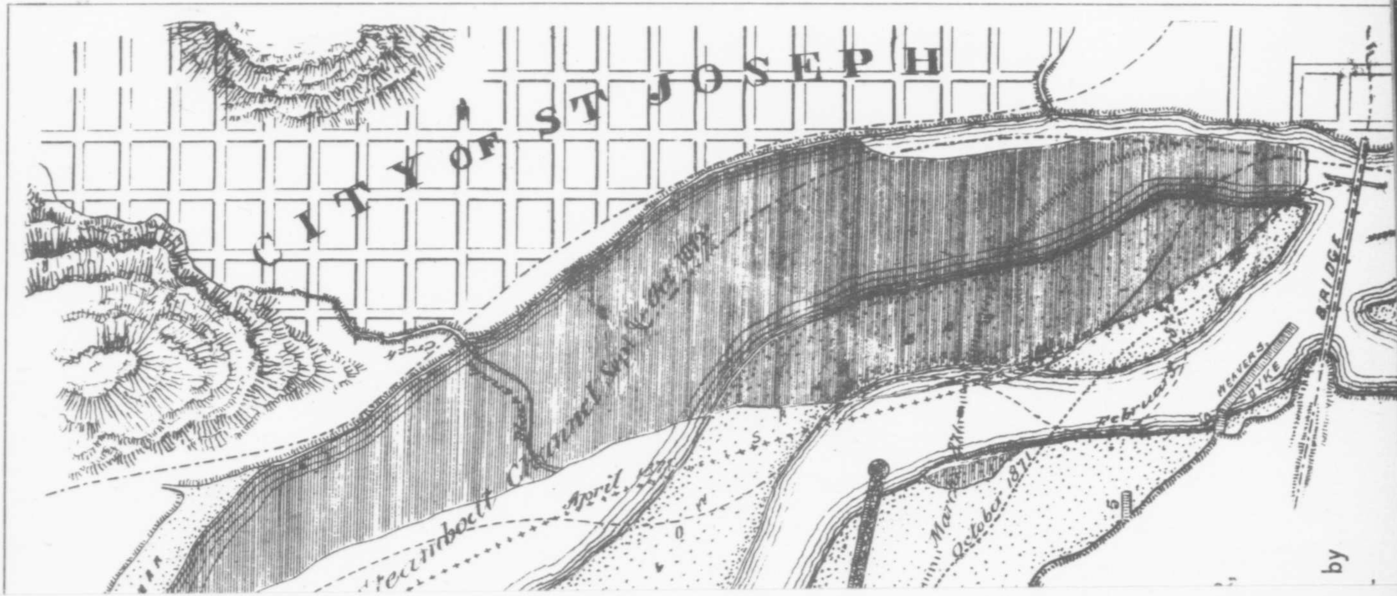
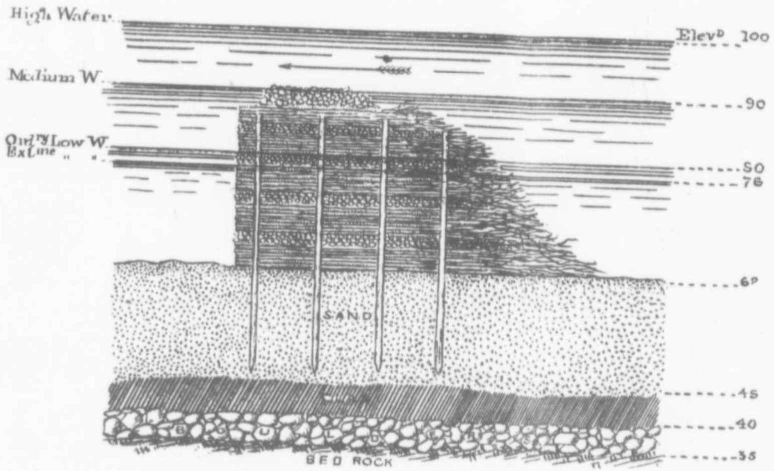
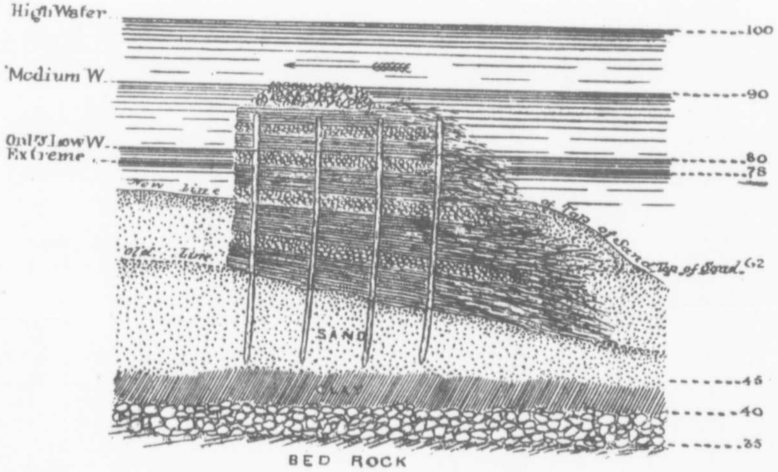

CITY OF ST JOSEPH
Creek
Steamboat Channel Sept & Oct 1872
April
S
O
March 1871
October 1871
February
HEAVERS DYKE
BRIDGE
5
by

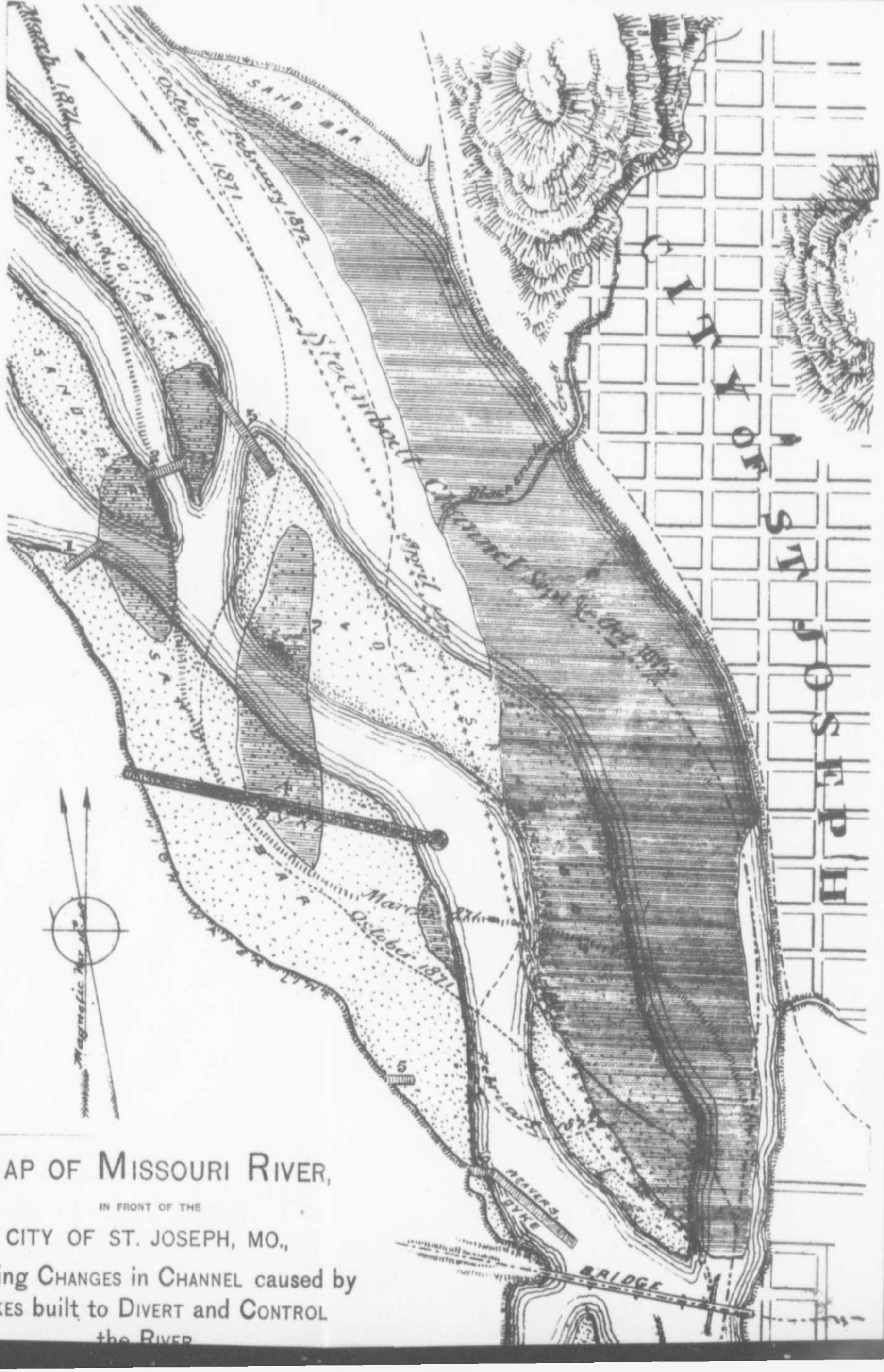
PLATE 8.



BREAKWATER No 4. AS DESIGNED



BREAKWATER No4 AS BUILT



MAP OF MISSOURI RIVER,

IN FRONT OF THE

CITY OF ST. JOSEPH, MO.,

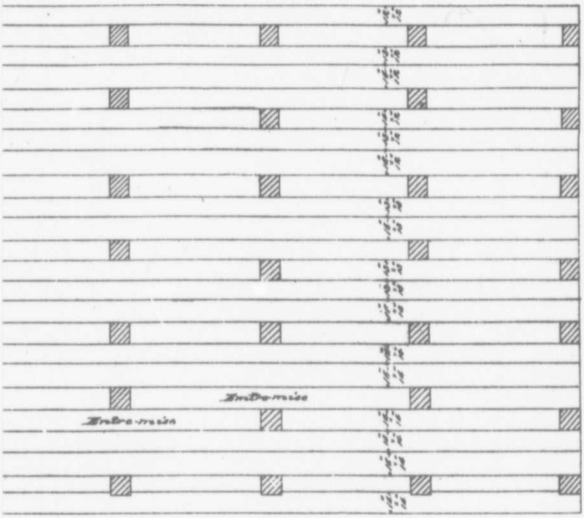
Shewing CHANGES in CHANNEL caused by DYKES built to DIVERT and CONTROL the RIVER

PLATE 9.

## PART FRONT ELEVATION

OF TIDAL HARBOUR CRIB-BLOCK

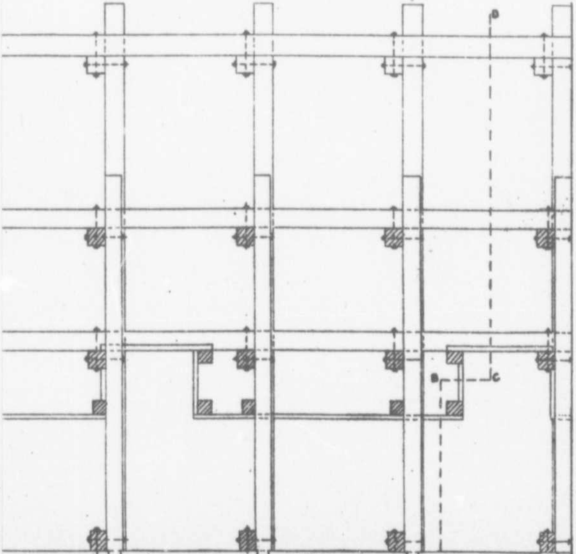
FIG. 4



## PART PLAN

OF TIDAL HARBOUR CRIB BLOCK

FIG. 3



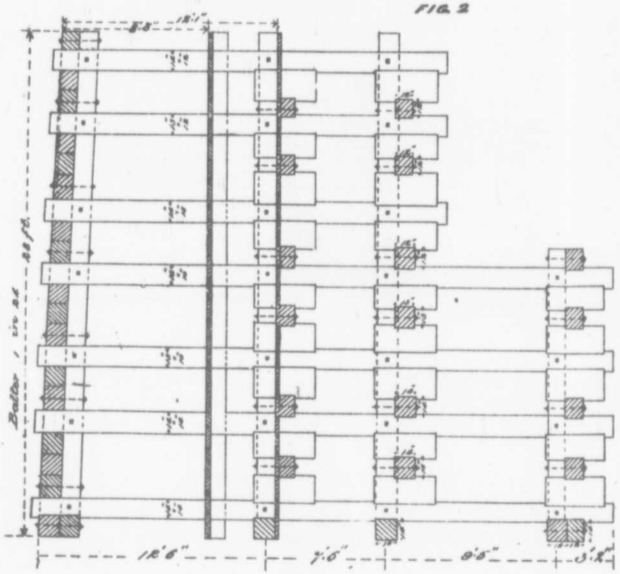
# QUEBEC HARBOUR WORKS

PLATE 9.

## TIDAL HARBOUR CRIB BLOCK

SECTION AT A.B.C.D.

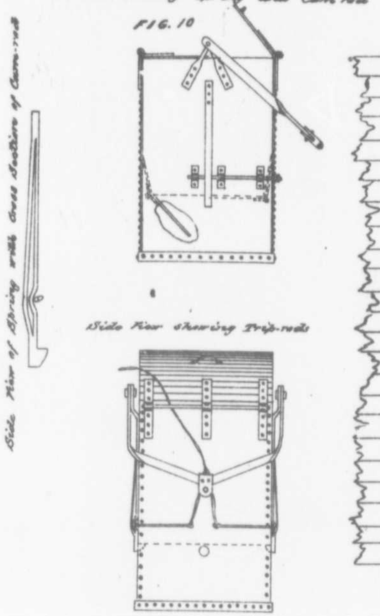
FIG. 2



## CONCRETE SKIP

Side View showing Spring and Cam rod

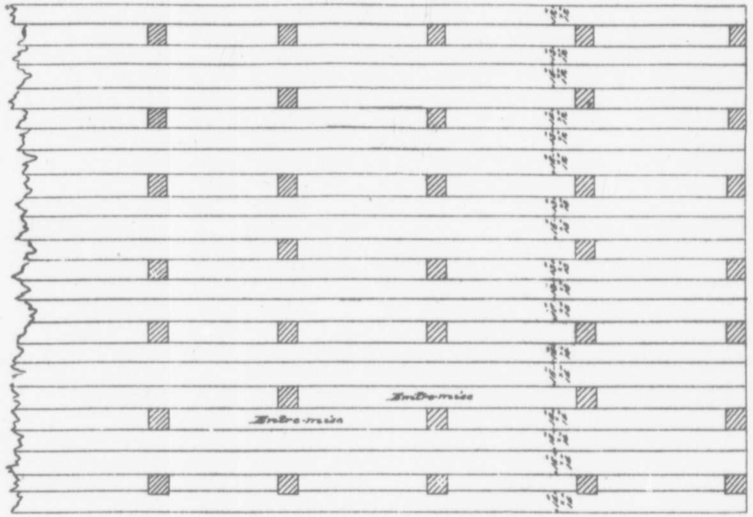
FIG. 10



## PART FRONT ELEVATION

OF TIDAL HARBOUR CRIB-BLOCK

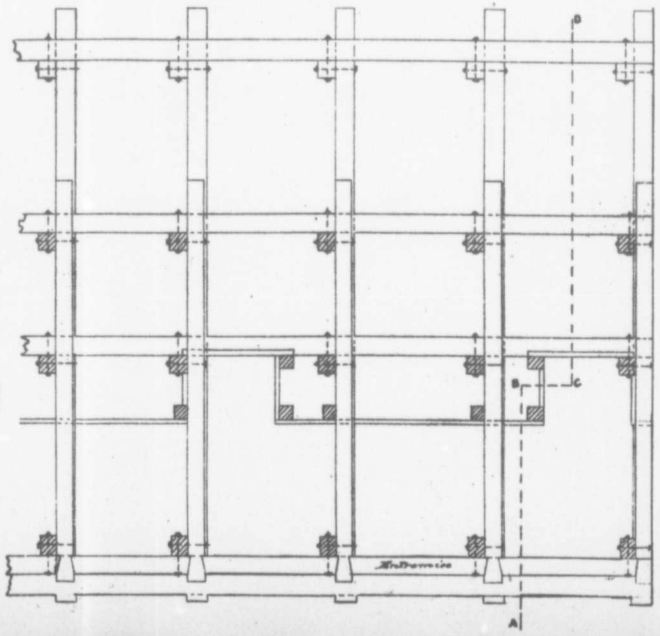
FIG. 4



## PART PLAN

OF TIDAL HARBOUR CRIB BLOCK

FIG. 3

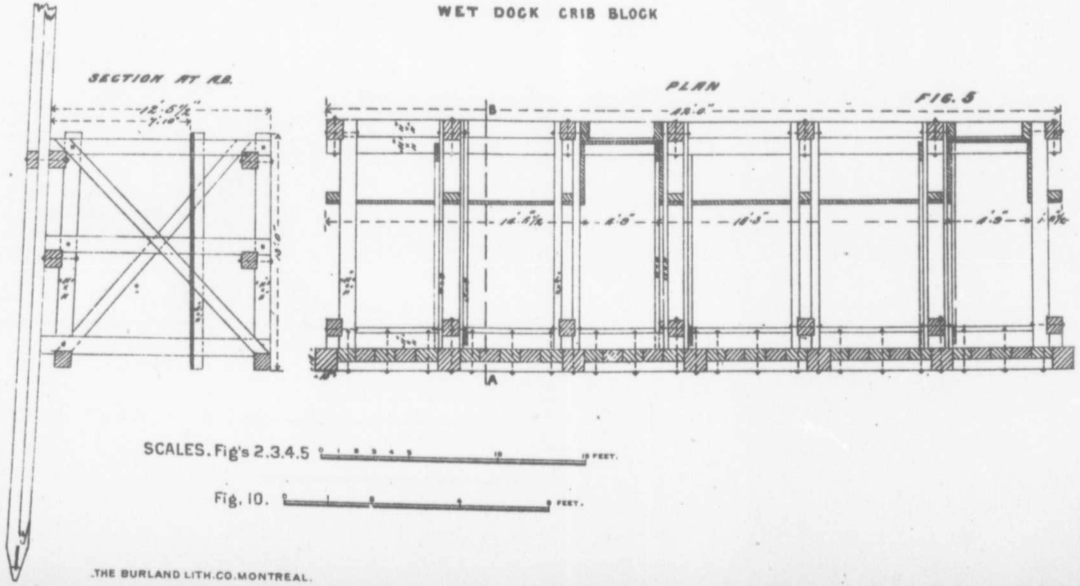


## WET DOCK CRIB BLOCK

SECTION AT A.B.

PLAN

FIG. 5



SCALES. Fig's 2.3.4.5 0 1 2 3 4 5 10 15 FEET.

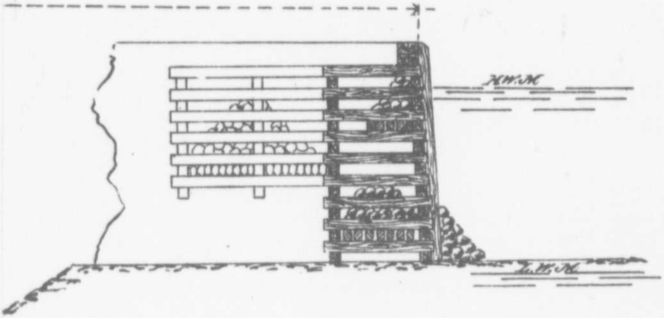
Fig. 10. 0 1 2 3 4 FEET.

THE BURLAND LITH. CO. MONTREAL.

PLATE 10.

ARBOUR

FIG. 6



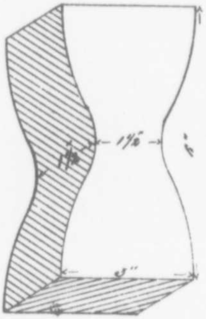
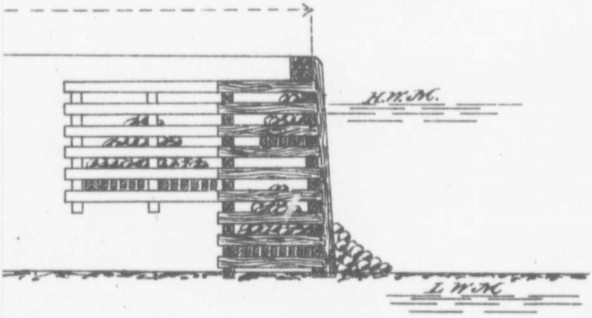


FIG. 17

FIG. 7



SCALE. Fig's 6, 7. 0 5 10 20 30 FEET.

Fig. 17. 0 1 2 4 6 INCHES.

# QUEBEC HARBOUR WORKS

## CROSS SECTION

THROUGH EMBANKMENT IN TIDAL HARBOUR

FIG. 6

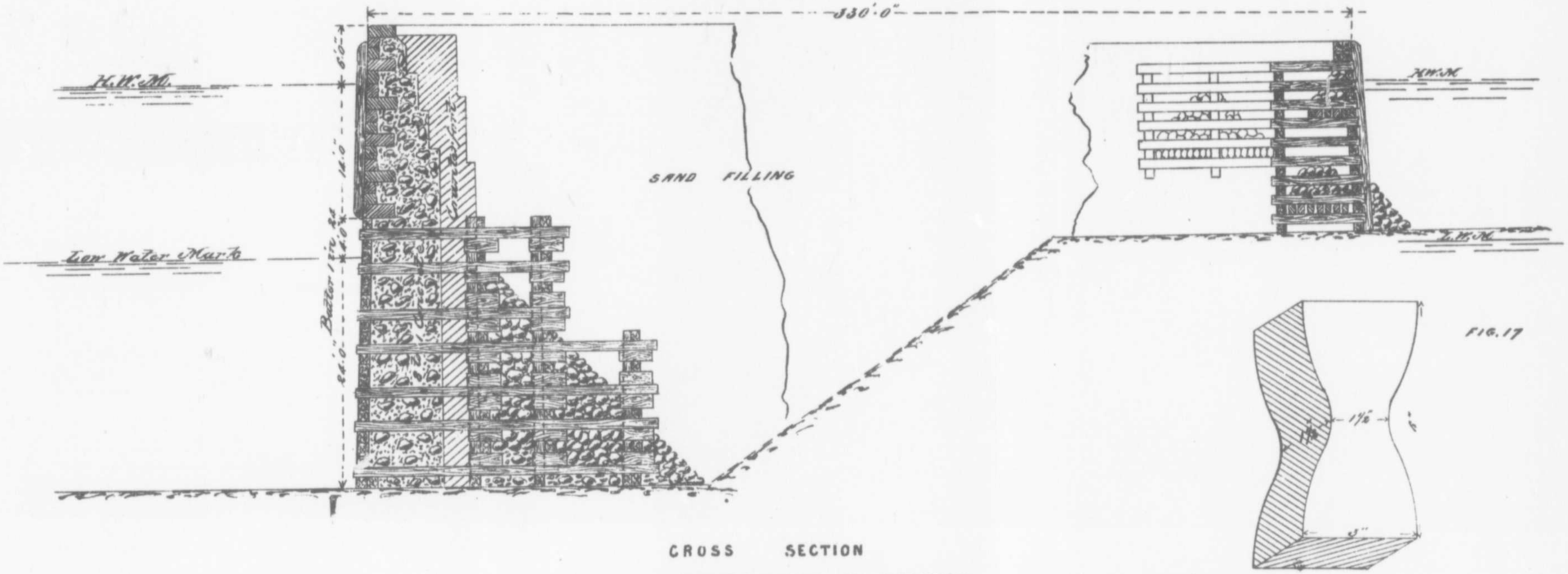
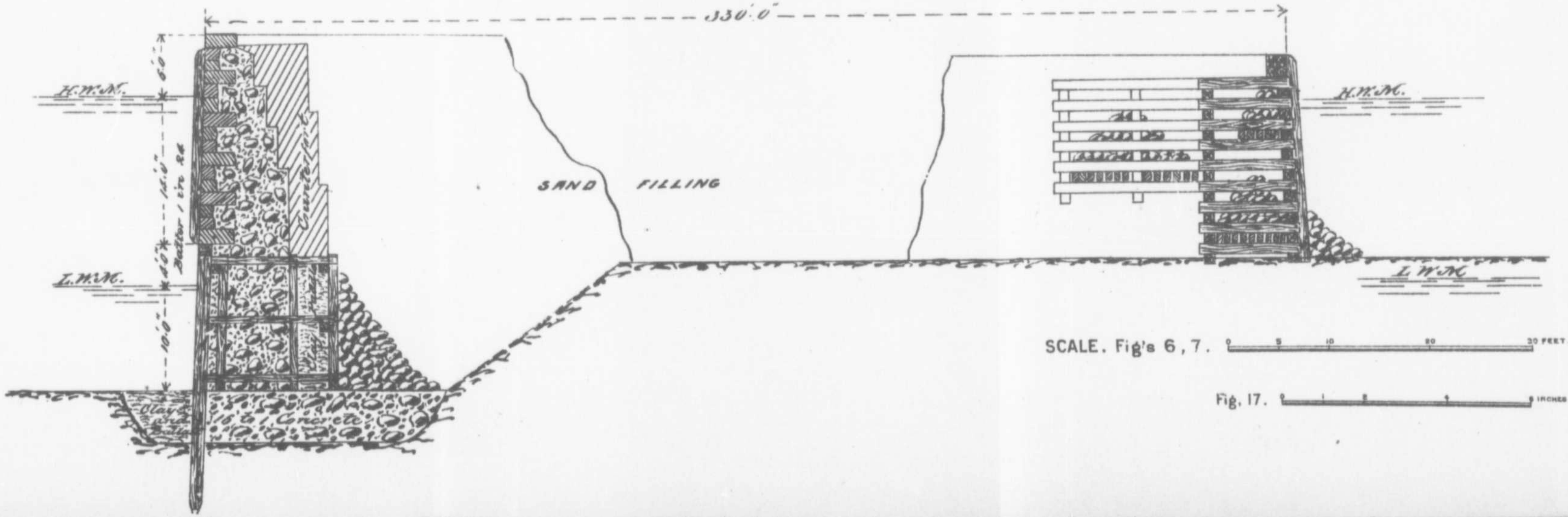


FIG. 17

## CROSS SECTION

THROUGH EMBANKMENT IN WET DOCK

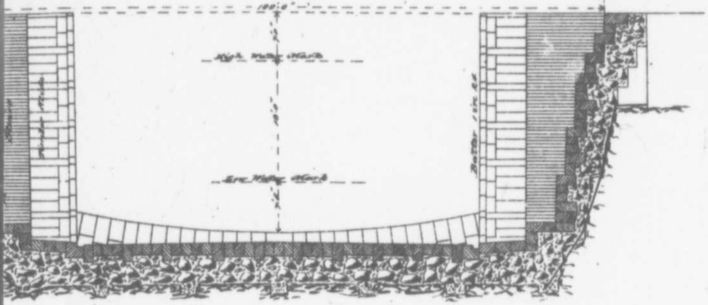
FIG. 7



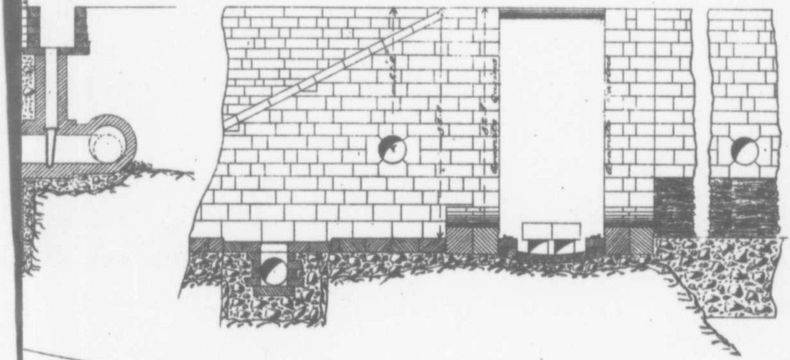
SCALE. Fig's 6, 7. 0 5 10 20 30 FEET.

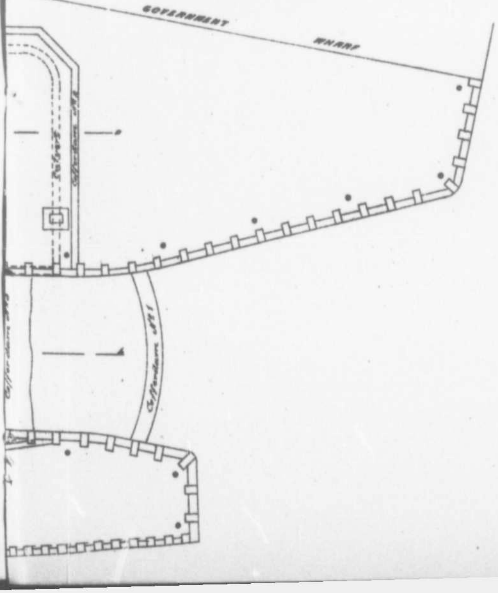
Fig. 17. 0 1 2 4 6 INCHES.

SECTION ON G.H. FIG. 16



SECTION ON K.L. FIG. 14



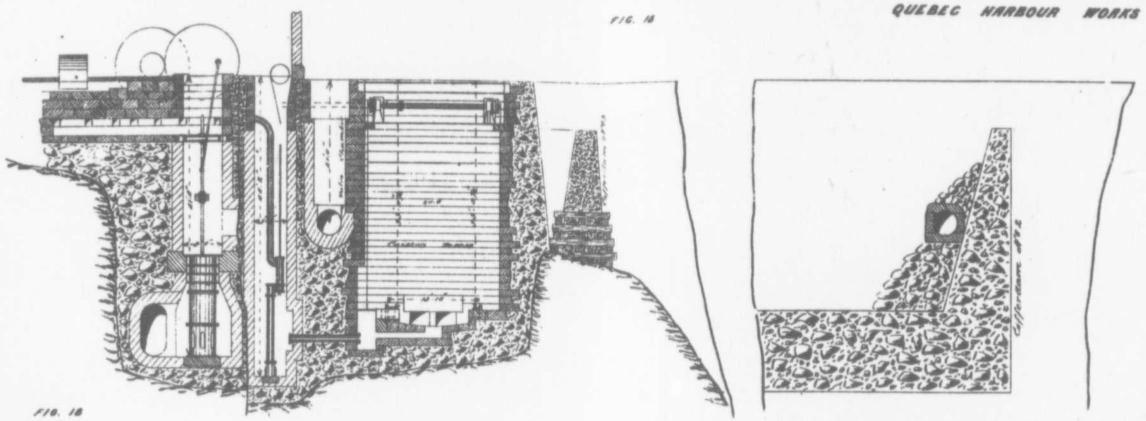


# GRAVING DOCK
## QUEBEC HARBOUR WORKS

PLATE II.

SECTION ON A.B.C.D.

FIG. 15



SECTION ON G.H.

FIG. 16

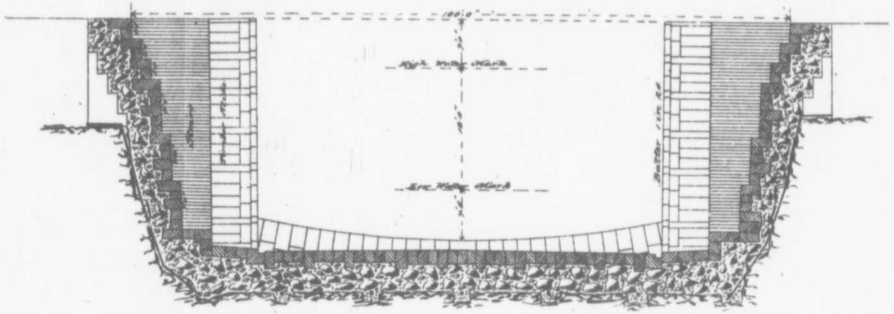
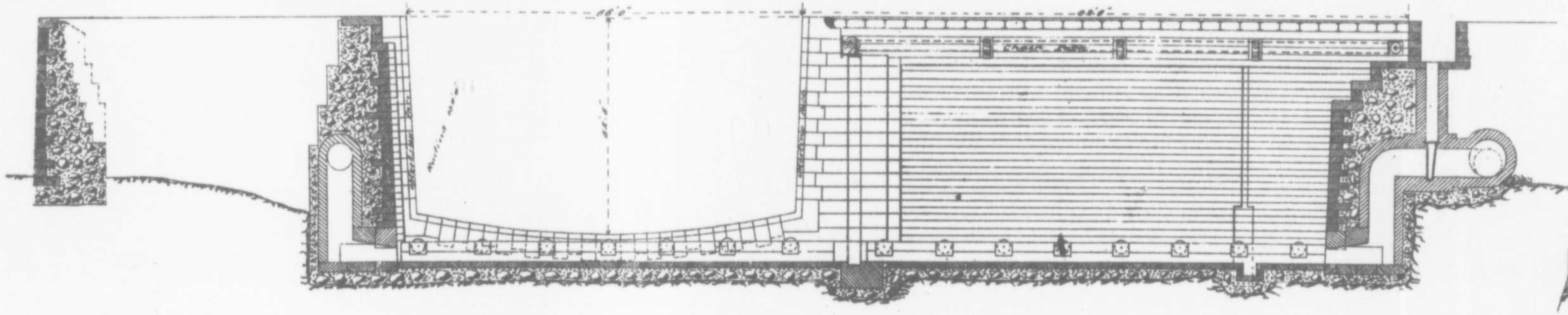


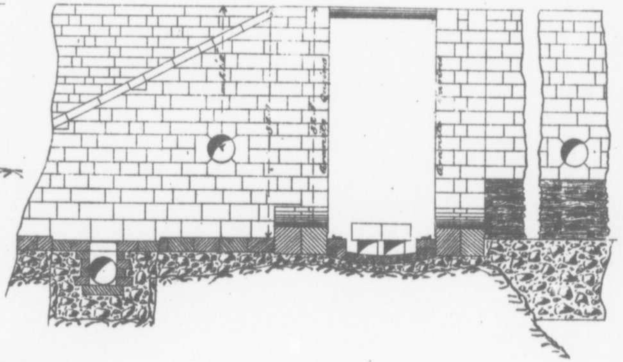
FIG. 18

SECTION ON E.F.



SECTION ON K.L.

FIG. 14



SCALE FOR FIGS. Nos 14, 15, 16, 18.

SCALE FOR FIG. No 13

FIG. 13

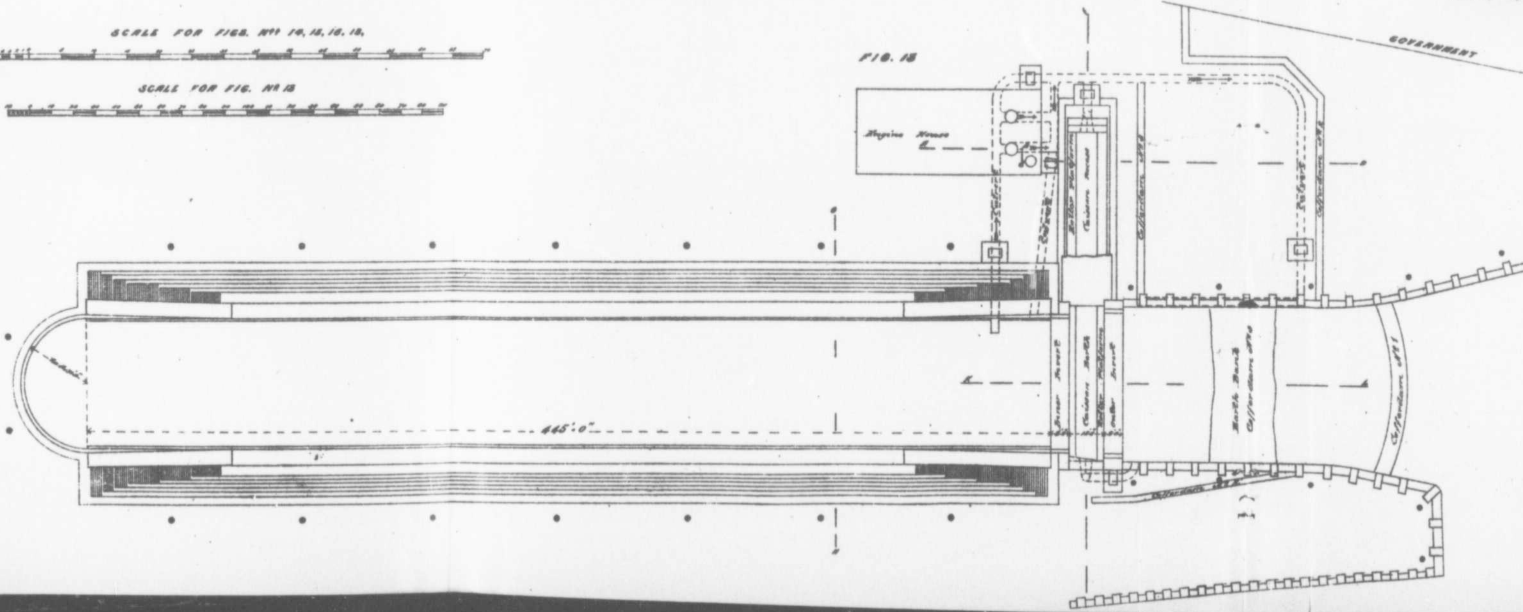
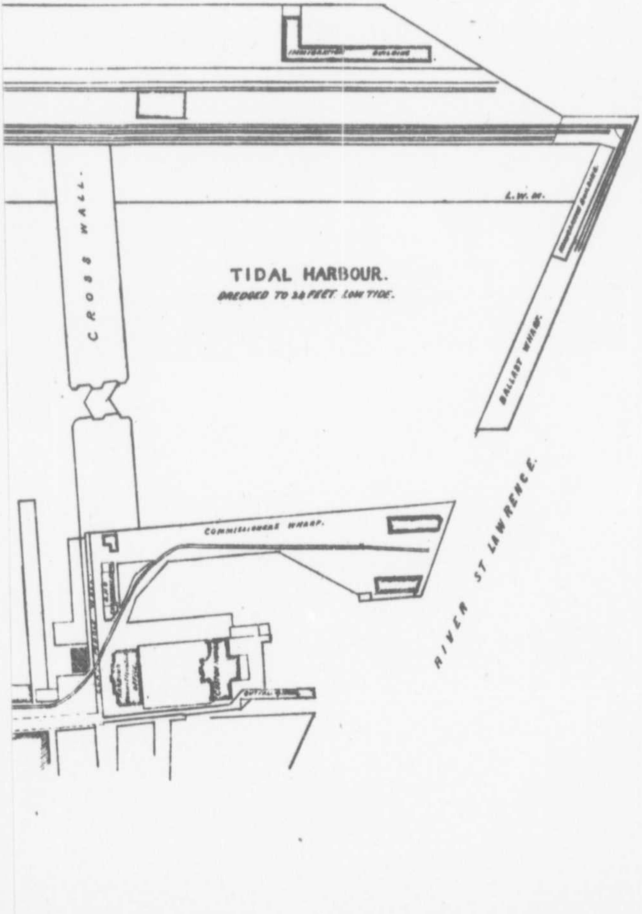


PLATE 12.

KS.__


IMMIGRATION BUILDING
L.W.M.
CROSS WALL
TIDAL HARBOUR.
DREDGED TO 24 FEET LOW TIDE.
BALLAST WHARF
COMMISSIONERS WHARF
RIVER ST LAWRENCE.

# QUEBEC HARBOUR WORKS.

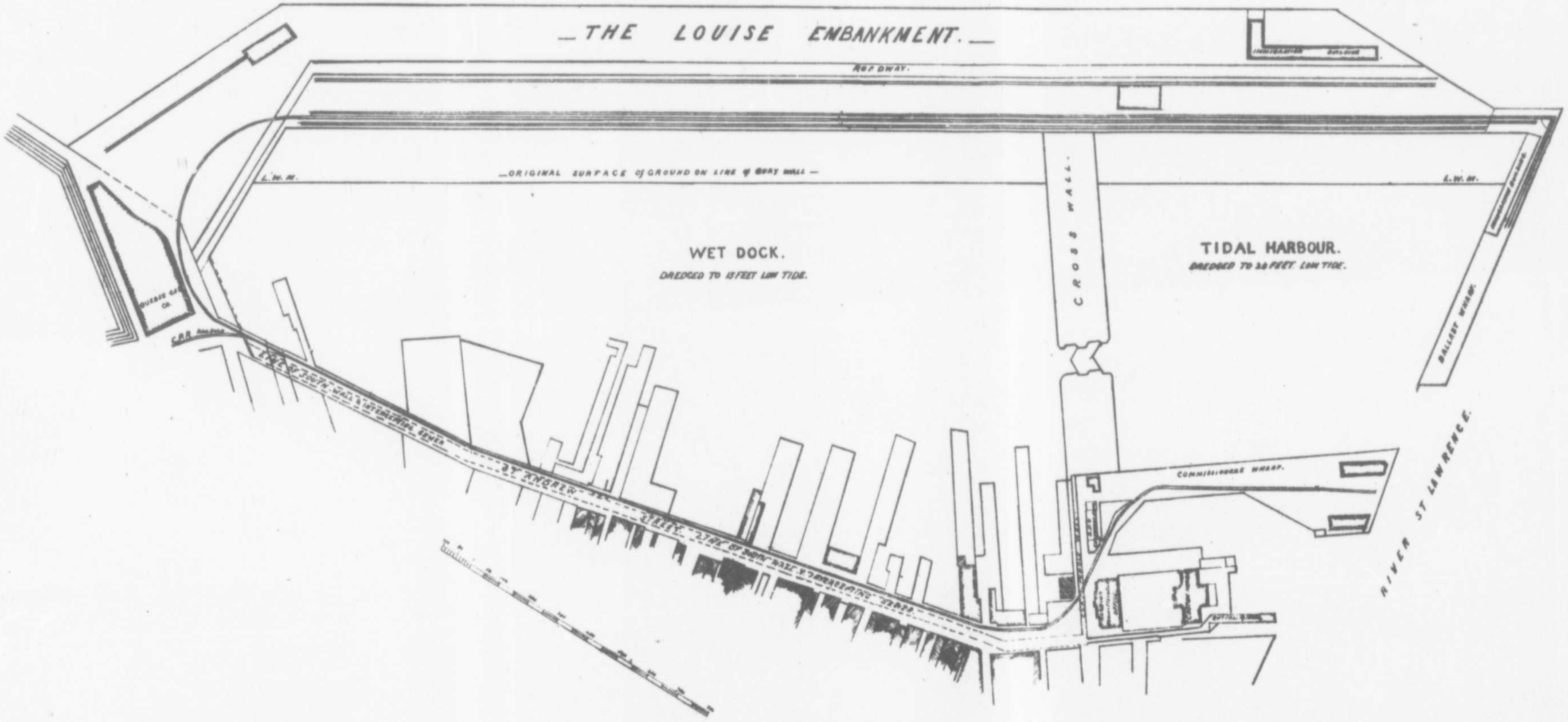
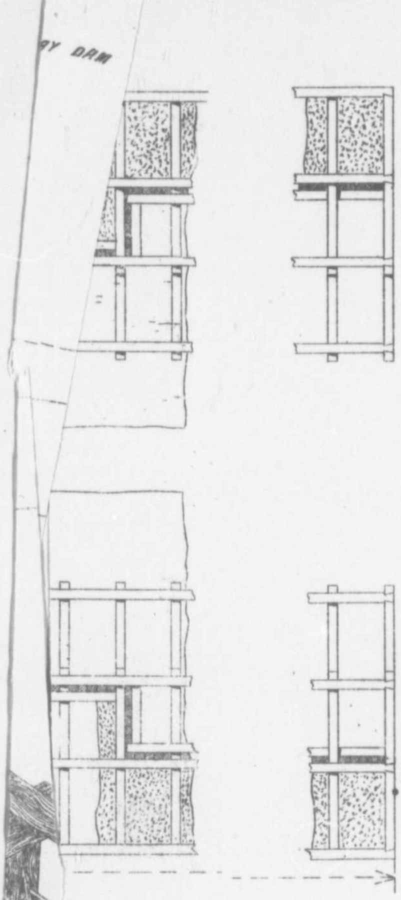
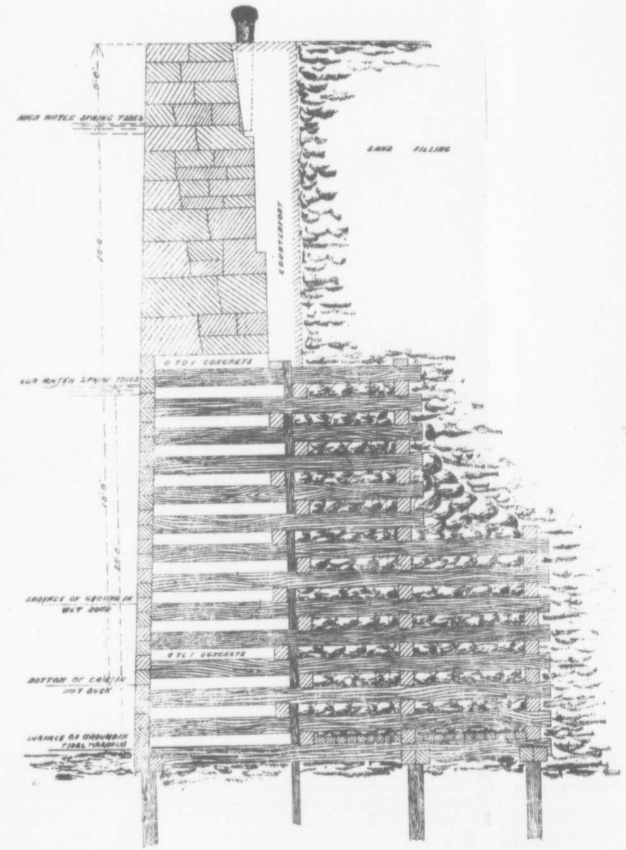


PLATE 13



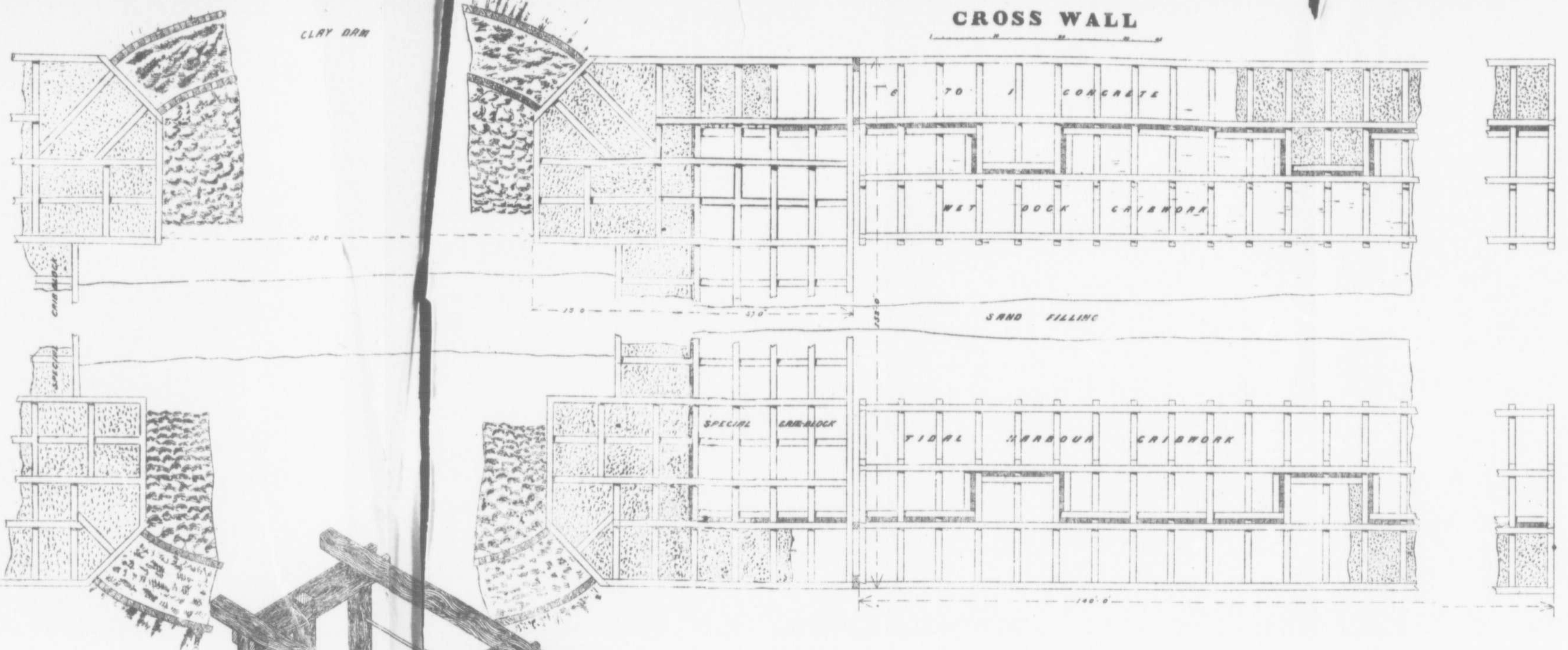
## CROSS WALL

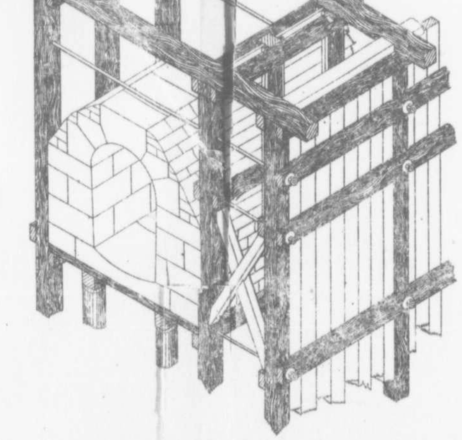
## CROSS SECTION OF QUAY WALL

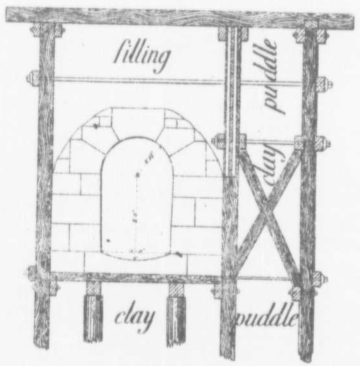


THE [illegible]AND LITHOGRAPHIC CO. MONTREAL

## CROSS WALL







## Q.H.W.

## SOUTH WALL