Issued June, 1887.

TRANSACTIONS

OF

The Canadian Society of Civil Engineers.

VOL. I.

MARCH TO JUNE.

Montreal:
PRINTED FOR THE SOCIETY.
By John Lovell & Son.

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

CONTENTS.

FIRST GENERAL MEETING.

The first general meeting for the organization of the Canadian Society of Civil Engineers was held in the Harbour Commissioners' Building, Montreal, on Thursday, February the 24th, 1887.

The following gentlemen were present:

Messrs. T. C. Keefer, G. A. Mountain, W. P. Anderson, J. L. P. O'Hanly, T. Guerin, R. Surtees, D. McPherson, J. P. Pim, E. V. Johnson, R. Steckel, H. A. F. McLeod, ...of Ottawa.

Messrs. P. W. St. George, J. Kennedy, H. T. Bovey, W. W. Gilbert, M. S. Blaiklock, P. A. Peterson, G. H. Henshaw, W. J. Sproule, W. McLea Walbank, L. Lesage, T. W. Lesage, W. McNab, J. A. U. Beaudry, G. R. Nash, H. Wallis, R. Forsyth, J. H. Bartlett, J. M. Shanly, J. R. Roy, B. D. McConnell, W. H. Laurie, S. Howard, L. J. Papineau, A. E. Childs, A. G. Eneas, C. H. McLeod, J. R. Barlow, A. Brittain, E. Berryman, J. Simpson, E. P. Quirk, H. G. Stanton, G. Holland, E. E. Gilbert, T. Middleton, R. F. Tate, F. Chadwick, F. B. La Vallee, K. Blackwell, F. R. Redpath.........of Montreal.

Messrs. A. Macdougall, H. Smith, C. H. Chapman, of Toronto.

Messrs. L. N. Rhéaume of Morrisburg, T. Berlinguet of Three Rivers, E. Deniel of Grenville, J. E. Belcher, J. G. Macklin and A. J. McLean of Peterborough.

L. S. Parizeau of St. John, P.Q., R. Rinfret of St. Stanislas de Batiscan, J. D. Barnett of Port Hope, G. F. Languedoc of Outremont, St. George Boswell of Quebec, C. E. Dodwell of Ste Anne de Bellevue, H. Carre of Brockville, T. Monroe of St. Catharines, J. W. Harkom of Richmond.

It was moved, seconded and resolved that Mr. T. C. Keefer, C.M.G., be requested to act as chairman of the meeting.

It was moved, seconded and resolved that Mr. A. Macdougall be requested to act as secretary of the meeting.

It was moved, seconded and resolved that Messrs. M. S. Blaiklock, G. A. Mountain, W. W. Gilbert, J. D. Barnett, J. G. Macklin and J. H. Bartlett be requested to act as scrutineers for the election of the President, three Vice-Presidents, Secretary, Treasurer, and of fifteen other members of Council for the ensuing year.

Resolved,—That the Report of the Provisional Committee be received and approved.

Resolved,—That the Constitution and By-Laws, as submitted by the Provisional Committee be adopted.

Resolved,—that the Council be authorized to make application to the Dominion Government for an Act of Incorporation.

The thanks of the meeting were presented to the following :—

To the members of the Provisional Committee for the efficient manner in which they had prepared the provisional Constitution and By-Laws.

To the Grand Trunk and Canadian Pacific Railway Companies, for certain travelling facilities.

To the Harbour Commissioners for the use of their building.

To the members of the Society, resident in Montreal, for the Conversazione, given by them in the Peter Redpath Museum, McGill University, in honour of the inauguration of the Society.

To Mr. T. C. Keefer, C.M.G., for the efficient manner in which he had conducted the business of the meeting as chairman.

To Mr. A. Macdougall, for acting as secretary, and for the efforts he had made to further the establishment of the Society.

The scrutineers then announced that the following gentlemen had been duly elected :—

President.

Thomas C. Keefer, Ottawa.

Vice-Presidents.

C. S. Gzowski, Toronto.
John Kennedy, Montreal.
Walter Shanly, Montreal.

Secretary and Treasurer.

Henry T. Bovey, Montreal.

Council.

H. T. Bovey, Montreal.
F. N. Gisborne, Ottawa.
E. P. Hannaford, Montreal.
W. T. Jennings, London.
Samuel Keefer, Brockville.
Louis Lesage, Montreal.
J. D. Lumsden, Toronto.
Alan Macdougall, Toronto.
Henry F. Perley, Ottawa.
Hurd Peters, St. John, N.B.
P. A. Peterson, Montreal.
H. S. Poole, Stellarton, N.S.
H. N. Ruttan, Winnipeg.
P. W. St. George, Montreal.
H. Wallis, Montreal.

The thanks of the meeting were presented to the Scrutineers, for he satisfactory manner in which they had discharged their duties, and he ballot papers were ordered to be destroyed.

Prof. Bovey having resigned from the Council, Mr. C. Schreiber, of Ottawa, was appointed to fill the vacancy at a meeting of the council held on April 14.

Canadian Society of Civil Engineers.

SESSION 1887.

TRANSACTIONS.

Thursday, 17th March.

J. KENNEDY, *Vice-President,* in the Chair.

Paper No. 1.

FRAZIL ICE:

ON ITS NATURE, AND THE PREVENTION OF ITS ACTION IN CAUSING FLOODS.

By GEO. H. HENSHAW, M.C.SOC.C.E.

The subject of this paper is one destined to become of increasng interest to Engineers in Northern countries, especially to those ngaged in works liable to be affected by ice, whether through direct ttack or through floods caused by the arrest of its movements. The uthor's object is to define the true nature of frazil, and to suggest a method of dealing with it, so as to prevent its more than suspected gency in producing floods.

Whether the vast masses of comminuted ice, which in places are found o underlie the surface ice, are composed of true subaqueously formed e, or are made up largely of drifted snow, and the broken scales of urface ice carried down by the current, is yet to be positively deterined ; still, from the evidence which exists of enormous quantities of pongy looking ice seen rising from the bottom, it is reasonable to conude that whatever may be the proportion of these substances, true azil is, really, their principal constituent.

Now, for an engineer to meet a difficulty with intelligence and success, is almost essential to understand the actual character of the enemy ainst which he is to contend. To speculate on this, in the present se, brings us somewhat out of the sphere of the practical engineer and o that of physical science ; but we are often compelled to this course hen scientific men neglect the subject, or leave us in the dark.

That so little of the nature of frazil is known among engineers is not rprising, when we find that the haziest notions, if any, regarding it, evail among our highest scientific authorities.

At a meeting of the B.A.A.S., held in Montreal on the 1st September, 1884, in presenting a paper on the subject, the writer was confronted with a casting in type metal, made in a plaster mould, by Mr. W. B. Dawson, of frazil ice, as stated on the label, but which was really a representation of anchor ice.

As explained by the President (Sir William Thompson), frazil was supposed to be the product of currents of water passing over and disintegrating solid anchor ice, exposing, as he expressed it, its "bones," just as rock is worn into irregular forms by the removal of its softer parts. Now, it is difficult to conceive how anyone, practically familiar with the appearance of frazil, could attribute its minute, needle-like fragments to a waterworn origin, or believe that a substance so developed could be produced in large quantities. We do, indeed, in the spring, see ice disintegrated to its bones, and falling to pieces, but that is only when it is exposed to sun and air, and when the formation of frazil is already a thing of the past. This experience convinced me that science had as yet no information to give; and that up to the present the best authorities regarded frazil merely as a curious formation of rare and limited occurrence.

The author thinks that many are hasty in assuming that all is known about the philosophy of ice formation. Tyndall, when he overthrew the theory of Rumford, did not exhaust the subject. We know that water can be brought above its boiling point without ebullition, and we know that it can be brought below its freezing point without congealing. We know that superheating requires pressure, but how much do we know of the conditions accompanying supercooling?

The author believes that ice never forms in water without an independent nucleus; that when it appears free on the surface the nucleii are supplied by minute particles of vapour, which, becoming frozen in their ascent and falling back upon the water, form, perhaps, the very stars seen in a block of ice when melted, through a lens, by the sun's rays.

That frazil, like anchor ice, forms under water seems unquestionable. Mr. Frank Gilbert, engineer, contractor for deepening the channel through the Gallops Rapids, states that he has passed in a boat over great beds of it, covering the bottom in dense masses of a spongy appearance, through which his pole swept with scarcely perceptible impediment. He also observed it upon a wire rope extended beneath the water, between his vessels, looking like bunches of iron filings lifted up by a magnet. In this case he noticed the curious fact that parts of the rope were bare and others covered with the growth, which seemed to negative the idea that the cold had been conducted through the rope. Under the circumstances it is plain that the exposure of the ends of the rope had little or nothing to do with the formation of the ice.

The conclusion come to by the author is, that frazil ice is formed in currents cold enough not only to preserve its crystals but to induce their formation.

But why should it grow luxuriantly on one spot, and yet refuse, as we have seen, to grow upon a closely adjacent spot of a character precisely similar?

Well, that is a question yet to be settled; but with your indulgence an attempt will now be made to offer an explanation.

All who have observed the action of fine drifting snow, when driven by the wind over a plane surface, such as a roof or a railway platform, will have noticed that it does not sweep along in clouds, or rolling volumes, but in long rifts or streaks with bare spaces between. With every lull of the wind these streaks rest for a moment, to be swept away by a succeeding blast into new combinations of a similar form, according to the variations, in force and direction, of the wind.

Now it is evident that these rifts are produced by the small inequalities of the surface of the plane; that the bare places are where the wind is least obstructed; and that the snowy streaks are the eddies where its force is partially obstructed. Now if this is admitted, we are brought to the important conclusion, that if the obstructions on the plane remain unaltered, and the direction, volume and force of the wind continue unchanged, the streaks of snow with the spaces between will always occupy precisely the same position upon the plane.

If we now apply these observations to the flow of a river, we shall find a close approximation to such supposed conditions. For taking the case of a stream with a rocky bed, we have the more or less permanent obstructions on the bottom; while, unlike the air, the volume, speed, and direction of the water are but little affected by superficial influences.

The bottom of such a river presents a confused succession of irregular obstructions, around, over and between which the water rushes in every direction possible at once, and at every variety of speed. Along its main channel, greater freedom gives the river current its highest velocity, so raising its volume at the stiller reaches that backward currents or eddies are formed at its edges.

Looking at the troubled tumbled surface such a river sometimes presents, one is tempted to believe it a hopelessly involved chaos of complicated motion; but there is no chaos there. Every movement is made under as strict a law as to which governs the piston of an engine. Every bulge or swirl that we notice at some particular spot comes from the self-same sunken rock or cranny, and each would repeat itself precisely, were it not for molecular variations, which we will not here take account of further than to note that they modify, in a minor way, the results about to be referred to.

Bearing these facts in mind let us take a horizontal or plano section of the river.

Here we have, in the currents so intersected, instead of the long streaks seen in our snow drift, an irregular network with meshes of every size and threads of every thickness. The threads represent the currents, and the meshes the comparatively still spaces enclosed. If we wish to represent the molecular effects alluded to, they may be shown as a sort of fringe of eddies along the sides of the threads.

As in the case supposed the general plan and position of the network is permanent, and as we know that water is a bad conductor of heat, it is plain that a sudden cooling of the water up stream would cause the threads of the network to become colder than the enclosed meshes; while the reverse would be the case on the water above becoming warmer, so that objects placed, the one in the mesh and the other in the thread, would be affected differently as to temperature.

Now for the formation of frazil.

The river is cooled down nearly to congelation; there is, we know, a very small margin to go upon at freezing point. The thermometer goes down to zero or below. The river in its efforts to part with its remaining heat steams, but its current is too rapid to freeze over; and so a supercooled current is borne down through the network. It is designated a supercooled current, because the author does not wish to commit himself to the statement that the water itself is below freezing point. Such water is always charged with minute icy particles, which may in themselves be the cause of the refrigeration of the bottom: the water charged with these particles is the current to which I refer.

The result is obvious, objects that present suitable nuclei in the threads are covered with a growth of frazil, while similar objects in the meshes remain bare. Similarly, on a sudden change to a warmer temperature the masses of frazil are thawed from their frail anchorage, rise, and are carried down by the stream; a phenomenon noticed by many observers. This theory also explains why frazil does not form on sandy or fine gravelly bottoms; for wherever there is any shifting of the obstructions on the bottom there will also be changes in the threads and meshes. preventing that continuous contact with the cold current which is necessary to the formation of frazil, or so mixing thread and mesh as to bring the whole above the required temperature. I claim for this theory if not absolute demonstration, at least the merit of accounting for all known facts in connection with the nature and action of frazil.

Frazil, as we know, appears in the form of a mass of frail particles, with very little cohesive power. It is plain then that in small quantities, or with anything like a free passage, it would pass away harmlessly seaward. It could not under such circumstances become sufficiently dense to stop even its own passage, except in eddies, wedge spaces, or "culs de sac."

Unfortunately in the St. Lawrence there are too many of all these. Every shoal or batture affords such asylums, into which the frazil gradually packs. Fragments of ice are thrust into the mass affording new crannies for accumulation, until the flow of the stream is confined to the deeper or more direct channels. In their turn these channels will be most choked at their bends, especially where shoals or low lying islands exist on the outer side of the curve of the current and receive its centrifugal impact.

Now when we consider that the volume of a river like the St. Lawrence is not greater in winter than in summer, but rather less, and that at certain points there are floods one year, and none the next, we naturally conclude that the floods are caused by more than usual obstruction below, and not by increased volume. The trouble is, therefore, local and may be removed without injuriously affecting other parts of the river.

We revert once more to the nature of frazil, in order to clearly point out the difference between it and surface formed ice when in motion and floating down stream.

Surface ice may be seen in process of formation on the open channel, shooting out its lances from floating nuclei, or, more frequently, proecting itself from the shore ice under the lee of salient points. It forms thin sheets through which the oars of passing boats crash like brittle glass. All along the open channel fragments are broken off by the action of wind and wave, and float down until stopped by some obstacle In cold weather these are either cemented together on their way or quickly consolidated when they arrive at a barrier, and thus, as a rule, s formed the surface crust over the open channel. Where the water is still or the current sluggish the opening closes smoothly by the extension of the ice from either side.

A channel closed by packing is always more or less rough, and it would be quite possible, by critical examination, to determine the relative force of the current at different places, at the time of its taking, from the degree of roughness in which it was left.

There is no evidence to show that floating ice is carried beneath the fixed ice to any great extent, except in a strong current. Even then the tendency to rise in packing seems nearly to balance the downwar movement. Huge hummocks are formed in such places, and tl obstruction to the river caused by them is due chiefly to broke sheets caught vertically, or at an angle with the surface.

The character and action of frazil are totally different. Rising i masses from the bottom, its buoyancy is so small that it floats to a co siderable distance below the surface ; while so little is its cohesion th when the mass becomes compacted enough to elevate its upper fa above the water, it falls apart and spreads over the surface. It oft attaches itself to floating ice or forms a nucleus for a new sheet of ic and should severe cold sufficiently consolidate the whole, the surfa ice would be swept beneath the barrier ice, in the train of the frazil which it was attached.

The Caughnawaga Indians, who in winter daily transport the mails and from Lachine, state that frazil or slush ice runs only in the ear part of the winter ; and that when it ceases to come down, they kno that the channel is closed at the upper end of the lake. If this is s it shows either that the frazil formed below the cascade rapids remai fixed to the bottom as anchor ice, or, what is more likely, that bei arrested by the friction of the overlying ice, it is thrust aside a jammed between the ice and the bottom, over the battures or shoa At any rate, it goes to prove that, without an open channel, frazil not carried down to any great extent from lake St.-Louis. As a fact in Montreal floods, therefore, we need seek it no further up than t foot of the Lachine rapids.

By keeping the channel open from these rapids down to the foot Montreal Island it would seem that the frazil would be carried pa without serious lodgment; but as there appears as yet no means effecting this object, our natural recourse must be to so prepare t bottom of the river so as to give as free a passage to the frazil ice as possibly can.

As will readily be inferred, I am strongly of the opinion that t disastrous spring floods from which the City of Montreal has suffere are caused primarily by the choking of the river during winter, which the area of the waterway is so reduced as to be unable to car away the increased volume produced by the melting of the snow. course this is aggravated by the down flow of ice from the lakes abov

This latter difficulty it has been proposed to prevent by placing i breakers, or rather ice arresting piers, in Lake St. Louis, intended keep it back until the barrier below has broken away.

Curiously enough, this contrivance, though one of the oldest know has of late been received by some with so much enthusiasm, th sputes have arisen as to who had the honor of first suggesting it; not ong engineers, however. It has been used in various beneficial ways, iefly in securing an ice bridge at some dangerous spot. The latest case the kind, known to the author, was for the purpose of making a road on which to haul stone and other material for the repair of the rillon dam; a part of which had been undermined and carried away e previous year. The attempt, which was entirely successful, was ade under the direction of Mr. Stark, superintending engineer of the ttawa River Canals.

No doubt such a plan applied to Lake St. Louis would ameliorate ring floods at Montreal if we were sure that it would entail no other nsequences. But there remains a serious question; whether in so ing, the ice would not pack so heavily above as to flood the upper untry, and the water obtain so great a head as to carry piers and erything else before it, and bring a worse disaster upon the city.

From the foregoing considerations it seems reasonable to conclude at the direction of any effective operations for the prevention of ods, should be in the following lines :

1st. Straightening the channels; or where this cannot be done larging them at their bends, by cutting away the inner sides.

2nd. Clearing away boulders and other elevations, on the shoals outde the bends, wherever the thrust of the stream tends to carry ice and azil into wedge places and culs de sac, and giving the bottom a downard grade of the stream to give free egress to ice entering from above.

3rd. Removing over the whole area of the part of the river affected, l boulders, ledges and other projections of the bottom. Thorough tting all sub-channels, so as to give them a free discharge at the outt; and benching such shallow slopes along the shoals as in combinaon with the surface ice afford the natural traps in which the frazil is ught.

Since writing the above a recommendation of the Government Comission on Floods has been partially put into effect, namely, an attempt keep open the river channel between Three Rivers and Sorel, by eans of vessels fitted to break up the ice.

While very doubtful of its success as a means of preventing floods at Iontreal, the author nevertheless heartily endorses the experiment. n such a difficult question the experience gained in an effort of this ind must greatly help on a solution, and may lead to other discoveries f benefit to the country, which otherwise would remain unknown.

DISCUSSION ON FRAZIL ICE.

C. Herschel Mr. Herschel stated that the New England equivalent for "Frazil" is "Anchor ice." Anchor ice is formed in our rivers only at times when there is no covering of solid ice upon them, and, generally, only for the 12 to 24 hours just preceding the formation of such a covering of solid ice. For instance: in the winter of 1885–6, the ice formed in, and went out of, the Connecticut River 4 times, giving 4 days of anchor ice, where there is usually but one. Its most distinguishing characteristics are: its low specific gravity, being nearly the same as that of water, and its adhesiveness to any protruding object in its path, as well as of the different particles, among themselves. For instance: some years ago it accumulated on the inlet pipe of the Detroit Water Works, in the Detroit River, which is laid in a considerable depth of water, until it threatened to or actually did shut off all supply to the city. He has seen it gather on the crest of the Holyoke Dam, and accumulate in bunches, aided, perhaps, by one or two flashboard pins, or other irregularities, until it would stop the flow of water over that part of the dam; this flow being at the time, in other parts, over a foot in depth. Mr. Herschel knew of no remedy for it, short of that which nature supplies, when she forms the covering of solid ice. Judging upon the facts stated in the paper, the Caughnawaga Indians are entirely correct in their statement that frazil runs only in the early part of the winter, and its cessation to run is a sign that the channel is closed above. Where the situation is such that the channel cannot close, by reason of rapids, for example, frazil may continue to form all winter. In such cases, and if it did continue to form, the depth and regularity of the channel below would constitute the only available mitigation of the evils to be expected from such frazil.

G.W.Ranney Mr. Ranney never observed the formation of frazil in still water or smooth current. It is formed in rapids where the water is broken up and intermixed with air. From the foot of Crow Bay to the commencement of the Rapids (Middle Falls on the Trent), a distance of about 1000 ft., there is a current with a smooth surface. At o° F. prisms of ice begin to form about 200 ft. down stream from the surface ice. The anchor ice begins to form as soon as the rapid commences, but does not adhere to the bed of the river until it has travelled 500 or 600 ft. down the rapid, where it commences so to settle on the bed of the river and to adhere to everything with which it comes in contact. Mr. Ranney built a mill on the Falls about 2,000-ft. below the outlet of the Bay, and formed the head of water by means of a ring dam which was filled with anchor ice, upset and forced sideways into the stream a distance of 100-ft. He has never observed anchor ice in any stream having abrupt falls, with a smooth current above and below, shewing that it requires a broken surface and cold air to form frazil. Frazil has sometimes formed an island on the very verge of Ranney Falls, with the current running at 10 miles an hour, and has remained there until the weather has moderated, while on the smooth floor of the Ranney slide it has made 2 ft. to 3 ft. in the throat with a decline of 1 in 20. On one occasion a chain cable was broken by a run of anchor ice which formed around the chain as thick as a barrel. Mr. Ranney has made bridges where the current was so strong as to prevent formation of surface ice, by placing obstructions to collect the frazil, and watering the surface. Anchor ice very soon dissolves where it is not covered with surface ice at about 20° F. He approved of Mr. Henshaw's suggestion to anchor the ice in Lake St. Louis until the river below is clear. Mill owners have to keep open channels through their ponds to the mills. He doubted whether any advantage would be derived from the straightening or smoothing of the sides or bed of the river, as anchor-ice will adhere to a smooth flat-rock or slide-floor.

Dr. R. Bell considered the action described in Mr. Henshaw's paper to be secondary, and that the real origin of frazil is due to terrestrial radiation, aided by the action of the chilled water in carrying down particles of ice from the surface. Dr. T. Sterry Hunt, Prof. Carpmael, and other meteorologists concurred in this latter view. He suggested the advisability of subjecting specimens of every variety of ground ice to careful and minute examination, so that the forms and arrangements of the component crystals might be ascertained, and thus shew whether there is such a substance as anchor ice differing essentially in origin and structure from frazil. Mr. Gilbert's observations at the Gallop Rapids strengthened the radiation theory, and the fact that the frazil formed on some parts of the rope and not on others is probably due to differences of conductivity in the bottom immediately below the rope, or to the fact that there were objects obstructing radiation above the rope. That frazil ceases to run when the channel at the upper end of Lake St. Louis is closed, as observed by the Caughnawaga Indians, is another confirmation of the radiation theory, as water must be open to the sky in order that frazil may form, and the process of formation ceases when the surface is covered with ice. The rise of frazil to the surface, and its floating down stream in large quantities, when there is a sudden change of weather, does not indicate that it has been thawed, but that the stony bottom has lost its holding power on account of the check to radiation.

Mr. Hannaford. Mr. Hannaford's experience has led him to the conclusion that frazil ice is to be found at the foot of rapid currents and in broken and shallow water, rather than in currents of greater depth. For example, frazil ice is practically unknown in the Niagara River at the International Bridge, where its width from shore to shore is 1,800-ft., its depth 46-ft., while the current runs from 5 to 8 miles per hour. At Montreal, on the other hand, the St. Lawrence is six times wider than the Niagara River at Fort Erie, its greatest summer depth at the Victoria Bridge being only 23-ft., while the flow of water at ordinary summer level is about 2,100,000 gallons per sec., as against 1,535,000 gallons in the Niagara River at Fort Erie. This great width and consequent shallowness tends to the blockage of the St. Lawrence above Montreal. The ship channel below Montreal along St. Helen's Island, where there is a width of 1,800-ft., a depth 60-ft., and a swift current, would act as a free carrier of frazil and ice, did it not back up from below by reason of the frazil and ice grounding on the flats below the city, where the river again widens. There are two periods of high water at Montreal, the first between the middle of December and the middle of January, the second in April. If the statement is true, that frazil forms an important factor in the early winter rise, then, in Mr. Hannaford's opinion, the spring rise is clearly attributable to the ice brought down from Laprairie basin and the Upper Lakes, which chokes or gorges the channels below the city, causing the water to back up. His remedy to prevent the floods at Montreal would be to raise the buildings, yards and streets in the lowest parts of the city above the highest known or recorded level of the River.

Mr. Gzowski. Mr. Gzowski considers that the jams and flooding caused by frazil ice might be remedied by giving the streams freer passage, removing obstructions, straightening and deepening the channel.

Mr. Brush. Mr. Brush dissents from the theory that frazil plays much part in obstructing the flow of the river St. Lawrence. His observations have shewn that the frazil forms in greatest quantities in the rapids during the months of January and February when the water-level is steadily *falling*. The fact that there has never been a spring flood, except when the lake ice has been prematurely broken up, and has come down in large masses while the ice bridge opposite the city has remained strong enough to resist its passage, seems a conclusive proof, 1st, that however mischievous frazil may be in choking up pipes and aqueducts or the channels of small and sluggish streams, it forms no obstacle to the flow of the St. Lawrence, and 2nd, that it is the strong surface ice which, brought down in large quantities by a strong current, and resisted by an impassible ice barrier, is carried underneath, packs the shoals, and naturally so obstructs points of the river that there is no passage for the volume of the water. To obviate these evils, either the moving of the ice must be prevented or its passage facilitated.

Mr. Lesage stated that the water supply of the city of Montreal was brought by an open aqueduct from a point in the river St. Lawrence above the Lachine rapids, where the river in winter is always open for a distance of seven miles to Lake St. Louis, and where immense masses of anchor ice are being daily manufactured at the bottom of the river. These masses becoming detached from the bottom, are carried down stream and propelled by a S. W. wind, a large portion finds its way into the aqueduct. Various means have been undertaken with more or less success to prevent blockage. A channel was made in the border ice opposite the entrance to the aqueduct by means of gunpowder, with the effect of dislodging those spongy masses of frazil which could not be moved with a pole or other implement. Next a pier about 40-ft. in length was thrown out at right angles to the river shore a little above the entrance, with the object of diverting the current and frazil, but without success. Indeed it seemed to cause an eddy, producing precisely the contrary effect to that anticipated. In the following year a similar pier was built below the entrance, but without any appreciable effect, and the subsequent extension of this pier towards the first, until a water-way only 20-ft. wide was left, made matters still worse and the piers had to be removed. Mr. Lesage suggested that a new aqueduct should be cut with an entrance 4,000-ft. higher up the river. Subsequently the entrance to the aqueduct was moved up to a deep bay called the Inland cut. A large basin was formed by part embankment and part crib work, which allowed the surface ice to be formed over an area of about 10 acres, and from this place the water-supply is now drawn without any further trouble from anchor ice. This seems another proof that frazil cannot form under surface ice. The entrance to the basin is about 1,500-ft. wide, and the frazil forming on the edge of the ice in the river offers no appreciable obstruction. Every winter he had observed large masses of anchor ice attached to the bed of the river, to boulders and in all places where there were eddies. The anchor ice assuming a fungus shape, gradually grows upwards. A rise of a few degrees in the temperature will cause the whole mass to break away from its anchorage, often carrying with it a boulder or any substance to which it is attached. Sometimes the river is nearly covered with these floating masses, plainly shewing that they had formed in the open water of the river. The formation was most marked on cold bright days, and the frazil rose to the surface on a cloudy day with a slight rise of temperature. Experiment has shewn that the temperature of the river water at the aqueduct mouth is generally 32° F., and some times 31° F., down to a depth of 20-ft., while the temperature of the atmosphere is several degrees below zero. Every year, when ice first covers the aqueduct, frazil forms in the settling basin and is carried into the wheels, which have to be stopped a few hours until the ice has covered the settling basin.

Mr. Poole. Mr. Poole stated that at the Acadia Colliery, Nova Scotia, the boilers are supplied with water from an artificial pond, and the feed pipe passes through an embankment at a depth of 5 feet below the surface of the water. The pipe has a movable elbow in the pond so arranged that its inlet may be turned up at any time to the surface for examination. The open end of the pipe has attached to it a barrel from which the head has been removed. In place of the head there is a partition of coarse wire netting ¾ in. mesh, filled with sponge to filter the water going to the boilers. On the morning of the 26th November last the supply of water diminished, and the end of the pipe was turned up and examined. It was found that the netting was coated over with coarse crystals of ice and the sponges solid lumps. The pond was open the day before, but the night was clear and very cold, a high wind blowing which died away towards morning and allowed ice to form on the surface. The flow of water through the pipe was not large, occasionally only at a rate of some 30 gallons per minute; but as the crystals of ice were uniformly distributed over the netting, and had every appearance of growing in situ, the possibility that they formed on the surface of the water and were drawn down by the current is very remote; and when it is remembered that the sponges were also frozen the evidence is almost conclusive to the contrary.

Mr. Murdoch. Mr. Murdoch has always seen anchor ice in the bottoms of shallow rapid rivers with rocky beds, and never in clay bottoms. Frazil, which he considered the same as anchor ice, will float under the surface of running water. He stated that he had found the water under the ice in Thunder Bay to be considerably below 32° F. At the mouth of the Saskatchewan, where the bottom is a limestone, and the banks for two miles below the rapids are 20-ft. high, it freezes from the bottom upwards until the ice reaches the level of the banks and the river overflows. Mr. McAdams from fourteen years experience at the Carillon rapids states that frazil does not adhere to surface ice formed previous to the accumulation of the frazil underneath.

Mr. Rheaume. Mr. Rheaume stated that in many of the bays of the St. Lawrence river frazil attained a depth of 12 to 14 feet. That the cause of the Morrisburg flood was the swinging of an ice bridge between Croil's island and the shore. He had no doubt that Mr. Henshaw's suggestion for the prevention of floods would prove effective, if carried out, but oubted its practicability on account of the magnitude of the work nvolved.

Mr. Wicksteed discussed the causes of the floods at Montreal, and in onsidering the proposals brought forward in the paper for their amelior-tion, feared they would involve enormous cost of maintenance. He onsidered that the jamming of the ice is due more to the general con-raction of the water-way than to individual obstruction, and desired to oint out the applicability of Captain Eads' remedies to the obstruction n the Mississippi to the case of the St. Lawrence.

Mr. Steckel, remarking on the origin of the word frazil, considered t to be a purely French-Canadian expression for "slush ice," and stated hat frazil was also the French for forge cinders. He pointed out the ropriety of adopting some term which would have but one meaning nd be common to both French and English, and suggested the word Frasis."

The discussions seem to point almost entirely to frazil formed on the ottom, or anchor ice, as distinguished from any other form of ice, as he chief obstruction in river channels. Probably, however, only a minor art of the frazil blocking channels has at any time been attached to he bottom. Anchor ice is not supposed to form in deep water, hence its ormation is probably restricted to shoals and to a comparatively narrow order along each shore, varying, of course, with the general depth of the iver at the locality. On the other hand ice in thin sheets is forming ver a large proportion of the whole area of open water, while the ther-nometer is below 32° F. This thin ice, varying from the thickness of aper to perhaps an inch thick, is carried downward and broken up in apids, or is ground against the bordage ice, and the ice under which it is rawn. This process reduces the thicker surface-formed ice to frag-nents, and the thin films to snow-like masses, which are probably often mis-aken for frazil that has been attached to the bottom; but on close xamination they would be found quite different. If it is borne n mind that according to the generally accepted theory frazil proper orms only at very low temperatures, and under comparatively restricted ircumstances, while a surface film is forming daily, hourly, every ninute, when the temperature is a few degrees below the freezing point, nd is being being carried onward constantly by a current of from one o two miles per hour, thereby allowing film after film to form in suc-ession for weeks and months, it must seem that a very large proportion f the obstructions found in river channels must be atttributed to ice ormed on the surface as described.

Mr. Harris stated his own experience goes to confirm Mr. Henshaw's pinion as to the origin and means of accumulation of this ice. It may be mentioned that the railway bridge across the Gatineau river close t Ottawa was built in 1877-78, with stone piers founded on piles drive into a blue clay river bed. During the winter of 1878 it was found tha although no great reduction of the water-way had been caused by th piers, yet a very rapid shove was taking place over the bed of the rive adjacent to several of the piers. It had gone to the extent of removin some 5 feet in depth of the clay before it was discovered and choked b riprap. The shove undoubtedly occurred by reason of the accumulatio of frazil ice clinging to the under side of the surface ice, and causing great reduction of available water-way adjacent to the piers, thereby increasing the velocity of current. Probably the stationary surfaces offere by the piers caused this accumulation to form at the time referred to.

Mr. Keefer, President.

Anchor ice, called by the French-Canadian "habitants" "frasil," an by our English-speaking river men "frozee," is so designated because i has been found "anchored" upon the bottom in open running wate during extreme cold weather. When so found it is a coarse granulate ice of nearly uniform texture; but when it leaves the bottom, and i carried under the fixed ice of the river surface, to the underside o which it becomes attached by frost, it is found more or less mixed wit fragments of thin plate ice, as well as with saturated snow and "slush ice of a similar granulated texture, which it has picked up in its descent and also with earthy material which it has torn up when rising fro the bed of the river. It never forms upon the bottom or in the water whe covered with surface ice. The name "anchor ice" is evidence of its being found at the bottom, while all other ice is at the surface, although i does not remain at the bottom as other ice does on the surface; but ther is still much difference of opinion as to its origin, and even as to it formation at the bottom, among those who have not seen it there, ye know that all ice is lighter than water, and who also know that it is no *always found* at the bottom when there is ice at the surface. There ar however, persons who insist that ice is not under all conditions lighter tha water, that it sometimes sinks, and that solid surface ice has been found under water. This last statement is true only when such ice has bee frozen to the bottom, and is overflowed and held down by the current Anchor ice will form on the bottom in shallow streams whenever ther are about 15° of frost, or more; but in deep water it is not found unti there are 40 or 50 degrees of frost. The depth at which it will form in th most severe weather has not been determined, on account of th difficulties and danger connected with the exploration. There is however, little doubt that in the latitude of Montreal, this extend to at least forty feet, and that the depth of water in which it is foun is in direct proportion to the descent of the mercury and the duratio

that descent. The depth or thickness of its formation on the bottom
pends on the duration of the cold which, if sufficiently prolonged,
uld cause such a bottom growth as to raise the river out of its bed,
d cause it to overflow its banks. In November Mr. Keefer has forded
hallow stream flowing rapidly over a stony bottom, having less than
oot of water, and on his return, three days afterwards, has found it
passible from anchor ice—a thin sheet of very cold water flowing
er a mass of porous ice filling the stream to the top of its banks.
ere is an abundant formation of "slush" ice on the surface in the
in channel, at the setting in of winter, when the current or wind
events the formation of sheet ice, which collects in masses by mutual
raction or cohesion of the spicules, the appearance of which is
nilar to that which is found as anchor ice at the bottom. If this be
e raw material from which the growth of anchor ice is made at the
ttom, the fact still remains that this ice is most abundant on the
rface when there is no anchor ice at the bottom; on the other
nd the growth of anchor ice at the bottom is most rapid when
d where there is no visible ice of any kind floating upon the surface. He
s crossed the St. Lawrence in a canoe opposite Montreal when
e thermometer was much below zero, and where there was no floating
; but the water instead of being transparent as usual was lead
lored, thick and "sandy," with ice, invisible from the surface, flowing
parently with difficulty, as does the Missouri when loaded with sand;
icules of ice, about the size of darning needles, attached themselves to
e paddle by their points, and when it was withdrawn from the water
od out at right angles to the wood—like iron filings on a magnet. In
is condition of the river, the water, no doubt at the deepest point, is
aded with ice spicules to the bottom, densely and uniformly distributed
roughout the whole mass, and would supply the raw material for the
rmation of anchor ice at the bottom whenever the latter was prepared
receive it. That it is not at all times so prepared is evident
om the fact that anchor ice is not always found when ice spicules are
undant in the water. If anchor ice is derived from ready made ice in
e water above it, the only explanation, in his opinion, is that the bottom
ust first become frozen before its formation can begin. Whether
be formed from the water or from ice in the water, the condi-
on precedent is a frozen bottom. Ice will attach itself to ice or to
her frozen bodies, but not to the unfrozen bed of a river. The
agnetism of frost seems necessary to attract the minute particles; and
hen once a covering is formed a rapid congelation may take place,
hich will continue as long as the frozen bottom overcomes the
ghter specific gravity of ice and holds the mass down. The supposition

of a frozen bottom would also explain the rising of the anchor ic When the air and the water are above the freezing point, anchor ic leaves the bottom. This generally occurs at an air temperature of abo 40° F: when the water is near its maximum density, and when its cold surface current has resumed its position at the bottom so far as thes conditions de prevail in rapidly flowing water. If the rising anchor ice was assisted by the increased density of the water whic accompanies its departure from the bottom, its tendency to let go woul be retarded by the now colder water in contact with it; but it is n probable that either of these conditions has any influence upon i rising or remaining. It is the change in temperature of the wate and not in its position or density, which releases the hold of th bottom on the ice, and this not by the contact of the now warmer wat with the frozen bottom,—for the two are separated by a mass of ice—bu by return of internal heat, in other words by the diminution or cessatio of radiation from a warmer surface to a colder one, from earth t water. When the air temperature is much below zero, that of th running water is below freezing, and prevented from freezing onl by its motion. The rapid abstraction of heat from the bottom b such a cold current, if intense and long enough continued, woul freeze the bottom, and thus prepare the foundation for anchor ice and whether this ice is derived in whole or in part from the dissem nated spicules in the water, or is a new creation from the wate his radiation, which is an important factor in the formation of ice, is, i his opinion, the chief cause both in supplying the material and in anchorin it at the bottom, that is radiation as well as convection from the water t the colder air, and radiation from the earth bottom of the river to the colde water above it, if not also through it to the still colder air above both As the water in a rapidly flowing river descends from the surface t the bottom, and rises from the bottom to the surface, the ice spicule must be carried down to the bottom when the thermometer is abov zero, as well as when it is below it; but in the first case they do n remain there as anchored ice, and in the other case they must do s unless anchored ice is formed out of the water at the bottom durin very low temperatures. Whether anchored ice, therefore, is of surfac origin depends whether any kind of ice can be formed except in con tact with the atmosphere. Doubtless some air is carried down with the cu rent, and some may be disengaged in the process of freezing. Mr. Keefe has stirred anchor ice in twelve feet of water where it was two feet in thick ness on the bottom, and bubbles (either of air or gas) came to the surfac

This form of ice is a great enemy to water-power taken from portion of the river uncovered by ice. Even in canals it forms before the surfac is frozen over to an extent sufficient to clog gateways, but disappears as soon as the surface is covered by ice. A covering of ice, or any artificial covering is sufficient to stop its formation, by preventing both convection and radiation. As it does not form under the arches of a bridge, while it may be found immediately above and below it, and as an overcast sky has been known to cause it to leave the bottom of a stream, the presumption is that radiation has more to do with its formation than convection. It has also proved an embarrassing obstruction to engineers in sinking crib work through the ice, whenever it has been deposited there from the open water above. It cannot be displaced by pressure, but must be entirely taken out or floated away. Intelligent and reliable mill-owners assert that this troublesome ice is never found in their mill-races—no matter how cold the weather is, whenever the sun is shining, or whenever there is a cloudy sky at night.

In conclusion,—anchor ice, which in certain rivers or portions of rivers is by far the most abundant formation of ice there, is not an unmixed evil—on the contrary it is a great benefactor. All the sections of our rivers which are open water in winter are factories of anchor ice, the formation of which liberates enormous quantities of heat to temper the severity of our climate. After the slack water portions of our rivers and our lakes are covered with ice and snow, and all other sources of terrestrial heat either by radiation or convection are cut off, abundant stores of water are poured forth from the lakes into the rapid sections of the rivers, and by their conversion into ice liberate the heat they have retained in greater or less quantities, and always in the greater quantity when most needed. Mr. E. Lewis, jun., in his "Physics of Ice," says:

"To melt a pound of ice requires 142 units of heat, that is an amount which would raise a pound of water 142 F. This is the equivalent of the molecular force exerted in solidifying the water, and the mechanical value of the two forces is the same. Expressed in figures it is the equivalent in mechanical force of the work done in lifting the same pound of ice 110,000 feet high. The melting of 20 lbs. of ice is equivalent in mechanical force to lifting 1,000 tons, nearly, to a height of one foot; or lifting two persons, weighing 300 lbs., 1,000 feet higher than Mount Washington."

The great rivers of Canada, the St. Lawrence and the Ottawa, with the large majority of their tributaries, are terrace-like in their profile, and studded with numerous lakes, as contrasted with the almost uniform slopes of the Mississippi, Missouri and Ohio, in the southern and greater portion of their length. At the outlets of all our lakes great and small, there are rapids with water open to a greater or less extent in winter. The amount of latent heat given out in the formation of anchor ice at all these numberless "breathing holes" must give a powerful check to the duration of that same temperature under which this peculiar form of ice is so abundantly developed, especially when we remember that the colder the weather the greater the disengagement of heat, being in this respect similar to the steam blast in the Locomotive, "the harder she blows the faster she goes."

Sir William Dawson.

Sir Wm. Dawson, being called on by the President, remarked that he did not profess to know much of those practical questions which depended on the so-called *Frasil*, a term which as applied to ice did not seem to be always used in the same sense. The best term for the form of ice referred to is that of "Spicular ice," which has been used by geologists in discussing this question. Such ice consists of thin blades or needles of a crystalline character, which may either form in a separate or detached manner in water which is cooled below the freezing point and which is agitated by the wind or by a rapid current so that the ice cannot become compact; or it may grow in the bottom in the manner in which crystalline needles form in some saturated saline solutions. In the first form the spicular ice constitutes what fishermen and boatmen on the coast call "lolly," which floats in the water and is perfectly soft and mobile. In the second case it constitutes sheets, masses or shrublike aggregates of crystals attached to hard bodies in the bottom of the water. It is then called "ground ice" or "anchor ice." This ground ice when it attains to certain dimensions, or when the temperature rises, may float up, sometimes carrying with it bodies to which it may be attached, and then, of course, it drifts in the same manner with lolly. Ground ice does not usually form under a covering of sheet ice, but, from the sections submitted by Mr. Kennedy, it would seem that in very cold weather spicular masses run down from the lower side of the ice in places, just as they do from the under side of the surface sheet of water in a dish of water when freezing, and these spicular growths may detain and accumulate the floating lolly drifting under the ice. With respect to the formation of ground ice proper, the principle is exactly the same as in the case of crystals forming around any hard body in a saturated saline solution. The water has first to be cooled to the point of crystallization, and when in this state it comes into contact with any hard substance, cooled by radiation or otherwise to the same or a lower temperature, it will crystallize on or around that substance, and shoot upward in needles, until broken off by violence, or until it becomes too buoyant to be any longer held down in the bottom.

The fact that it forms most readily in open water without any covering of ice, and in clear cold weather, indicates that radiation from the bottom has an important influence in its formation; but where the water is sufficiently cold it may crystallize on any nucleus presented to it; and more especially, it would seem, on metallic bodies and stones which are good conductors of heat. Hind states that on the coast of Newfoundland anchor ice forms in large masses in the sea, at depths of sixty and seventy feet, and it has been known to raise stones and anchors from the bottom, and to freeze around fish caught in nets. He also states that when the salt water has been cooled below the freezing point, the fresh water of streams pouring into it from the land is at once converted into lolly or floating frasil. In this last action there is something analogous to what takes place when water at about the temperature of 32° is tossed about in a rapid and mixed with air at a still lower temperature, perhaps below zero. These are merely desultory observations from the point of view of a geologist; but they may serve to show that there are different kinds of spicular ice, and that they may be formed in various ways. It seems certain that several of these modes of formation are concerned in the production of the spicular ice so troublesome in our river, so that it is not prudent to limit ourselves merely to one theory of formation, any farther than the general principle that they all depend on the somewhat rapid crystallization of water, under circumstances in which it tends to form groups of spicular crystals rather than solid sheets.

Mr. Tate remarked that whenever the water at a temperature of 32° F., or less, was passing over the river bed at a higher temperature, a formation of ice might occur after the manner of hoar frost possessing great cohesiveness and tenacity, until disturbed by a higher temperature or other forces. A thickness of 2 or 3 ft., as observed by Mr. Peterson, might be thus formed, and might then be detached by the weight and possibly by fluctuations of temperature.

Mr. W. Bell Dawson remarked that there was one point of difference between the conditions in still water and running water that had not been sufficiently emphasized. As water attains its maximum density at 39° Fahr., the coldest water remains at the surface after reaching that temperature if the water is calm, and the ice naturally forms there. But in rapidly running water the current mixes the different parts together, and the whole volume may fall to 32° or even a little below, and it may then crystallize on the bottom or sides, or on any object in the stream. The crystals so forming would most of them be detached by the current and swept on with it, so adding to the amount of frazil in the water. With regard to the word itself, the term "fraisil" or "frasil" is correct French, and means coal-dross or cinders. It has probably become applied to the kind of ice it denotes, much on the same principle as "poudrer" is used for the drifting of snow, a word which originally referred to dust.

Mr. T. Guerin.

Mr. Guerin, after remarking upon the point of maximum density of water, stated his opinion that frazil consisted of particles which must have been frozen separately; that this might be effected, the water must have been divided into separate and distinct particles at the time of freezing, which could only occur in a rapid or series of falls, where the water is violently agitated and converted into foam and spray, of which the minute watery particles are frozen, and form the frazil under discussion. He did not believe that frazil is always formed at the bottom. The lifting and displacing of anchors, and other substances, are caused by ice, which, from shoving and piling, has become so thick as to reach the bottom, and has afterwards risen with the rise of the water level, carrying the anchor, etc., with it. He does not think that the rise of frazil masses to the surface is not affected by a change of temperature. He finds it difficult to believe that the frazil was found lying at the bottom of the C. P. Ry. bridge at Lachine, especially when it has been shown that a current of 10 miles an hour, such as that in the place in question, can move loose rocks or boulders 6 feet in diameter. He has never found frazil at the bottom of lakes and rivers in any place in which it did not also reach to the surface.

Mr. P. A. Peterson.

With reference to what Mr. Guerin has stated as to frazil only forming below rapids, Mr. Peterson remarked that during the winter of 1881-82 when engaged upn the survey of the river where the present St. Lawrence Bridge is located, above the Lachine rapids, and below a long reach of slack water (Lake St. Louis), he found, when taking soundings in depths of water, varying from five feet to forty feet, that the bottom of the river was frequently covered, over its entire area, with frazil from two to three feet in thickness; when the sounding rod was let down upon it, the frazil was of such a consistency as to sustain the rod, which could be forced through it by a couple of strong men without much difficulty. This frazil formed during a period of intense cold, when the thermometer was below zero. When the temperature rose above zero, the frazil would rise from the bottom, and on a mild day it could be seen umpijng up above the surface of the water all over the open portion of the river, which here extends over a distance of from four to five miles. This formation of frazil and its subsequent rise to the surface occurred during the entire winter whenever a period of intense cold was followed by mild weather.

Mr. W. McLea Walbank.

Mr. W. McLea Walbank was of the opinion that that Indians referred to by Mr. Henshaw did not properly understand what was meant by frazil. He spoke from experience, having crossed the river at the points in question twice daily for the past five winters, and stated that frazil formed in the Lake at both sides, and in fact almost all over the river between Lachine and Caughnawaga during the whole winter, and could be seen on the bottom on a clear day at the end of the new pier of the Lachine Canal. It always came up to the surface on cloudy days, turned upside down, and floated down stream. He also stated that it was generally known that the ice bridge had formed at Pointe Claire when the sheet ice and slush stopped coming down. Mr. Walbank did not agree with Mr. Guerin that frazil was formed from spray and foam caused by rapids, as he had often seen it form where the bottom was rough and the current strong but no spray or foam existed.

The temperature of the river bed cannot well be less than 32° in the case of large rivers, and is very probably higher, as it would be kept up by heat from below. The fact that large stones and masses of earth become detached from the bottom by the floating power of anchor ice proves that the ground below the bed of any large river is not frozen solid. How then could a stone, whose upper surface is at, or almost at, 32°, and whose lower surface is at a somewhat higher temperature, radiate cold into a body of water from which it is itself receiving cold? Is it not much more likely that such stones are only kept cold enough for ice to adhere to them, the cold in the atmosphere above the water, being transmitted through the water, a theory borne out by the fact that when the air gets warmer the frazil begins to rise from below? Is it not probable that anchor ice and frazil both have the same origin, their formation being finally completed under different conditions? It was stated that frazil did not form under ice, it is also well known that a body of ice thickens from below so that the water under such ice must be cooled enough to freeze; and, further, it is well known that quite a considerable quantity of air mixes with the water of a river while flowing, enough to purify the water by oxidation. Now, the air cannot mix with the water when it is covered with ice, and may not that be the reason why frazil does not form under ice, and that a greater part of the frazil is formed by particles of very cold air mixing with water? This being the case especially below rapids, where more air would be mixed with the water. Frazil formed in this way, being very cold, might well be almost as dense as the surrounding water (for ice contracts on cooling), and would, therefore, be easily carried to the bottom, and would crystallize most readily round any substance with a cold and rather rough surface. If forming in large quantities, and so partially able to protect itself, and not subject to too strong a current or too great pressure, what is known as a mass of frazil would be formed; but if forming in small quantities, and subject to great pressure or a strong current, the frazil will be consolidated into anchor ice. In the case of the suction-pipe referred to by Mr. J. Kennedy, the failure to prevent the formation of anchor ice might have been due to the fact that the covering did not extend over a sufficiently wide area. Particles of ice formed in the water would be carried by the suction of the pipe towards its mouth, adhering to the stones which would be kept cool by the stream of cold water, and made to consolidate by the strength of the current. Such a formation would take place slowly, but a small deposit of ice per hour would soon choke up a large pipe; how stones around such a pipe, receiving their cold from the water, could yet give up to the water enough cold to deprive it of its latent heat of liquefaction, seems difficult to understand.

Mr. J. B. Francis.

Mr. Francis saw no reason to change the views expressed by him on the subject of anchor ice (or frazil) in an address before the convention of the American Society of Civil Engineers, held in Montreal in the year 1881, and published in the transactions of that Society.

Mr. J. Kennedy

Mr. Kennedy said he held views as to the formation and accumulation of anchor ice, similar to those set forth by Mr. J. B. Francis. He supported these views at some length, and by way of illustration and proof cited numerous facts which had come under his own observation, and had been gathered from reliable sources. Plans and sections, showing large accumulations of anchor ice in the St. Lawrence at Montreal, were exhibited.

Mr. Henshaw.

In replying to the remarks made by those who have taken part in a very full discussion of my paper, it is a matter of regret that a generally recognized terminology regarding this kind of ice formation does not exist. The American and some of the Canadian critics state that what is termed frazil in the paper is known by them as anchor ice.

Now, the word frazil is, in Canada, commonly used to designate slush ice of every description, but for want of a better word, especially refers in the paper to that kind of ice, seen in a sort of efflorescence, clinging to the bottom of streams. Its origin is the same as that of anchor ice, but it detaches more readily and frequently. Anchor ice is formed when the current is too swift to allow efflorescence, and may be likened to an accumulation of roots when branches and foliage have been swept away. The objection to regelation is that it is purely a theory without a single fact to support it, except the still-water experiments of Faraday and Forbes. It seems incredible to suppose that the loosely combined masses that are seen floating can ever have been able to attach themselves to the bottom of flowing streams, even if it is assumed that the nuclei have by some means reached the necessary temperature, and still more so that particles from the surface should arrange themselves in forms suggestive of luxuriant vegetable growth.

Objections were made by some members to the description of subcurrents, apparently with the idea that it was original. It was, of course, only stated as an incontrovertible fact, in order to show the manner in which the river bottom could become refrigerated. That these currents do and must exist, and that in unchanging river bottoms they must be permanent, it is only necessary to invoke the law of persistence of force, which lies at the base of all physical science, as a proof. A current then highly charged with ice particles, formed under a very low temperature, must have a strongly refrigerating effect, and this has only to be demonstrated in order to account for a natural growth of ice below the surface or on the bottom.

Interchanging currents in running streams are mainly offshoots from the subcurrents and the consequent reflex action ; their strongest action is from below, and their intensity is proportioned to the obstructions met by the subcurrents. When where is no subcurrent there is no formation either of frazil, or anchor ice. In lakes or ponds the interchange is due to waves or ripples, and the weak action of such currents would not permit the formation of ice at any considerable depth, unless aided by artificial currents, such as those produced by the supply pipes of waterworks, where, according to Mr. Herschell, Mr. Poole and others the ice has formed in large quantities. The theory of radiation is attended with as great difficulty as that of regelation, for while there is no trouble in accounting for hoar frost by radiation through the air, the denser medium supplied by water would render it very doubtful in the case of frazil, even if the still more important difficulty of a surface more or less ruffled or uneven were thrown aside.

31st March, 1887.

Mr. JOHN KENNEDY, M. Can. Soc. C.E., Vice-President in the Chair.

The discussion upon Mr. G. H. Henshaw's paper on Frazil ice occupied the evening.

14th April, 1887.

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

Ambrose Duffy has been transferred from the class of Associate members to that of members.

The following candidates were balloted for and duly elected as

MEMBERS.

JOHN DYER.
JOHN RANDOLPH HERSEY.
ARMITAGE RHODES.

ASSOCIATES.

THOMAS BRIGGS BROWN.
GEORGE REAVES.
JOSEPH RIELLE.
JOHN TAYLOR.

STUDENTS.

WILLIAM J. CARMICHAEL.
LOUIS HENRY CHAPERON.
FRANCIS W. W. DOANE.
ROBERT E. HUNTER.
PETER L. NAISMITH.

Paper No. 2.

CONSTRUCTION OF THE CANADIAN PACIFIC RAILWAY GRAIN ELEVATORS.

BY STUART HOWARD, M.C.SOC.C.E.

The Grain Elevators lately constructed by the Canadian Pacific Ry. Co. in the City of Montreal, are located south of the old Quebec Gate Barracks, now the Dalhousie Square Station, and above the wharf belonging to the Montreal Harbour Commissioners. This property has been reclaimed from the river, the front being protected by cribwork, and the space filled in with stone, debris and clay.

There are two Elevators, 210 feet long and 80 feet wide, built on the old river slope over the Harbour wharf. It was thought expedient to pile the foundations and not to trust to any unsound bottom, as the total weight of each building, including masonry, timber, and a full elevator of 560,000 bushels of grain, amounts to a little over 40,000,000 lbs. The area is divided into 102 bin spaces, of about 12 ft. square. Each bin is supported upon a pier of masonry, and the weight upon each pier is 497,000 lbs., equal to 70 lbs. on each sq. inch of concrete foundation.

A retaining wall, 12 feet wide at the bottom, 22 feet in height above the wharf level, and 5 feet below it, containing 7½ cub. yds. per running foot of wall, has been constructed from the masonry of the Brock Street Ramp to the eastern elevator, a length of 118 feet; then for the eastern elevator a length of 208 feet ; and between the two elevators a length of 230 feet. From the west end of the westerly elevator the same section of wall is built to Barrack Street, and after a gap of 50 feet leading to a double ramp, it is again continued to Fripponne Street, on a grade of 1 in 20 to the level of the Harbour revetment wall. The new level of Water Street being 10 feet above the old level, this retaining wall was built to support the earth filled in at the back in order to make the new street, which is carried some distance south of the old river bank.

Piles were used in the entire foundations of the elevators and connecting buildings, the front wall or that nearest the river having three rows, and the back and end walls two rows placed at 3 ft.' centres. Each pier, of which there are 80 in each elevator, is built upon a cluster of 9 piles ; the engine and boiler beds, and the chimney, also resting upon a pile foundation. The piles were driven in by means of a driver worked by steam, with a fall of 20 feet, the ram weighing 1400 lbs. They were cut off 9 inches above the bottom of the trenches, which were 2 feet deep, the whole of these excavations being filled in to the level of the natural ground surface with well rammed concrete, composed of 2 parts of sand, 1 of White's Portland cement, and as much stone as was required to fill all the voids. On this foundation, which extended 12 inches beyond the walls on either side, the masonry was commenced. The front wall is 6 ft. wide and has a concrete bottom width of 8 feet, the footings being 7 feet and the wall 6 feet wide. The back and side walls are 4 feet in width and the concrete 7 feet, the atter being further strengthened by buttresses 4 feet wide, placed every 25 feet, and bonded into the piers, in order to resist the thrust of the outside earth. The piers are 4 feet square with two-6 inch footings, the concrete being 7 feet square. These are finished off at a level of 23 ft. 8 ins. and the copings of the walls are 34 ft. above low water. Earth is filled in o a level of 9 inches below the top of the piers, the space up to the street level being utilized as a sort of cellar to contain the iron receiving tanks and the bottom of the elevating legs used for raising the grain from these tanks to the top of the building for distribution into the different bins. It will readily be seen from the foregoing description that the foundations up to the street level were necessarily very deep and expensive, the height from the wharf to this level being 22 feet A casual observer approaching from the Station side would imagine th foundations to be only of an ordinary description, until on looking ove the retaining wall described above, a solid wall of masonry 22 feet i height is seen. The total quantities of piling, concrete and masonr in the two elevators, revetment wall, engine, boiler, and chimne foundations were 43,389 lineal feet of piles, 1,362 cub. yds of concret 16,187 cub. cyds of masonry, and there were over 40,000 cub. yd of excavation and filling, the cost amounting to $10,847 for pile driven, $10,554 for concrete, $125,450 for masonry, and $8,000 fo earthwork, making a grand total of $154,851 for work now covere up and hidden from view, and presenting only a fine face of masonr wall to the river.

On each pier four 12 ins.×14 ins. posts 26 ft. 6 ins. long are placed an kept one inch apart by wooden keys, the whole being thoroughly bolte together. On these posts and mortised to them are two 12 ins.×12 in caps, and above them two 12 ins.×14 ins. pieces are also keyed and bolte and strengthened by 8 ins.×8 ins. braces set at an angle of 45°, an tenoned into the posts. These caps run from front to back, resting al upon two 12 ins.×14 ins. posts on the copings of the walls. On the timbers and running longitudinally are two 12 ins.×16 ins. timbers plac midway between the posts, forming mouths at the centre of the bi 12 ins.×14 ins. longitudinal pieces placed directly over the posts, al thoroughly braced with the four cross timbers, carry the bin walls. T posts around the building and on the copings, are immediately opposi those on the piers, and are two 12 ins.×14 ins. timbers.

The railway tracks (two in each building) are carried by 12 ins.×14 i stringers, directly under each rail, resting upon 12 ins.×12 ins. timbe opposite each cluster of posts, and thoroughly braced with 9 ins.×9 i pieces. The flooring is supported on 3 ins.×12 ins. joists, at 24 ins. centr laid upon 8 ins.×12 ins. longitudinal pieces let into the sides of the pos and well bolted to them. The bin walls are constructed of 2 ins.×6 i planks, and the outer walls of 2 ins.×8 ins. planks laid one upon the oth breaking joint, and well spiked with 5 inch spike nails, every 15 inch The bottoms are at an angle of 45°, with an opening of 12 inch square in the centre, resting on the 12 ins.×16 ins. longitudinal timbe to the underside of which the castings for the revolving spouts a fixed. These bins are 50 feet in depth with a ladder in the corn of each made of $\frac{3}{4}$ round iron, flattened at the ends, and placed betwe he planking. The inside bottom of each bin is lined with iron to prevent the planks from wearing away by the friction of the grain. There are 102 bins in each elevator, of which two are lost, one being used for the staircase, and the other for the driving belt. The remaining 100 having a total capacity of 560,000 bushels.

The cupola or central portion at the top is reduced to a width of 49 feet, and so that it may have a solid bearing and not be dependent upon the shrinkage of the bin walls (as the upper stories in elevators formerly rested immediately upon the bin walls), it is carried by 10 ins.×10 ins. posts set in the corners of the bins, and resting upon the posts on the piers, and held by iron straps passing round them and through the bin walls. There are four stories above the bins, the framework being posts 10 ins.×10 ins., with caps 10 ins.×10 ins. braced with 6 ins.×6 ins. pieces, and running through the length of the building are 10 ins.×10 ins. timbers, also thoroughly braced. The floor joists are 2 ins.×10 ins. at 18 ins. centres running lengthwise of the building, the flooring being 1¼ ins. thick. The rafters are 2 ins.×8 ins. at 16 ins. centres resting on 6 ins.×10 ins. plates. The roof is ¼ pitch, covered with one inch boarding and Canada plate. A staircase with 104 steps, 3 ft.×6 ins. wide, risers 8 inches and 9 inch treads, is placed in the S.E. corner of the building and carried by upright posts 6 ins. square, being thereby made independent of any shrinkage of the bin walls; this leads only to the level of the top of the bins. Above this are two other staircases from floor to floor, one at each end of the building. The timber in the elevator above the foundations amounts to about 1,250,000 ft. B. M. The elevator is supplied all through with speaking tubes and gongs, and well protected in case of fire, by pipes connecting with the engine room. The pressure of water being supplied from the City, and in case of necessity worked by a Northey pump of 120lb. pressure, connected with the engine, branches with hose and nozzles being laid on each floor. The whole exterior of the walls is covered with corrugated iron 26 gauge, the corrugations on the cupola and lower part being vertical. On the bin walls horizontal iron fire escape ladders are also provided.

The upper story of the cupola contains the machinery. The shaft carrying the pulleys, being from 6 to 5 inches in diameter, is made in sections, bolted together and supported by cast-iron brackets, on a strong timber frame. The driving pulleys, of which there are nine in all, four for the south elevating legs and five for those on the north or track side, are 5 feet in diameter and 22 inches face, they are fixed to movable sleeves through which the shaft passes, and are thrown in or out of gear by strong clutches worked by levers with screw bar attached, and operated by means of wheels turned by hand. The legs on the north side are set in motion by belts running over pulleys on the main shaft, tightened b tightening wheels attached to a frame, and worked by ratchet gearin The elevating legs are made of 2 ins. T and G plank, screwed togethe forming a box with an internal dimension of 12 ins.×24 ins. running fro the bottom of the receiving tanks to the top of the building. The be to which the buckets are fixed is inside, and passes round a wheel 24 in in diameter at the bottom and the 5 ft. diameter pulley on the mai shaft at the top of the building. The bottom wheel works in a cast-iro frame, and can be lowered or raised at pleasure by a ratchet. The bel in the elevating legs are 256 feet long and 20 inches face, the bucke being 18 ins.×7 ins.×7 ins. placed every 15½ inches, and bolted to t belt. Each bucket holds ⅕ of a bushel. Thus, as the pulley makes 3 revolutions per minute, the belt travels at the rate of 569 feet pe minute, each leg being able to raise 5,250 bushels per hour. Befor proceeding to show the method of manipulating the grain, it may be we to describe the power used for setting the machinery in motion.

The Boiler House is a substantial brick and timber structure, 40 ft. 47 ft. placed midway between the elevators, with a height to the eav of 20 feet, the roof sloping each way, and surmounted by a good ve tilator. It contains at present three boilers 5 ft. 6 ins. in dia. and 15 fee long, with fifty six 3¼ ins. tubes and a firegrate 4 ft. 6 ins.×6 ins. The were built at the Montreal shops of the Canadian Pacific Railway.

The boilers are placed upon a strong timber foundation of two thicknesses of 6 ins. timber, placed on 10 ins.×10 ins. caps, mortised on t piles placed at 3 ft. centres, driven through the 22 feet of earth fillin over the wharf level, into the solid ground below, and which are at leas 30 ft. long.

The steam from the boilers is conveyed to the engines, which ar placed in buildings 24 ft. × 40 ft. adjoining the elevators, by a 6 inch pip laid in a wooden box, containing also the feed pipes for the boile and the exhaust pipes. The engine of No. 1 elevator is a Wheeloc Horizontal Engine with condenser attached, making it equivalent t 175 horse-power. The cold water for the condenser is pumped by Northey pump, direct from the River through an eight inch iron pip passing under the revetment wall and into a well at the river front i the wharf cribwork, the water entering by a hole cut through the fron timbers, 12 inches below low water. Inside the well a foot valve i placed to equalize the pressure. The waste water is run through a ordinary 9 inch sewer pipe, laid in the same trench as the water pipe but carried down stream on approaching the river. The dimensions o the engine are, cylinder 20 ins.×46ins with a fly wheel of 16 ft. diamete making 65 revolutions per minute. This is reduced to 36 by means of

ft. 4 ins. and 9 ft. 4 ins. diameter cogwheel, with a face of 16 inches; pitch
f teeth 5 inches. The flywheel is on the 10 ins. driving shaft, to which
e driving pulley with face of 48 inches and 7 ft. in diameter, is attached.
he main belt, 46 inches wide, of 6 ply rubber, made by the Canada
ubber Co., 250 feet long, passes round it, and over a 7 foot pulley
heel on the main shaft at the top of the elevator, setting in motion the
achinery for driving the elevating legs.

Between the two tracks is a platform 4 feet above the rails, and 11
et wide, and below this are five receiving tanks made of 2 inch T and G
lanks, and lined inside with iron, set in wrought iron tanks and placed
n the level of the piers. These tanks are 35 feet centre to centre, or as
ear as possible opposite the car doors. At the level of the rails and
xtending up to those nearest the platform are iron gratings. The cars
n be moved about at pleasure by means of a hawser wound round a
pstain, and attached to the front of the cars. When the grain is
ady to be unloaded, it is effected by a wooden shovel, with 2 handles
ttached (in shape like a railway scraper) with a rope connected to it,
nd wound round a drum working automatically on a shaft fixed to the
osts over the platform and running the whole length of the building.
here are five of these shovels, one over each tank; the shovel is drawn
to the car, and as soon as the tension is taken off the rope, a small
ammer falls, and the drum is turned, winding up the rope, and scraping
he grain from the car's door, down on to the grating through which it
asses into the tank, the sides of which are at an angle of 45°. It pours
hen through a small door at the bottom, immediately under the elevating
g, the buckets scooping it up, and elevating it to the top of the build-
g, where it is discharged into a receiving hopper. From this it drops
to the weighing hopper, of a capacity of 30,000 lbs., or 500 bushels
f grain. The shovels have an unloading capacity of one car of 600
ushels in 15 minutes, in most cases 5 cars per hour, and as there are
ive shovel machines with two drums on each, the total number of bushels
hat can be unloaded per hour, with all the machines working, amounts
o 30,000 bushels. The scales used are those made by the Fair-
anks Scale Co., and are nine in number, with a weighing capacity
f 40,000 lbs., an accurate account of the grain weighed being kept.
Under each weighing hopper is a circular table, around which are
ixed a number of wooden spouts leading to the bins belonging to its
articular radius; the grain is therefore discharged through a revolving
pout, fixed to the bottom of the weighing hopper, and placed opposite
ny particular spout, leading to the bin required to be filled. There
re four legs on the south side similar to the five on the track side, so that
rain can be taken from any bin, run into one of these tanks, elevated,

and put into another bin. By dropping it, and continually passing it o it is possible to take grain from a bin at one extreme end of tl building, and put into one at the other.

The grain can be thoroughly cleaned by being passed through separating machine, the smut and dust dropping into a receptacle f that purpose. The air is conducted from the cellar through a tig wooden box, the draught being caused by two fans, 4 ft. in diameter, ea making 625 revoltions per minute. There are two separators, one at ea end of the building, and on the same floor as the scales and weighi hoppers.

Two spouts on the lower floor are used for loading cars, and t discharge is so great that a car of 600 bushels can be filled in thr minutes. On the lower floor is a 4 inch shaft, connected to the ma driving shaft,and running longitudinally, supported on iron standards, tl centres being 18 inches above the flooring, which is utilized for driving t conveyor belts. The conveyors are carried across the wharf on trestle formed of 5 ins.×8 ins. timbers, resting on sills bolted to posts, the ben being well braced and bolted, and placed at 42 ft. centres. The chords a of two 3 ins.×8 ins.pieces strengthened by braces and straining beams,key and bolted to the chords. On these rest the floor joists 2 ins.×8 ins., 11 long and at 3 ft. centres, the flooring being 2 ins. thick and 11 feet wid The upper portion is made as light as possible, being a simple framewo supporting convex rollers 38 ins. long, placed at 6 ft. centres, there bei two rows, 14 inches centre to centre. The grain in transit is protected a tarred canvas covering, fastened to circular iron bands 3 inches wi and $\frac{1}{2}$ an inch thick, placed 18 feet apart, and supported also betwe these at every 3 feet by $\frac{3}{4}$ inch bars bent to the same radius, namely inches. Openings with flaps are opposite every roller, so that the journa can be oiled from the outside, a space being left between the covering a the outside of the floor to admit of decent footwalks protected by ha railings, leading across the entire structure from the elevator to t tower.

On a small shaft in the elevator is a 48 ins. diameter pulley, face 38 in on a loose sleeve, worked with a clutch, and set in motion by a reversib bevel gearing, so that the conveyor belt can be run either in or out the building for loading or unloading vessels. The conveyor belt is 36 i wide, 515 ft. 6 ins. long, of 4-ply rubber, and is carried on a level over t convex rollers, the grain being dropped on to it from the bins abo through a small hopper. The belt is bagged at this particular point as to run the grain on to the centre. The conveyor belt travels at t rate of 455 ft. per minute, and its capacity is about 9,000 bushels p hour. The transit of grain should be seen in operation to be realize s the idea that wheat and other grain, and especially peas, can be arried along on a flat and level belt without running over the sides is a onderful fact. The grain after passing into the tower, which is at the iver end of the structure, is discharged into a small hopper, to the ottom of which is fixed a rotating iron spout, capable of being raised or wered so as to suit the height and position of the vessel's hatches, through hich it drops into the ship's hold. There are two conveyors to each levator placed at 146 ft. centres, which are made as light as possible, the hole structure being put together with bolts, as they must be removed rom the wharf as soon as navigation closes, and before the river rises. n the towers are horizontal tighteners, around which the belt passes, ixed to a movable iron frame, and worked by hand.

The Halifax elevator, as also the million bushel one in Boston, have onveyors on this principle. During a visit to the latter place the author ad the pleasure of seeing peas carried by a conveying belt out to the cean steamers. Here the conveyor was over a quarter of a mile in ength, and built not in one straight line but around corners, the grain eing thrown from one belt on to another. The motion of the belt was transmitted by means of a bevel wheel keyed on to the shaft of the pulley wheel at the extreme end, and set into another on the adjoining belt, at right ngles to the centre, and at the angle of the turn. The last portion of he conveyor is built down the centre of a wharf, with vessels on either ide, and at certain distances on each side of the structure are receiving hoppers with spouts attached, under which the vessels are placed.

Movable trippers are placed under the belt, lifting it up some little eight above its level. The grain ascends the incline, and being shot orward by its velocity over the summit, falls into any particular hopper, pposite which the tripper is placed, and is conveyed into the vessel's old.

The chimney rests upon a pile and concrete foundation, with forty-nine iles at 3 ft. centre, the concrete being 21 ft. 6 ins. square. Up to the evel of the street is carried a solid mass of masonry 20 ft. square at the ottom, 22 ft. 6 ins. high, and 15 ft. square at the ground or street level. The ashlar work is carried up to a height above the street of 19 ft. 3 ins., with a heavy chamfered coping. From this the brickwork starts, with square base of 12 ft., rising to a height of 132 feet with a batter on ach face of 1 in 47½. The walls are 48 ins. in thickness at bottom, with n air space of 12 inches, which is carried up to a height of 100 feet, he wall being reduced alternately 4 inches on either side of this space at very 25 ft. of height, up to the point at which it is vertical, the walls eing there 16 and 20 inches thick. The top is surmounted with an iron ap, weighing over a ton, which is thoroughly bolted down to the brickwork. It was made in eight sections and bolted together in place. Th shaft is 4 ft. square inside measurement, and up to a height of 40 ft above the stonework is lined with 8 inches of firebrick. The walls ar bonded together with iron bands, and iron steps are built into the brickwork in one corner the whole height of the chimney.

In connection with this work, it should be stated that Mr. P. A Peterson, M.C.Soc.C.E., was the chief-engineer, and Mr. S. Howard M.C.Soc.C.E., the engineer in charge.

From the drawings accompanying the paper, Plates I and II hav been prepared.

DISCUSSION.

. The loads permitted to each square inch of foundation are rather reater than is usually considered advisable. The Bismarck Bridge, on lay of a very hard and compact nature, is limited to 39½ lbs. per square nch; the Niagara Cantilever, on massive boulders, with a concrete mono-ithic base, is limited to 41 lbs. to the square inch. The foundations of he Capitol building at Albany are loaded to a much greater extent, nd as they rest on clay, and have shewn no serious settlement, it nay be safely assumed that the Bismarck and other bridges have an un-sually large factor of safety. The pressure on the clay at the foot of the asement walls at the Albany Capitol is in some places as great as 166 bs. to the square inch. Provision has been made for the removal of he dust; this is a very necessary precaution (too often neglected), as here can be no doubt that finely disseminated dust when brought into ontact with a flame, from a candle or lamp, will explode with great iolence. Would not the same result be obtained more cheaply, with owerful exhaust fans for the conveyors, on the principal of pneumatic ransmission, as is now secured by the conveyor belt?

Endless bands for the conveyance of grain were first employed n the Waterloo Dock Corn Warehouses, Liverpool. These ware-ouses line three sides of the dock, and the distance over which the rain can be carried on bands is nearly 1⅓ miles. The superiority of his mode of conveyance was demonstrated by Mr. P. Westmacott, M. Inst. M.E., in an elaborate series of experiments, which shewed that vith an 18-ins. band, 1·02 H.-P. were required to convey 50 tons of grain er hour through a distance of 100 ft., as compared with 25 H.-P., with tubular screw in revolving casing, and 18·38 H.-P. with the common crew in stationary casing. The warehouse 18 ins. bands ("made of 2 lies of stout canvas covered with vulcanized india rubber") are driven y 8 H.-P. hydraulic engines, which receive the pressure from an accu-nulator in the central block. The engines at 25 revolutions per min. ive a band discharge of 60 tons per hour, and in the same time use 120 ub. ft. of water, costing about one-fifth of a penny per cub. ft. At the ame speed a 6 H.-P. engine with a 12 ins. band will convey 25 tons per our, and use 75 cubic ft. of water. In the experiments it was also ound, "that the maximum band speed was 8 ft. per sec. for light oats, ran, flour and similar grain, 9 ft. per sec. for heavy clean grain, and a still higher speed for peas." Corners are easily turned by the band, being raised at any given point by means of a simple piece of mechanism, so tha the grain runs up-hill towards the ridge, leaves the band and, is received into a curved spout, which leads it away in any required direction This method of changing the direction of the moving grain has prove more effective than the air blast or brushes. A great deal of fine dus is thrown off, and is liable to injure the machinery unless protected. Th grain is distributed over the floor by means of a fan, which receives i from a spout leading to its upper surface. A large amount of valuabl information on the subject may be obtained from Mr. Westmacott' paper read before the Institution of Mechanical Engineers, England. I would be of interest and value if Mr. Howard could give data as to th power required to carry the grain in the C.P.Ry. Elevator, and as to th best speed at which it should be carried. The endless band system i often made use of for the conveyance of broken stone, charcoal, and man other kinds of material.

Mr. S. Howard. It is somewhat difficult to estimate the cost of handling grain, as th delivery and discharge of grain is so very uncertain. There may be day when the machinery is running to its full capacity, at other times ver little business may be done, and yet the boilers must be kept going, an the wages of the employees paid. The cost for four weeks amounted t $1130.25, and during that period 238,812 bushels were received and 308,863 delivered into vessels, at a total cost of 1-5th of a cent pe bushel; at other times the cost has been $\frac{1}{8}$ of a cent, and again nearl one cent.

Taking each H.-P. expended at 2 cents per hour, the cost for th steam shovels, (using, say 10 shovels, requiring an expenditure of 1 H.-P.,) in unloading 15,000 bushels, is 15 cents, that is one cent fo every 1000 bushels; the cost for the elevating legs, at say 10 horse-powe for each, is 20 cents, elevating per hour 8790 bushels, that is one cent fo every 440 bushels; there is also the capstan cost, and the cost of cleaning and moving from bin to bin. Thus the total H.P may be taken a for shovels 15 H.P., capstan 7, fans 6, a total, with 90 for legs, of 11 H-P. equivalent to $2.36 for 79,110 bushels, or 335 bushels for on cent. This is a very extraordinary cost, as it is upon the assumption tha everything is working satisfactorily and to its full capacity; even takin it at one half, the cost will be at the rate of 167 bushels for one cent.

The conveying of grain to the vessels is slightly different, and from th following results it is seen that with a small additional horse-power, an an increase in width of belting, the amount carried is considerably increased, and the cost of handling very much reduced. The discharg from the bins is only about 6000 bushels per hour, and it is seldom tha more than two bins are discharging at the same time, so that a 42 inc belt would be the most economical. Taking the cost of handling at two cents per horse-power, a 24-in. belt takes four horse-power and delivers 4000 bushels; or 1 horse-power for every 1000 bushels, costing one cent for every 500 bushels.

A 30 inch belt takes 52 H.-P., and delivers 6000 bushels ; or 1 horse-power for every 1150 bushels, costing 1 cent for every 600 bushels.

A 36 inch belt takes 7 H.-P., and delivers 9000 bushels ; or 1 horse-power for every 1285 bushels, costing one cent for every 643 bushels.

A 42 inch belt takes 94 H.-P., and delivers 13,000 bushels ; or 1 horse-power for every 1380 bushels, costing one cent for every 690 bushels.

A 48 inch belt takes 12·5 H.-P., and delivers 18,000 bushels; or 1 horse power for every 1440 bushels, costing one cent for every 720 bushels.

The power required to work the Archimedean screw, formerly used for pushing along the grain in mills, is so great, and the result so small, that it has been of late years entirely superseded by the flat belt; it would be entirely out of place where the conveying structure had to be removed yearly, the weight being so enormous, and the fixtures in connection therewith requiring such careful adjustment. For instance, a screw to carry the same amount of grain as a 36 inch belt, viz., 9000 bushels per hour, and at the rate of 450 feet per minute, would require a diameter of 24 inches, 12 inches pitch, and should make 300 revolutions per minute, with an expenditure of about 40 horse-power.

The ordinary charges are :—

$1\frac{1}{2}$ ct. per bushel for winter storage.
1 " " summer storage, 15 days.
$\frac{1}{4}$ " extra for every 10 days after.
$\frac{1}{8}$ " turning, and $\frac{1}{2}$ cent cleaning.

Mr. Butler, in his remarks, must have overlooked the fact that the piers rest upon piles. The weight is distributed over nine piles, and as they were mostly over 12 inches in diameter, or say at least 130 square inches, or perhaps more, this would be equivalent to 423 lbs. per square inch of pressure; they were driven to the solid foundation of the river bed, and Rankine allows 1000 pounds per sq. inch for piles driven home, and 400 in ordinary ground, so that there is little fear of the building settling.

28th April, 1887.

JOHN KENNEDY, Vice-President, in the Chair.

The following candidates have been balloted for and duly elected as

MEMBERS.

ROGER ATKINSON.	PHILIP L. FOSTER, B.A.Sc.
FRANCIS ASHLEY HIBBARD.	ARTHUR THOMAS TIMEWELL.

ASSOCIATE MEMBER.

PIERRE ALFRED PERRON.

ASSOCIATES.

JAMES FERGUSON ARMSTRONG.	GEO. M. DAWSON, PH.D., F.R.S.C.

STUDENTS.

NOEL EDGELL BROOKE.	HENRY MARTYN RAMSAY.
JAMES HERRICK McGREGOR.	ONESIME SIMARD.

Paper No. 3.

FOUNDATIONS OF THE ST. LAWRENCE BRIDGE.

BY G. H. MASSY, M.C.Soc.C.E.

In the autumn of 1881 the Atlantic and North Western Railwa Company decided to build a bridge across the St. Lawrence, in th vicinity of Montreal. Accordingly, in October, 1881, surveys were mad at several places. The first line surveyed was at the Lachine rapid crossing Heron Island. The river here proved to be very wide, but in othe respects a tolerably favourable line was obtained. The next surve was made in November at the Nun's Island. This line shewed dee water and a wide crossing, worse in every respect than the line a Heron Island. The third and last survey was made where the bridg now stands. At this point the sounding shewed the existence of an irregular reef about 500 feet wide, extending from the north shore to th main channel with a depth of from 5 to 20 feet of water. The curren here runs at a speed of from 2½ miles to 6 miles per hour at low water and from 4 to 9 miles at high water, the difference between high an low water being about 6 feet.

The soundings were taken from a boat allowed to float down stream over the points where soundings were required. At a given signal from he man at the lead line the exact position of the lead line was fixed by means of two transits on shore. In order to avoid any possibility of confusion or mistakes, each sounding was numbered, and the man in the boat who booked the sounding held up a card with the unit figure of the sounding, so that both transit men and the man in the boat checked the number each time; by this means from 3 to 15 soundings were taken, according to the velocity of the current, each time the boat dropped down stream; the direction and velocity of the current were aken by floats in a somewhat similar manner, but the position of the loat had to be taken at fixed intervals, say half a minute apart.

These soundings when plotted gave full information as to the surface of the river bottom, and from these soundings seven trial lines were laid down and the position of the piers marked. A scow was then moored over the site of the piers, and borings taken with an ordinary steel rod $\frac{1}{2}$ in. diameter furnished with a screw bit.

This rod answered very well, except at places where the depth of the water exceeded 25 feet with a strong current, when it was found necessary to protect the rod by means of a tube 6 ins. diameter, 20 feet long, through which it was passed. The borings shewed bare rock near the north shore, but towards the centre the bottom was covered o a depth of several feet with gravel and hard pan. The rock forming he bottom of the river is mostly Utica shale, interspersed with veins and floors of trap; above this formation the blue limestone appears on he south shore.

This was the amount of information furnished when it was decided o call for tenders. However, nothing further was done in the matter until August of 1885, when one or two other lines were tried, and the Company in the following November let the contract for the masonry, in which it was stipulated that the work should be finished by November 30th, 1886, thus giving 12 months for its completion.

The specification allowed the contractor to use "cofferdams or sink bottomless caissons fitting closely to the rock, into which he can deposit Portland cement concrete to a depth not exceeding $\frac{1}{3}$ of the depth of he foundation from the surface of the water; when the concrete is perfectly set the caisson may be pumped out and the masonry commenced from its surface."

The latter plan was adapted as being a much more expeditious method than that of cofferdams. During the winter of 1885-6 stone was cut for the masonry and broken for concrete, caissons and scows built, and all made ready for spring.

The abutment on the north shore and piers Nos. 1 and 2 were built during March, April and May. On the 12th of May the first caisson was brought down for No. 4 pier. The foundation here was bare rock, so that all required to be done was to get the caisson into place and commence concreting. The caisson was towed out of Lachine harbour by two powerful tugs, both tugs pulling up stream, thus allowing it to drop slowly down with the current. The caisson was built of 12 x 12 in. timber, spiked together by rag bolts, and braced at every 10 ft. with12 x 12-in braces, as shewn on Plate III; the joints were caulked and made water-tight; about five of the upper courses of timber were fastened to those below by long screw bolts, so arranged that by turning the bolts they could be taken out and the upper courses of timber detached after the pier was built, thus removing all timber which would otherwise appear above water.

Three strong posts were built into the front of the caisson to which the anchor cables might be attached, and two similar posts at the stern end to which guy ropes might be fastened, when the caisson had to be twisted round so as to get it at right angles to the bridge centre line. A scow measuring 23 x 70 feet was placed on either side of the caisson, and two timbers stretched from scow to scow crossing the caisson at the bow and stern, these timbers were made fast to the caisson by chains, and the ends jacked up from the decks of the scows so as to lift the caisson several feet out of the water, thus lessening its draught. This was found necessary in order to avoid striking boulders or rocks on its way down.

The caisson carried three anchors weighing 4 tons each, and each scow carried one weighing one ton; the chains attached to the 4 ton anchors were formed of 1¼ in. links, and the steel wire ropes used were 1¼ in. and 1½ in. diameter. The chain for the smaller anchors was made of ¾ in. iron. The total number employed on the contract were twelve 4-ton anchors and twelve 1-ton anchors with 2 miles of chain cable and 2 miles of steel wire rope. When the caisson was about 600 feet above the site of the pier, the three heavy anchors were dropped, and the whole draft of scows and caisson allowed to hang on the first, so as to make certain of its having taken hold in the bottom; this chain was loosened and the second tested in a similar way, and then the third anchor, so that each caisson had always three anchors out, any one of which was capable of holding it, besides the smaller anchors from the scows kept in reserve. The anchors from the caisson were not in one line, but spread a little, so that by loosening one chain and keeping the others tight the caisson could be placed directly over the site of the pier. The caisson was thus lowered down to the bridge line.

Towards the north shore the current ran very oblique to the ridge line, thus necessitating the swinging of the caisson round, in rder to bring it into position; this was often a slow operation, as he moving of the caisson round generally threw its centre north or south f the site of the pier. As however there was an allowance of 5 feet between he inside of the caisson and the masonry of the pier all round, it was onsidered sufficiently accurate if the caisson was placed within 6 inches f its intended position. It required about one day to place each aisson.

The foundation of piers 4 and 5 was bare rock, and therefore when he caisson was placed over the site of the pier it was loaded down with shlar laid along the top timbers.

The next operation was to prevent any current passing between the ottom of the caisson and the rock, by placing sheet piles of 3 inch plank ll round the bow and spiking them to the caisson.

A curtain of canvas fastened round the inside of the caisson, at a listance of a few feet from the bottom, was spread on the rock and oaded with bags of concrete; this was necessary in order to exclude any urrent from washing over the concrete and separating the cement.

When this was finished the concrete was prepared by mixing Port-and cement and sand in the proportion of one to one; to this was dded as much broken stone as would make the whole into a mass of tone, whose interstices were filled with mortar, the whole thoroughly ixed. The stone was broken to pass through a 2½ inch ring. The roportions were about 3 of broken stone, 1 of cement, and 1 of sand. This concrete was lowered into place by means of an iron box holding ½ yards, the box was constructed of iron ¼ inch thick, with a floor inged about 2 ft. 6 ins. from the bottom, and opening at the centre; by urning a lever this floor was allowed to fall, permitting the concrete to lip through, but being still protected from the action of the water by the ides of the box; in this manner, with two gangs by day and two at ight, 80 yards could be placed in 24 hours.

When the concreting was finished the caisson was left for 2 or 3 lays until the concrete had set, when the water was pumped out the oncrete levelled off and the masonry commenced.

Very little pumping was required to keep the caisson dry.

The anchors were never removed until the masonry was above water evel.

In sinking the caissons it was necessary to take into account that ater might get between the concrete and the rock, and thus place the aisson is the same position as a tub when being sunk in the river with ts edge above water and then bailed out, in danger of rising and floating away bodily.

Over the foundations of Nos. 6 and 7 piers there was a considerable deposit of gravel, this was partially removed before the caisson was brought down, by means of a large rake worked from two scows anchored over the foundation. The rake was hauled up stream along the sides of the scows by men, then dropped and pulled down stream by a horse and windlass.

The head of the rake was formed of an iron bar about 2½ inches × 2½ inches, and 5 ft. long, on which steel teeth 1 in. by 2½ in. were fastened, and the whole attached to a long handle. This arrangement removed a quantity of loose stones and gravel; the remainder was taken out when the caisson was in place, by means of a "Hayward excavator."

The next foundation commenced was for No. 8 pier. The surface gravel was raked off and the caisson placed.

The rock here was covered with 4½ feet of hard pan, so tough and hard that the Hayward excavator could make little impression on it. An ordinary clam shell dredge was tried, but without success; recourse was then had to dynamite, and holes were drilled to a depth of 2½ feet at different places and charged; small quantities of hard pan were loosened in this way by each explosion.

Three weeks were occupied at this work with little effect, when a long iron bar was made with a chisel edge of steel at one end and a ring at the other. The bar was about 25 feet long and weighed 1,700 lbs.; this bar was hoisted up vertically some 10 or 15 feet by an ordinary pile driving engine, and allowed to drop with its full weight, and by this means the remainder of the hard pan was loosened and removed by the excavator.

From the experience gained at No. 8, it was decided to procure dredges for the remaining foundations, and, accordingly, dredges No. 5 and 6 were hired from the Harbour Commissioners; these worked in a most satisfactory manner, and notwithstanding the hard, tough character of the material to be excavated, Nos. 9, 10, 11 and 12 caissons were brought down and placed without much difficulty.

Some of these were only partially built at Lachine, the remaining courses of timber being added when the caisson was near the foundation for which it was intended, as the water was shallow just above the site of several of them.

At No. 14 the foundation was covered with 14 feet of hard pan, requiring the constant employment of No. 6 dredge from June 22nd until August 6th.

From the foundation to the surface of the water at this pier was about 33 feet with a current of 4 miles per hour.

Previous to dredging, a guard crib was sunk in front of this foundation 8 feet wide at bow, 26 feet at the stern, and 26 feet long, with its lower end 3 feet above the bow of the caisson (when in place), i.e., just far enough above to clear it, thus forming an eddy in which the dredge could work with little difficulty from the current. This crib was placed in position in a similar manner to the caissons, with the exception that one of its anchor chains was secured to an iron bolt on shore.

This caisson was so deep and required so much loading that rails were used as well as stone to sink it. Some of the rails were placed along the outside near the bottom, and the remainder rested on the cross timbers inside.

At this and several of the other foundations the electric light was used at night and also in the daytime under water, to assist the divers in clearing the foundations and placing the bags of concrete round the edges of the caisson.

No. 13 pier was always looked upon as the most difficult. It stands in 28 feet of water and at the swiftest part of the current, and on it is to rest the cantilever spans of 408 feet each.

It was of the greatest importance that the foundation should be first class in every way, so as to avoid any possibility of settlement when the weight of superstructure came on it. The pier is much larger than any of the others, and the placing of the caisson required much care.

A guard crib was also sunk in front of this, similar to that used at No. 14, but a little larger, being 30 feet wide at the stern.

This crib was brought down when about half built in a manner similar to that used for bringing down the caissons, being placed between two scows and supported by cross timbers. No. 13 pier stands directly in the centre of the main channel, the current here being so strong as to sweep off all loose material, leaving the bottom bare rock, and thus affording little chance for anchorage.

Accordingly a "dead man" was placed on a projecting point on the south shore, about 1,700 feet above No. 13 pier. This "dead man" consisted of a 16 in. pine log, let into a trench excavated purposely in the limestone; both ends of the log were well loaded down with stones, and round the centre the 1½ wire rope was lapped and secured, the other end of this rope was rolled in a coil on the deck of a scow anchored about 400 feet above the site of No. 13 pier. The scows attached to the crib carried three four-ton anchors, and two one-ton anchors, these large anchors were dropped as the crib floated down, and as it passed the scow the end of the 1½ wire rope was taken on board and secured to the "snubbing posts." Thus, the crib had three 4-ton anchors, and the wire rope; two of the anchor lines passed through the front timbers of the crib a few feet from the bottom, thence up to above water level, then over another cross timber, and round the snubbing posts, and the other two lines passed directly above water over the front timbers and around the posts.

As the line from the "dead man" passed diagonally across the steamboat channel it was necessary to load it down so as to avoid any risk of accidents to passing vessels; for this purpose 3 heavy pile hammers were used, tied together and dropped over the line at the centre of the channel. The breaking strain of the 1½ inch rope would be about 30 tons.

The crib was thus lowered, so that her stern remained about 10 feet above the position of the bow of the caisson when in place.

The crib was completed here and sunk, and when the caisson was floated down and dropped behind the crib, it required to be forced *down stream* to get it into place, so strong was the eddy formed by the protection crib.

The bottom was bare rock perfectly clear, so that when the caisson was sunk concreting commenced at once.

It was in connection with this pier that the greatest loss of plant was sustained by the contractors. No. 5 dredge was brought over to try the nature of the bottom before the protection crib was sunk. A scow was moored alongside and secured to the dredge; the action of the current on this scow swung the dredge round, and after swinging for a time she broke away from her anchor and dropped swiftly down stream, till meeting with a more shallow part of the river, the "spuds" came in contact with the bottom, and the dredge went over on her side, where she now remains, the men on board having a narrow escape from drowning. As soon as the piers were finished the caissons were well protected from the action of the current by rip rap to within a few feet of low water level.

Some curiosity being felt as to the power required to hold No. 13 caisson in the heavy current, some experiments were made with two models one 4 times the section of the other. The models were held in the current, and the strain on the line holding them measured. By observing the strains in currents of different speeds, it was found that the force varied as the cross section of the caisson, and as the square of the velocity of the current from which the calculated holding strain on the large caisson in the main channel was estimated to be from 60 to 100 tons, being subject to serious fluctuations due to shearing from side to side.

Before sinking No. 12 caisson, an anchor crib was placed about 1,500 feet above the site of the pier, to which one of the chains was attached. The crib was 12 feet wide by 25 feet long, and filled with stone.

In depositing the concrete two different sized boxes were used, one olding $2\frac{1}{2}$ yards, the other 1 yard. The smaller box was found conenient for filling corners and places where the large one could not ass; but the large box was chiefly employed, as the concrete deosited by it appeared superior to that deposited by the smaller one.

An experiment was made by mixing sand, Portland cement and roken stone, in the proportion used for concrete. Some of this was ixed with water and placed in a sack, the remainder was filled dry nto a similar sack, and the whole submerged into the river. After wenty-four hours the sacks were examined, when it was found that he concrete submerged in a dry state was quite unset, while the other ad commenced to harden. The sacks were replaced in the water and ft for several days, and, when again examined, the dry concrete was ound in the same unset state, while the other was quite hard. Both acks were left in the air for a month; the wet concrete continued to arden, the other became quite dry and loose. This experiment was epeated, but with the same curious result.

On pumping caisson No. 14 the concrete was found not to have set, nd to be nearly of the temperature of newly slacked lime, while an nusually large amount of laitance was deposited at the lower end, in a pace left for the pump. The caisson was allowed to fill again, and he temperature of the water inside observed daily, when it was found o be several degrees higher than that of the water in the river. At he end of six days the temperature had cooled down, when the caisson as again pumped, and the concrete found to have set.

No swelling or cracking of the concrete, which always accompanies he action of quicklime, was observable.

The quantity of concrete in the foundation was 890 yards, made rom several different, but all good brands of Portland cement.

Although there was a slight rise of temperature in the concrete of ome of the other foundations, No. 14 was the only one which caused ny inconvenience.

The Chief Engineer of the above work was Mr. P. A. Peterson, I.C.Soc.C.E., Mr. Massy, M.C.Soc.C.E., being the engineer in harge.

From the drawings accompanying the paper, Plate III has been repared.

DISCUSSION.

Mr. C. E. Dodwell. Mr. Dodwell said that the Society was indebted to the author for a capital paper on a most interesting and important work. It was a work in which he took a special interest, having assisted the author in the winter of 1881 and 1882 with the surveys, soundings and borings referred to in the paper.

The heating of the concrete referred to by the author had been pretty well discussed, but before leaving it he would just like to ask the author what degree of temperature had been reached—he understood him to say he had used thermometers—and how long this temperature, whatever it was, had been observed to last. While building the bridges at Ste. Anne and Vaudreuil, he had heard of this instance of the heating of the concrete at Lachine, and he had, therefore, kept a good look out for similar action. Nothing of the kind had, however, been observed. The cement used at the Ste. Anne and Vaudreuil bridges had been almost exclusively "Johnson's," the same, he believed, as had been used at Lachine. Something over 7,000 barrels had been employed, and the only peculiarity he had noticed in connection with it was a somewhat heavy efflorescence from the joints of masonry laid in the winter. He had frequently before observed an efflorescence from masonry and brickwork, but rarely if ever as excessive as in this case, and the deposit was generally an insoluble salt of lime, such as the carbonate. Here, however, the deposit was highly soluble, and, from its taste, he believed it was chiefly composed of Sulphate of Soda. He had collected a quantity of it, and was having an analysis made. It did not seem to have any prejudicial effect on the cement, for the joints were nearly as hard as the stone.

There were one or two other points in the paper upon which he would like a little information.

He noticed in the diagram exhibited that the stern of the caisson was framed to a sharper angle than the bow. It appeared to be about 60°, while the bow was 90°. Doubtless, in a current such as the work in question had to contend with, the sharpening of the stern of the caisson served to lessen very materially the shearing and swinging from side to side of the caisson which the author had spoken of, and it would be interesting to know exactly what angle was the best suited for this purpose. Perhaps the author could state how his caissons came to be framed to the angles shewn on the diagram; why, for instance, the stern angle was not 10° more or 10° less than that actually adopted.

Several of the piers, standing in the deepest water and in the strongest current, were built directly on the bare rock. He would like to ask the author whether in these cases any precautions had been taken to roughen or step the rock bottom so as to give the concrete a better hold, and prevent the pier with its caisson and concrete base from sliding bodily down stream. If this had not been done, it became a vitally important question whether the *vis inertia* of the pier, aided by friction, was sufficient to withstand the pressure of from 60 to 100 tons, which the author had stated as the probable effect of the current on the caisson.

With regard to the large harbour dredge that had been sunk and lost, he happened to be on the work the day the accident occurred. He was in company with the chief contractor on pier No. 7 or 8, when they heard the dredge whistle in a very alarming manner. They at once knew that something was wrong, so jumping into their boat they made all haste in the direction of pier No. 13, where the dredge was working. Before they had proceeded far, it became evident that the dredge had broken her moorings, and by the time they had got within a couple of hundred yards of her, the "spuds" had struck the bottom and she had heeled over and sunk. It was quite an exciting five minutes. He would merely like to ask the author whether any steps had been taken to raise or remove the dredge, and, if so, with what success. Lying as it did almost in mid-channel, it was a serious source of danger to steamers running the rapids, and one the Harbour Commissioners would hardly approve of leaving.

Mr. MacPherson remarked that, in reference to the rule for force of resistance to currents, deduced by Mr. Massy from experiment, and the theoretical rule given by Prof. Bovey, it appeared evident any such rule must be materially modified, not only by the size, but by the shape of the resisting body, and he wished to know if, in the opinion of Prof. Bovey, such was not the case; if so, to what extent was this force modified by the caissons of the St. Lawrence bridge being made with an angle of 90° at the bows instead of being rectangular in plan.

In order to measure the resistance R to the motion of a body, wholly or partially immersed in a current, it is usual to employ the empirical formula,

$$R = C.A.\ w.\frac{v^2}{2g}$$

A being the transverse sectional area of the immersed portion of th body, w the specific weight of the fluid, v the *relative* velocity of th current, and C a coefficient depending principally upon the form of th immersed body. When a body is moving in a current of very gre width, the following approximate value may be assumed for C:—$\frac{1}{1}$ for a prism with square ends having a length from three to five tim the least transverse dimension; 1, for the same prism with a taperin stern; $\frac{1}{2}$, for the same prism with a tapering stern and a triangular a semi-circular prow; $\frac{1}{3}$, for the same prism with a tapering stern an a prow with a plane face at 30° to the horizontal; $\frac{1}{6}$, for the faste ships.

The valves of C are further modified when the width of the curre is small, and also by waves.

The effervescing and the slow setting of the concrete, alluded to b Mr. Massy, were doubtless due to the presence of an excessive amou unslaked lime, and must be attributed to the bad quality of some of the brands of cement which were employed in the mixture.

12th May, 1887.

JOHN KENNEDY, Vice-President, in the Chair.

The following candidates have been balloted for and duly elected as

MEMBERS.

GEORGE ARTHUR BAYNE.	JOHN PAGE.
WILLIAM EDWARD GOWER.	RICHARD BIRDSALL ROGERS, B.A.SC.
FRANCIS J. LYNCH.	FRANK LINN SOMERVILLE.
ERNEST MARCEAU.	TOUSSAINT TRUDEAU.

ASSOCIATE MEMBERS.

PROFESSOR JOSEPH HAYNES.
CHARLES HODGSON OSTLER.

ASSOCIATES.

WILFRID THEODORE SKAIFE, B.A. SC.
WALLACE CUTHBERT TROTTER.

STUDENTS.

JOHN HOLDEN ANTLIFF.
JOSEPH NARCISSE ALF. HAMEL.
CONWAY EDWARD CARTWRIGHT.

THE SUPERSTRUCTURE FOR THE ST. LAWRENCE BRIDGE.

By J. W. SCHAUB, M.A.SOC. C.E.

The St. Lawrence Bridge was first outlined, about five years ago, by Mr. Peterson of the Atlantic and Northwest Railway Co., but it was not until November of 1885 that the contract for the Superstructure was awarded to the Dominion Bridge Co. of Montreal, with Mr. C. Shaler Smith as consulting engineer, and Mr. P. Alex. Peterson as chief engineer for the Railway Company. The designer of the bridge is the late Mr. C. Shaler Smith; Mr. Frank D. Moore, as chief assistant engineer, having full charge of the calculations and the details.

In adopting the lengths for the different spans at the selected crossing of the Saint Lawrence River, there was no precedent to guide the designer, excepting the lengths which had been adopted for the Victoria Bridge, which are as follows:—24 spans each 240 ft. centre to centre of piers, with one channel span of 350 ft. centre to centre of piers. In the St. Lawrence Bridge we have eight spans of 240 ft. centre to centre of piers, two spans of 269 ft. centre to centre of piers, and two channel spans of 408 ft. centre to centre of piers, (See Plate IV).

The St. Lawrence Bridge begins properly at the first crossing of the Grand Trunk Railway, which is by an 80 ft. through girder. The next crossing is the Canal, which is a swing bridge 240 ft. long. The general design of this swing bridge is of the triangular pattern, known in Mr. Smith's office as the "Menomonee" type. This swing has a rim-bearing table, turning on 34 wheels which are placed on a circular track, and operated by hand power or steam power from the centre. There are two classes of draw spans, rim-bearing and centre-bearing, the centre-bearing being used for spans of short lengths up to 150 feet; for spans of longer lengths, it is customary to use the rim-bearing, or the rim-bearing and the centre-bearing combined, it being easier to operate the rim-bearing swing for longer lengths. The first span of this pattern (the triangular) was designed by Mr. G. H. Pegram, M.A.S.C.E., formerly assistant to C. Shaler Smith, for the Chicago, Milwaukee and St. Paul Ry. The advantages in this form of swing are in having low inclined chords at the ends, which aid in deflecting a possible derailed car which might strike the bridge, and which also reduce the area exposed to wind pressure at the ends of the arms, making it easier to handle during high winds. The supposed advantage in avoiding all counter strains in this form of bridge, which Mr. Pegram had at first supposed to be the case, is not true. One particular feature in this span are the rocker links at the centre, which tend to equalize the pressure on the turntable, making the strains on the centre posts at all times alike in any one pair. (See Plate IV). The ends of the arms, when the draw span is closed, rest on the crowns of inclined beds, which are set at a proper elevation to give the reactions necessary for a beam continuous over three level supports.

The heights at the ends are determined by calculation, and ample margin is made for any discrepancies in these heights due to unequal expansions from temperature, lack of uniformity in the elasticity of the material, or any imperfections in the workmanship.

After crossing the canal, we come to the river spans proper, which consist, first, of three 80 ft. deck plate girders, then the eight 240 ft. deck spans.

It might be stated in regard to the plate girders used in the St. Lawrence Bridge, that they are all provided with rockers at the end supports, so as to allow any vertical movement in the girders themselves due to deflection from passing loads, or to neutralize any imperfections in the workmanship which would tend to bring any undue pressure on the bed plates or expansion rollers.

This has been Mr. Smith's late practice for all girders above 50 feet, and was first used for the Denver and Rio Grande Railway in 1884.

The general design of the deck spans is the double intersection Pratt Truss.

The two systems are entirely independent of each other throughout (see Plate IV). Where the diagonals cross the vertical posts, there s a pin running through the post, making the ties in two lengths. It s a matter of regret that this practice has been used so indiscriminately by the Engineers in the States, without any regard to its pernicious effects. This has been the case, for example, in such large structures as the Plattsmouth bridge, in which there are posts 50 ft. long on centres, divided into half lengths by the ties crossing at their middle, without any provision for the effects of distortion due to strain in the members; he effect of a load coming on a structure framed in this manner can be easily shown (see Plate IV). Supposing the trusses to be cambered when there is no strain in any member, the intersection of the tie is at some point below the centre of the post. Now, when the load comes on the span, the chords tend to become horizontal, the posts tend to become vertical, bringing the intersection of the ties with the posts more and more towards the centre of the post, until finally, when the entire camber is taken out of the truss, the intersection must necessarily be at the centre of the post; the amount of this movement depends on the length of the panels and the depth of the truss. In the 240 feet spans of the St. Lawrence Bridge, this movement amounts to about ¼-in. and has been provided for by making the holes in the posts 1-in. larger than the pin, thus allowing ample movement for the pin when the load comes on the bridge. This movement can be noticed in a structure at any time where the pin is free to move, as in the St. Lawrence Bridge. Where the pin is not free to move the distortions must necessarily take place in the members themselves; and, moreover, this practice is questionable where it has been done with a view to figure the posts for half their total length, and consider them as fixed ended where they are held by the diagonals at the centre.

The next portion of the bridge to be considered are the two 269 ft. spans and two 408 ft. spans, forming four continuous spans over five supports (see Plate IV). There were two designs proposed besides the one that was finally adopted (see Plate IV). The design as adopted was known in Mr. Smith's office as the "Flying Cantilever," and was first proposed for the Storm King Bridge over the Hudson River, in State of New York. As used in the St. Lawrence Bridge it is, properly speaking, no cantilever bridge, as the spans are continuous. The cantilever principle is used here for erecting the bridge only, which is built out from the piers on each side, the ends being joined at the centre when the final coupling is made and the spans become continuous over five supports. The advantages of the cantilever principle are only in saving in the erection, there being no saving in the weight, as there is merely a

different distribution of the material from what there would be in ord
nary disconnected spans. In a continuous girder there is necessarily
saving in the weight over the piers, as was the case in the St. Lawren
Bridge, but the saving in the mode of the erection is the principal ite
to be considered here. The advantage of using two centre piers instea
of one would have been a considerable saving in the cost of erection, bu
not sufficient to counterbalance the increased cost of the extra masonr
this was the principal reason why one centre pier was only used instea
of two, as shown in Plate IV.

In speaking of cantilever bridges, it might be here stated that t
first cantilever bridge built in America was the Kentucky River Bridg
built by Mr. C. S. Smith in 1876. Mr. Smith also built the Minnehal
cantilever in 1881, long before the Niagara cantilever was ever thoug
of. The Kentucky River Bridge is a wonderful structure, from t
fact that it is really the first continuous pin connected girder that w
ever built in America, and is remarkable also from the fact that inste
of being continuous over four supports (Plate IV.) it had i
points of contra-flexure fixed by cutting the chords after the brid
was erected. In a letter of Mr. Smith's, written two years before t
bridge was built, he says: "I feel so confident of my calculations of t
"continuous girder that I now propose to cut the chords at their poin
"of contra-flexure, thus fixing these points beyond a question of doubt.
This statement was the forerunner of the Kentucky River Bridge,
which the points of contra-flexure were fixed at*. (See Plate IV
These points of contra-flexure could have been fixed in the river arn
instead of the shore arms, and it is a curious fact that they should n
have been fixed in the river arms, as was subsequently done by M
Smith in the Minnehaha cantilever, where the point of contra-flexure
fixed in the centre of the river span, there being two shores arms ar
two river arms without any mid span hung from the ends of the riv
arms, as in the Niagara and St. John cantilever bridges.

In regard to the Kentucky River Bridge, the question might
asked:—How is the expansion of the river span—that is, that portion
the bridge between the towers—provided for, inasmuch as the truss
are rigidly fixed to the towers? The towers must necessarily defle
longitudinally when expansions take place, and here the deflection in t
towers from temperature, and also from the effect of a train of ca
skidding on the rails, with brakes set, has been provided for in propo
tioning the sectional areas of the material in the towers. When t
bridge was tested, a train of freight cars, moving at forty miles p
hour, was brought to a dead stop on the bridge. Of course it w
anticipated that a movement would be noticed in the towers, in t

lirection of the moving train; and provision was made for measuring he amount of this movement. However, the friction of the wheels kidding the whole train along the bridge had no apparent effect on the nertia of the large mass of the material in the bridge itself, and the only novement that was noticed was when the train first came on the ridge, when the first tower deflected towards the train coming on implyowing to the deflection of the shore spans; and as soon as the ntire bridge was covered the towers resumed their normal positions.

In any beam continuous over any number of supports, when any lexure takes place $\frac{1}{R} = \frac{M}{EI}$ in which,

M, is the bending moment at any point in the beam.

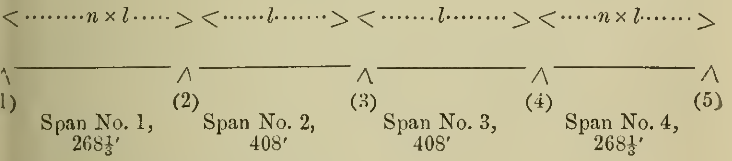
R, is the radius of curvature of the beam at that point.

E, is the modulus Elasticity of the material.

I, is the moment of inertia of the cross-section of the beam at that oint.

By assuming all the supports to be level; and assuming " E " and " I " o be constant, the Theorem of Three Moments may be obtained, and given in all text books on Applied Mechanics. However, it was not ntil September, 1875, that Professor Mansfield Merriman gave, in the ondon Philosophical Magazine, the formulæ for a beam continuous ver any number of level supports, which are at all practicable. These rmulæ are as follows:

Formulæ for obtaining pier moments and reactions, as applied to the ur continuous spans in the St. Lawrence Bridge :—



"m" is the number of any pier.

"r" is the number of any loaded span.

M is any pier moment.

s is the total number of spans = 4.

The Pier Moment when m < r + 1. is given by

$$M_m = \left(\frac{C_m}{l}\right) \times \frac{A\, c_{s-r+2} + A_1\, c_{s-r+1}}{C_{s-1} + 2\,(n+1)\, C_s}.$$

When $m > r$,

$$M_m = \left(\frac{c_{s-m+2}}{l}\right) \times \frac{A\, c_r + A_1\, c_{r+1}}{c_{s-1} + 2\,(n+1)\, c_s},$$

in which
$$\left.\begin{aligned} A &= P\, l^2_r \,\{2\, k - 3\, k^2 + k^3\} \\ A_1 &= P\, l^2_r \,\{k - k^3\} \end{aligned}\right] ; \qquad k = \frac{a}{l_r}.$$

P denoting the load in any span.

l_r denoting the length of that span.

a = distance from nearest left hand support to the load "P," which necessarily a concentrated load; c is a number, and in present case,

$$c_1 = 0 : c_2 = 1 : c_3 = -\,(2 + 2\, n) = -\,3{\cdot}3154.$$
$$c_4 = 4 + 3 + \{n \times (4 + 4)\} = +\,12{\cdot}2616.$$

SHEARING FORCES.

$$S_r \text{ (in loaded span)} = \frac{M_r - M_{r+1}}{l_r} + q$$

$$S_{r+1} \text{ (in loaded span)} = \frac{M_{r+1} - M_r}{l_r} + q^1.$$

$$S_m \text{ (in unloaded spans)} = \frac{M_m - M_{m+1}}{l_m}.$$

$$S_{m+1} \text{ (in unloaded spans)} = \frac{M_m - M_{m-1}}{l_{m-1}}.$$

in which $q = P\,(1 - k)$; $q_1 = P \times k$.

S_r denotes the shearing force immediately to the right of the neare left hand support, and S_{r+1} denotes the shearing force immediately the left of the nearest right hand support of the loaded span.

S_m and S_{m+1} apply to the unloaded spans in the same manner.

The above formulæ are given by Dubois in the "Strains in Fram Structures," page 135, but unfortunately the signs + and − shou be reversed.

The principles of the design for the four continuous spans, up which the calculations were based, are the strains from dead weig which are calculated as a cantilever each way from "W" (see Pl IV). After the dead weight is swung complete, proper adju ments are made by means of adjustable ties each way from "W," a adjustable beds at the ends of the balancing spans at "A"; the secti "XY" of top chord is rivetted in place when the four spans act as co tinuous as far as live load is concerned. The calculations for live lo strains were then made in accordance with the formulæ before given a girder continuous over level supports, and the two were combined.

The objections to any continuous girder are: 1st—the modulus elasticity "E" is not constant; 2nd—the moment of inertia "I" is constant; 3rd—the supports are not necessarily level. These objecti will be discussed in order.

1st.—The modulus of elasticity, as is well known, has wide marg of variation in the same material, but by rigid inspection of the material at the mill this variation may be reduced to a minimum. Mr. Bouscaren gives the margin for variation of the modulus of elasticity of iron in general from 23,000,000 to 28 000,000. For mild steel, which is a far more homogeneous metal than iron, this margin may be very much reduced. It is to be regretted than no experiments, of sufficient extent, have been made with a view to determine the margin for variation of the modulus of elasticity in steel. Of course slight variations in the percentage of carbon in steel produces wide margins in its ductility, but a rigid inspection at the mill can guard against this. In the St. Lawrence Bridge great care was taken in securing a mild uniform steel with an ultimate strength of about 60,000 lbs. and a ductility of 18 per cent. in 12 diameters. The tests subsequently made on some of the full-sized members at Pittsburg, Penn., shewed the material to be the same as when tested in small specimens. The material was found to be all that could be desired, and the Steel Company of Scotland deserve great praise in furnishing a uniform steel, a material not easily obtainable. Their mode of manufacture is the Siemens Open Hearth process.

2nd.—The moments of inertia in the formulæ are assumed constant, and give results which are entirely on the safe side, the stresses being greater than they actually would be, especially over the piers.

3rd.—The supports which may be assumed to be out of level can be at any time adjusted by means of the adjustable beds at the ends of the balancing spans at A (see Plate IV), and any inaccuracy in the distribution of dead weight can be at any time noticed in the variation of the strains in the ties at the centre of the channel spans at "W".

The three objections to the continuous girder are very serious, and would have undoubtedly been sufficiently strong to have prevented the use of a continuous girder for these spans, had it not been for the conditions under which this design was made. A consideration of these will at once shew that the problem for closing the two channel spans was certainly solved in the most scientific manner, when it is borne in mind that the positions of the piers were all fixed, and it was considered unadvisable to use false-work in raising the two channel spans.

The trusses for the continuous girders, it will be noticed, are of the double intersection type, as in the eight 240 feet deck spans. A question might be raised as to the possibility of making correct calculations of the strains in the curved portions of the channel spans, inasmuch as the two systems here combine their strains one into the other. It would be impossible to do so if the calculations were made for each system separately, but here the calculations for the two systems were carried through together, and the work was very much simplified by using the graphical methods entirely, for calculating the strains in the continuous girders for the St. Lawrence Bridge. As to the methods used in the calculations, the author wishes to say that Mr. Moore, of Saint Louis, has recently prepared a lithograph, which shews all the essentials necessary to understand the methods used in a very concise form, consequently here full details as regards the calculations will be omitted.

The unit stresses used in the details are essentially as follows:

Steel @ 12,000 lbs. per square inch for tension.
Iron @ 8,000 " " " " " "

The only tension members that are iron are counter-rods and the wind bracing. For the wind bracing a higher unit stress was used. The compression members were all figured by the "Rankine-Bouscaren" formulæ, which are certainly the best formulæ in use, as they give results which agree more nearly with the results obtained from actual tests than any other formulæ. As used in the St. Lawrence Bridge the formulæ for steel are:—

$$P = \frac{10000}{1 + \frac{l^2}{36000 \times r^2}} \quad \text{for fixed ends.}$$

$$P = \frac{10000}{1 + \frac{l^2}{24000 \times r^2}} \quad \text{for one fixed end and one pin end.}$$

$$P = \frac{10000}{1 + \frac{l^2}{18000 \times r^2}} \quad \text{for two pin ends.}$$

These formulæ are so well known that no explanation is necessary The 10000 lbs. for steel in the numerator is substituted for 8000 lbs. for iron, as given by Mr. Bouscaren in his report to the Board of Trustees of the Cincinnati Southern Ry. As the matter of guard rails in railway bridges has now become so very important, it would perhaps be well to say that when the St. Lawrence Bridge is completed, a train of cars could be run off the track for the entire length of the bridge, without the passengers being aware of it. The ties are spaced with 4 inch openings, and the wheels are guarded by two heavy guard rails on each side of the track. The only accident that could possibly happen to a train of cars on this bridge is, that they might be blown bodily off the track, provided a western cyclone should happen to visit this section of the country, which is not at all probable.

DISCUSSION.

Mr. Schaub's very interesting description cannot fail to be received with pleasure by the members of the Society. It is to be hoped that the description given is but the prelude to a more elaborate monograph, giving in full details all the particulars relating to the design of the bridge, similar to the admirable papers prepared by Mr. Geo. S. Morrison on the Plattsmouth and Bismarck bridges, and by Mr. Schneider on the Niagara cantilever.

The novel and interesting features of this bridge are, of course, the continuous girder of such great length resting on five supports, and the pleasing and ingenious method of passing from a through into a deck bridge. In the absence of the plates it is a little difficult to follow the description clearly. It seems that Mr. Schaub has drawn attention to an important defect in the construction of double intersection Pratt Trusses, and one which Mr. Butler had never seen alluded to before. In all such bridges, each system is supposed to act independently, yet it is perfectly obvious that where the long diagonal is coupled to the post of the other system ("When the pin shall fit its hole within the $\frac{1}{15}$th of an inch"), unless the workmanship is mathematically correct, the whole or a part of the load may be transferred to the post of the other system, or else so pull the post out of its place that the other half of the diagonal may do its work. The function of the pin at the centre of the post should be merely to couple the two halves of the diagonal, and to hold them in place, thus preventing the excessive vibration that would naturally occur in such long slight members. In view of the fact that rails 60 and 90 feet long have been rolled, would it not be better to have these long diagonals rolled in one piece, and hold them against the side of the posts by some simple device, thus obviating the necessity of pin and hole, with its reduction of section and expensive reinforcing of all long posts.

Of course, it may be said that the pin also seems to shorten the post, but when provision has been made for the effects of the distortion, due to the cause mentioned by Mr. Schaub, it is difficult to see how it could be so considered. His point therefore seems well taken in questioning the practice of "figuring the posts for half their total length, and consider them as fixed ended, when they are held by the diagonals at the centre."

Owing to the necessary alternating stresses, to which many of the members in a continuous girder are subjected, it would seem that this was a case peculiarly well adapted for the use of Laundhardt's and Weyrauch's formulæ.

The designers of the St. Lawrence bridge, by their adoption of mild steel throughout, have disarmed criticism, and have created a valuable precedent on this Continent.

The steel used in the Bismarck bridge for compression members had an ultimate strength 80,000 to 90,000 pounds per sq. inch, with an elastic limit of from 49,600 to 65,000 lbs. per sq. inch, with an elongation of from 12.75 to 21.25 per cent. in eight inches.

The steel used in compression members of the Niagara cantilever ranged from 79,300 to 89,980 to the sq. inch for ultimate strength, with an elastic limit of from 49,450 to 65,780 pounds to the sq. inch, with an elongation of 18.25 to 22.75 per cent, in eight inches, and a reduction of area of 41.2 to 37.7 per cent. Such high grade steel was very difficult to get, and consequently cost very much more than a milder type would have done.

The recent experiments in England, on the effect of cold on steel axles, also go to show the disadvantage of the higher grades of steel where subjected to extremes of temperature.

It would be interesting and valuable to compare the weight of channel span with the 400 ft. span of the Bismarck Bridge, noticing also the deflection under a similar test load to that adopted in the testing of that Bridge.

Ir. G. Bousca-ren. Mr. Bouscaren saw the designs for this bridge at the time they were being prepared in the office of his late friend Shaler Smith.

Whatever may be said as to the economy of the general plan, Mr. Bouscaren thinks that it solves the local difficulties which had to be contended with, in a very elegant manner, and is well worthy of the name of the designer.

He was very glad to see the tribute paid to Shaler Smith, as one of the earliest promoters of the use of cantilivers in bridge construction in the United States.

The idea of fixing the points of contra-flexure in continuous girders was first suggested by Professor Cullman in the first edition of his graphical statics; it was subsequently applied by Gerber and other European engineers, as early as 1866 and 1867. Its first advocate in the United States, he believed, was Louis Nickerson, of St. Louis, known by his ingenious experiments on glass beams; but to Shaler Smith belongs the claim of priority in its application, as made in the Kentucky River Bridge in 1876. Speaking of this structure

Mr. Schaub says: "These points of contra-flexure could have been "fixed in the river span instead of the shore arms, and it is a curious "fact that they should not have been fixed in the river span." Having co-operated with Shaler Smith in the designing of this bridge as "principle Engineer of construction" on the Cincinnati Southern Railway, he would ask to be permitted to explain why the hinges were placed in the shore spans.

One of the principle objects sought in fixing the points of contra-flexure is to avoid the reversions of strain, which take place in the different members of the continuous truss with the displacement of the load. In a continuous girder of three equal spans, it is quite clear that this object is better served by hinges in the shore spans, whereby the directions of strains are fixed in *two spans*, and reversible *in one* only, whereas the contrary would be the case if the hinges were located on the middle span.

It is only when the shore arms are much shorter than the middle span, and the initial strains in the short spans from the dead weight of the middle span preclude reversion to a very large extent, that the hinges in the middle span become advisable in point of economy. Such is the case in Mr. Schneider's bridge over the Niagara.

The theorem of the three moments was discovered by M. Bertot in 1855. In applying it to a continuous girder of any number of spans, it takes the form of a number of simultaneous equations, and the general solution of these is due to Clapeyron. The theorem in its original form assumes the load to be uniformly distributed over the extent of each span. This is satisfactory for rivetted structures to which it was first applied, but is not convenient in the case of pin trusses in definite panels, where the loading is at isolated points, and usually varies from one panel to another in the course of the same span. A modified form of the equation makes it applicable to the case of isolated loads. It has always seemed to Mr. Dawson safer to work directly from the general equation, rather than to use formulae derived from it.

It is very desirable that a bridge in which the chords are cut should not be called "continuous," as the cutting of the chords is the essential difference between a continuous girder and a cantilever. The advantages of doing so are, that reversed strains, for which pin trusses are less adapted than rivetted work, are almost entirely avoided, that any slight inequality in the levels of the piers, due to inaccuracy in setting out or to settlement afterwards, does not effect the stresses as originally calculated, and also that the expansion for temperature takes place under better conditions.

The cantilever principle is eminently applicable to pin trusses, as they have hinged joints already supplied by the pin connections, and there is greater difficulty in making them act satisfactorily under expansion for temperature when they are continuous than in the case of rivetted girders.

The method of allowing a continuous girder to act as a cantilever during erection is a favourite one in France, and presents undoubted advantages. It is there used in erecting high viaducts, which are pushed forward from one bank as built, the forward end acting as a cantilever for the whole length of a span, until the next pier is reached.

With regard to the effect of a variation in the moment of inertia of a girder, a gradual change in the depth appears to have no appreciable effect in modifying the stresses. In taking out the stresses in a draw span of 396 feet total length for the Sault Ste. Marie Bridge, in which the top chord has an inclination of nearly 1 in 12, the moments at the centre and the reactions were calculated directly from the theorem in question with the assumption it involves, and yet in working out the stresses in the individual members by the graphical method no appreciable error could be detected in the closing of the figure.

It seems safe to say in such a case that the stresses as thus calculated are within one per cent. of the absolute truth, as far as the questions of theory involved are concerned. In the case of a swing of the triangular design, such as that erected over the Lachine Canal, the want of coincidence might well be greater, owing to the more rapid variation in the depth of the truss. The problem of the distribution of the weight of the swing, when open, around the rim of the turn-table, is one of much interest, and would deserve separate discussion. In the Sault Ste. Marie swing, designed by the Detroit Bridge and Iron works, this has been attained by bringing the weight down upon radial beams in the drum which, so far as this particular object is concerned, is an excellent method.

Mr. Dawson then expressed the wish that further explanation should be given with regard to the expansion of the Bridge from temperature; and also the effect in modifying the strains of the adjustment as between the dead and live loads.

Mr. K. Blackwell. The works with which Mr. Schaub is connected have established a most elaborate system of annealing, and it would be interesting to learn the general result as regards the percentage of elongation in the mild steel used in the St. Lawrence Bridge.

Mr. R. F. Tate. What is considered to be the maximum inch-stress, to which the metal is subjected in the arms of the Bridge from the centre piers during erection, and before any connection is made with the adjacent arms? What the maximum unbalanced load that the arms from the centre pier may safely bear during erection, and before any connection with adjacent arms?

Mr. Peterson stated that he had listened with considerable interest to Mr. Schaub's paper, which he read at the last meeting, and thought that he deserved the thanks of the Society for the trouble he had taken in this matter, as it requires a very great effort in these pushing days for a busy man to sit down and write a paper.

He had always intended to prepare a paper himself, covering the entire question of the bridge, and hoped to have had Mr. C. Shaler Smith's assistance upon the continuous portion of the superstructure, the general design and detail of which are due to him. He regretted exceedingly that Mr. Smith had not been spared to see it finished.

At present, he proposed to give a sketch of what was done before the date at which Mr. Schaub takes up the matter, and to state some facts regarding the early history of the work which Mr. Schaub had not been in a position to become acquainted with.

On receiving the appointment of Chief Engineer of the bridge in September, 1881, a report on the bridge was submitted to Mr. Peterson, together with a rough chart made by the late Col. Roberts, past president of the American Society of Civil Engineers, who had been employed by the late Sir Hugh Allan, the then president of the Northern Colonization Railway, and who was about to undertake the construction of the Canadian Pacific Railway.

Col. Roberts reported very fully, and made estimates upon a great number of crossings, but gave a preference to the crossing at Ile Heron; and for this reason, as well as from the fact that the company had purchased a considerable tract of land near what would have been its Northern terminus, the Directors desired Mr. Peterson first to make a survey of this crossing. He made careful surveys of this crossing, of one at Nun's Island, of another below the Victoria Bridge, and lastly of the present crossing at Caughnawaga, which Col. Roberts had not examined. After thorough surveys of all these crossings had been made, and careful estimates had been prepared, he found the Caughnawaga line to be very much the cheapest. His estimate for a double track bridge from grade to grade for the Ile Heron line was $2,176,475; for the Nun's Island line $2,946,186; and for the Caughnawaga line $1,407,373.

He reported in favour of the Caughnawaga line, as he considered it preferable from an economical point of view, as well as from its position, which gave the shortest line between the west and the Atlantic seaports, and at the same time an easy entrance into Montreal. This report was adopted by the Board of Directors, in January, 1882, and plans were approved by the Railway Committee of the Privy Council in the following April.

This design had ten deck spans of 300 feet in the clear, and one through span of 330 feet, with a clear headway of 60 feet above ordinary summer water. The bottoms of the deck spans were placed 30 feet above ordinary summer water.

Although he adopted 300 feet spans at this time, he was well aware that it was not the most economical design. This length was chosen in order to obviate any difficulty in connection with the Government approval of the plans, as the directors were under the impression that there would be a considerable amount of resistance to bridging the river at this point, on account of the damage which it was supposed by some would be caused by the holding back of the ice, and the flooding of the country above, while it was also suspected that objections would be made by the lumbermen as interfering with the running of rafts.

No further steps were taken towards the construction of the bridge until the spring of 1883, when, after seeing the ice pass out, new plans were submitted to the Government, with 12 spans of 250 feet, and one of 330 feet. The latter length was required for the channel span by the charter, which gave a saving of about $75,000. This arrangement of spans was objected to by the pilots engaged in running rafts down the channel, and in order to meet their views, Mr. Peterson arranged to change the plan to eleven spans of 268, and one span of 340 feet, but nothing further was done towards commencing the work at that time.

Mr. C. Shaler Smith was called in as consulting engineer for the superstructure in the summer of 1884. He apprehended much greater difficulty in the construction of the piers in deep water than Mr. Peterson did, and suggested that in place of the eleven spans of 268 feet, and one span of 330 feet, then proposed by the latter, there should be introduced two spans of 258 feet and 2 spans of 408 feet over the channel, thus getting rid of one deep water pier, and probably one year's time in the construction of the Bridge; the complete design thus embraced eight spans of 252 feet, two spans of 269 feet, 10 ins., and two spans of 408 feet, centre to centre of piers in each case. With these arrangements the 252 feet span extended further over the shore than Mr. Peterson considered safe, on account of the tendency of the ice to shove on the shore and lift the span out of position. To obviate this, the 252 feet spans were changed to 242 feet, which gives the arrangement of the spans as it has been executed.

Tenders were not called for the construction of the work, until a year after this, September, '85, when Mr. Peterson asked in his specification for prices based upon the following arrangements: eight spans of

242 feet, two spans of 269 feet, 10 ins., two spans of 408 feet all centre to centre, and also nine spans of 268 feet, two spans of 269 feet, and one span of 340 feet centre to centre, stating at the same time that tenders and plans would be received for any other arrangement, providing the position of the east pier of the channel span was not changed, and that no piers were placed closer than 242 feet centre to centre. Plans were sent in by the Union Bridge Co. of New York, the Dominion Bridge Co. of Lachine, and the Phœnix Bridge Co. of Phœnixville.

The Dominion Bridge Co. sent in a tender, based upon the arrangement of the long spans suggested by Mr. C. Shaler-Smith, and this was accepted; but before the contract was signed, Mr. Peterson had the floor system changed, so as to place it between the trusses, instead of on top, as he considered this would make a much more compact bridge, and by the arrangement the top chord would form admirable guard rails, and render the bridge absolutely safe for a derailed train, while it would, at the same time, improve the appearance of the structure. With this latter view, he also had the top chords in the curved portion, where they were built of eye bars, cased in so as to give them a uniform width and appearance throughout.

The adoption of the two 408 feet spans did away with one pier in deep water, which Mr. C. Shaler-Smith convinced the Directors was a very important consideration in the rapid completion of the work. He thought that the greatest difficulty and delay would be in the construction of the deep water piers. Mr. Peterson was not of this opinion, and apprehended no great difficulty in the work, nor did he apprehend that there would be any serious difficulty in erecting the channel spans from false works in the river. The result would go to prove that the fears entertained, regarding delays likely to arise from the deep water piers, were to a great extent groundless, as the masonry was finished nearly a month in advance of the contract date, viz., 30th November, 1887, whereas the superstructure, about which it was supposed there would be no difficulty, is not at this date completed.

vey. The method of equalizing the pressure on a turntable, by means of a rocker-link, was adopted in 1878, in the truss of a counterbalanced swing-bridge, erected by Messrs. Cunningham and Keepers of the Milwaukee Bridge and Iron Works. The posts over the main bearings are inclined and rivetted to a strong plate, which carries a pin B. The top chords and bars are attached to a pin A. AB is a short link which transmits the whole load to the main posts, and, however, unequally the arms may be loaded, there will be an even distribution of pressure on the turntable. Imperfection of workmanship will modify this result to some extent, which could only be absolutely true when the line of action of the resultant load coincides with the axis of the link and bisects the angle between the inclined posts.

What the author calls the Rankine-Bouscaren formula would, perhaps, be better described as Rankine's modification of Gordon's formula, the coefficients being those adopted by Bouscaren. Rankine substituted the ratio of length to least radius of gyration, for the ratio of length to least dimension in Gordon's formula, and thus eliminated the variation due to a change of sectional form.

Very elaborate calculations seem to have been made in order to determine the stresses in the different members of the double-intersection trusses; but it is certainly impossible to determine these stresses with any degree of exactness, and under a moving load the diagonals are subjected to wide variations of stress, and, therefore, require a proportionately greater sectional area. The live loads to be allowed for are also continually increasing, and it seems useless to calculate for a particular distribution of loads on engine wheels. Indeed, the opinion seems to be gaining ground that it would be practically as good to design a bridge for a uniform load, say of 3000-lbs. per lineal ft. with an excess of 25,000-lbs. concentrated at the head. Floor-beams and short spans may then be designed for two loads of 40,000-lbs. on a 14-ft. wheel base (or on axles 7-ft. apart). One great objection to almost all pin-connected bridges is that the safety of the bridge depends upon the strength of individual members. This has been made painfully evident by recent bridge accidents, which would certainly not have occurred, had the members been rivetted together and made, to some extent, mutually dependent, as is the common practice with European engineers

The most striking feature, and the one most naturally subject to criticism in the St. Lawrence Bridge, is the bold and novel method adopted for passing from the deck to the through spans. The design originally proposed by Mr. Peterson, the chief engineer, in which the piers for the deck spans were to be carried up sufficiently high to support the ends of the ordinary disconnected trusses, certainly possesses many substantial advantages. It does away with the necessity of curving the lower chords at the haunches, and, therefore, also with the precautions which have had to be taken in providing against the excessive straining which such curving induces.

It would be interesting to know why the original cantilever design was departed from, and the continuous girder system adopted.

The former possessed the advantage of rendering possible a definite determination of the stresses, while in the latter the movement of the points of contra flexure under a live load considerably complicates the problem, and renders its solution extremely difficult.

The formulæ given by Mr. Schaub for the moments and shears in the case of continuous girders are based on certain assumptions. Recently, in a paper before the Royal Society of Canada, Professor Bovey has deduced formulæ somewhat simpler and more easily applied in practice, the assumptions being the same.

The bending moment upon the r-th pier counting from one end, under a load upon the r-th span, there being n-spans in all,

$$\text{is } \frac{a_r}{a_{r-1}} \cdot \frac{B - c\,A}{b\,c - 1} \text{ if } q < r$$

$$\text{and } \frac{a_{n-q+1}}{a_{n-r+1}} \cdot \frac{A - c\,B}{b\,c - 1} \text{ if } q > r$$

where $A = \Sigma \frac{w\,p}{l}\left(l^2 - p^2\right)$, $B = \Sigma \frac{w\,p}{l}\left(l - p\right)\left(2l - p\right)$,

$b = 4 - \frac{a_{r-2}}{a_{r-1}}$ and $c = 4 - \frac{a_{n-r}}{a_{n-r+1}}$,

the co-efficients a being determined by the law,

$a_1 = 1,\ a_2 = x,\ a_3 = 4a_2 - a_1 = 4x - 1,\ \ldots\ a_r = 4a_{r-1} - a_{r-2}$

It also at once follows that the bending moment at any pier is a maximum when the two adjacent spans and then every alternate span, counting in both directions, are loaded and the remainder unloaded. The inclination of the neutral axis has been neglected in the calculations of the St. Lawrence Bridge, but the modifications introduced thereby would in all probability be too small to be of any serious account.

r. The paper of Mr. Schaub and the diagrams of Mr. Moore present the consideration of a quite remarkable structure and a bold piece of engineering. The circumstances of the location certainly justified and even necessitated a type of structure, which should obviate the use of false works in the channel spans, but just what conditions compelled double intersection triangulation in which uncertainties in web stresses may reach anywhere from 10 to 25 per cent. of their values is not clear. It is undoubtedly a simple operation to assign definite duties to each system, and compute the resulting stresses, but the latter possess largely imaginary values in many of the web members.

It is a well known analytical truth, that an exact determination of stresses for such a structure is an absolute impossibility. Their real values cannot be demonstrated, and many of them may vary between comparatively wide limits. Ten years ago limited facilities in producing and handling large members justified a loosely approximate division of stresses, with sufficiently low working stresses, but the example of a two truss 550 ft. span, designed to carry a double track railway, two roadways and two sidewalks, by American engineers, with one system of triangulation only, leaves scant reason for a double system in such a structure as the Lachine bridge.

The double system stresses are not only indeterminate in amount, but give rise to excessive metallic fatigue by the quick transitions of alternately heavy and light concentrations from one system to another.

The combination of the cantilever principle for the fixed load, with that of continuity for the moving, is open to serious objection with a simple form of truss; but where there is added the uncertainties of form already considered, together with the super-addition of positive omission in the computations, the objections do not decrease. The very approximate character of continuous stresses in fixed spans, and under conditions favourable to the truss, are too well known to require specific consideration, as indeed, Mr. Schaub clearly shows; in the present instance, however, some very complicating conditions were introduced in the design, and appear to have been entirely neglected in the computations.

Mr. Schaub gives various familiar formulæ for the moments and shears under continuous girders on the assumptions that the co-efficient of elasticity and moment of inertia are constant, also that the supports are all on the same level, also that the girder is *straight between supports*. The latter condition, it will presently be seen, has considerable meaning. The co-efficient of elasticity, even in mild steel, will vary from 5 to 10 per cent. either way from a mean value in the same structure, and the moment of inertia ordinarily varies much more. But Mr. Schaub is probably correct in assuming that the consequences are not very serious, so far as these items are concerned. It is safe to assert, however, that the derangement of stresses arising from unequal settlement and simultaneous variety in temperature, which will at times exist throughout the structure, will very frequently be far beyond the reach of the adjustable supports at the ends of the balancing spans.

The only effective adjustment is an absolute fixedness of stresses in a design that will not permit their variation.

There can be no doubt that the omission of the fact that the girder is not straight between supports throws a very grave element of doubt over the results of the computations for the moving road. Instead of using the common form of the theorem of three moments for the straight girder, the following form should have been employed if E and I be assumed constant :—

$$u_{1a} \overset{a}{\Sigma} P\, l_a \left(1 - \frac{z^2}{l^2_a}\right) \quad + u_{1c} \overset{c}{\Sigma} P\, l_c \left(1 - \frac{z^2}{l^2_c}\right) z$$

$$+ 3 \left(\mathrm{M}_a\, u_a\, x_a + \mathrm{M}_b \left(\overset{1}{u_a}\, \overset{1}{x_a} + \overset{1}{u_c}\, \overset{1}{x_c} \right) + \mathrm{M}_c\, u_c\, x_c \right) = 0$$

l_a and l_c are adjacent spans, and z is the horizontal co-ordinate of the point of application of P from the extreme end of either span.

$$u_a = \frac{2}{l^2_a} \int_0^{l_a} u \left(l_a - x\right) dx\,; \text{ and } \quad x_a = \frac{\int_0^{l_a} u \left(l_a - x\right) x\, dx}{\int_0^{l_a} u \left(l_a - x\right) dx}.$$

In these formulæ "u" is the varying cosine of the inclination to the horizontal of a curved line drawn through the centres of gravity of all the normal sections of the truss chords. The values of u_a and x_a are typical of all u's and x's in the moment formulæ.

As the 408 ft. spans are through and the adjacent spans deck, the line passing through the centres of gravity of the truss chords in the two adjacent spans is sharply curved in the vicinity of the pier, between the two spans ; hence "u" would have a value very considerably different from unity for a long distance on either side of the pier just mentioned, so that the omission of its consideration in the computations will materially affect the results. As a matter of fact, however, if the proper varying value of "u" had been introduced in the formulæ, and the resulting moments and reactions determined accordingly, it is not improbable that the complications in the results would have justified the rejection of the plan. It does not appear to be good engineering or proper design to omit such considerations. It is very true that the safety of the structure is not endangered by such action, but it is equally true that where types of structures can be used, in which the computations of exact stresses is easily secured, and the proper disposition of the metal to meet them is perfectly under control, such types should be selected.

Prof. Burr does not agree with Mr. Schaub, either that it is common practice among American engineers to place pins at the centre points of posts in perfectly fitting pin holes, or that the practice is pernicious in the few cases in which it has been done. The movement of the pins, which he mentions, has taken place in a large pin hole, such as is used in the St. Lawrence Bridge, is probably due to another cause than that of the deflection of the bridge with the consequent relative movements of its parts. Eye-bar members in double lengths will never lie in a straight line, but the centre pin will lie below the line joining the pins at the extremities, in consequence of the weight of the eye-bars, their heads and the pins, since the latter have no support; and they will lie further below that line, when the bridge is free from the moving load, than when it is covered by it. It is not improbable that the difference in elevation of this pin, under the two conditions of loading, would amount to nearly a quarter of an inch in the case under consideration. It is by no means improbable, therefore, that the larger part, perhaps the entire movement which he mentions, is due to this cause.

The almost indefinitely small movement of the centre of the column, in the case of the closely fitting pin, would affect the column alignment much less than the incidental results constantly occurring in the shop, in the very best of work, and the resulting derangement of stress in the column is probably too small to be worthy of any serious consideration.

One point in connection with this work is of the highest importance at this period of transition from iron to steel in structural work; and the course of the designers of this bridge is a wise one in selecting a very mild grade of steel wherever that metal was employed. The almost universal practice of using steel of 70,000 pounds ultimate tensile resistance for eye-bars, and 80,000 pounds ultimate resistance for the steel in columns, is as yet open to some criticism. The working stresses in these high steels are taken at a value proportionate to their ultimate resistance. While this ought to be a safe rule to follow, if our experience were sufficiently extensive to confidently contro the effects of shop processes and manipulations in the production of finished members, bridge members of these high grades of metal, free from internal conditions of stress, which in some cases militate very seriously against their ultimate resistances, cannot yet be produced. It is far wiser and better engineering, therefore, to use mild steel with corresponding values for working stresses, as was done in the case under consideration.

Tensile steel with an ultimate resistance, of 62,000 pounds per square inch, and compression steel running from 65,000 to 70,000 pounds per square inch in ultimate tensile resistance, will give finished bridge members of a thoroughly reliable character, and it is in all probability much safer to use higher working stresses with such metal than with the higher grades of steel, which have been very generally used.

It is a matter of congratulation, therefore, to the engineers of this structure, that they have selected a material which can be confidently relied upon in the performance of its duties.

Mr. Butler's suggestion to make the long diagonals in one length is generally carried out where the lengths do not exceed forty-five feet. In this country it is more convenient to use shorter lengths, say thirty-five feet. In general, all lengths in the Lachine Bridge had to be confined to about forty feet, which necessitated splicing all members above that length. In the 520 feet span of the Ohio River Bridge at Cincinnati, it was specified that the long diagonals should not be coupled by a pin through the post, and here the coupling was made by a pin a short distance away from the post, obviating all the objections to making the long diagonals in two lengths.

The use of the Launhardt formulæ, as Mr. Butler suggests, being well adapted for the continuous spans in the Lachine Bridge, is very questionable.

The Launhardt formulæ are based on a few experiments made by Wöhler on small specimens in tension only; from which Launhardt and Weyranch deduced the formulae for working stresses acting in opposite directions. The formulae are, as used by Mr. Joseph M. Wilson, M. Am. Soc. C.E., Consulting Engineer P.R.R. :—

For pieces subject to compression only or tension only,

$$(1)\ a = u\left(1 + \frac{\text{minimum stress in member}}{\text{maximum `` ``}}\right)$$

For pieces subject to stresses acting in opposite directions,

$$(2)\ a = u\left(1 + \frac{\text{maximum stress of lesser kind}}{2 \times \text{max. stress of greater kind}}\right)$$

in which

a = permissible stress per square inch, either tension or compression.

u = for doubled-rolled iron in tension per sq. inch, 7500 lbs.

u = for rolled iron in compression, 6500 lbs.

The Launhardt formula as used by the Union Bridge Co., for the Kentucky and Indiana Bridge over the Ohio River at Louisville, is :—

For pieces subject to stresses acting in either one or opposite directions.

$$a = u\left(1 + \frac{\text{minimum stress in member}}{2 \times \text{maximum stress in member}}\right)$$

which is identically the same as formula (2) given by Mr. Wilson, the minimum stress in any member becoming the maximum stress of the lesser kind when the minimum stress is negative and the maximum stress positive. The formula as used by the Union Bridge Co., for members subject to stresses acting either in one or opposite directions, is entirely wrong. It should have been applied to members subject to stresses acting in opposite directions only. For members subject to stresses acting in one direction only the formula (1) should have been used. The use of the formula as given here, inasmuch as some tensile members in steel are allowed to be strained above 18,000 lbs. per square inch for a working stress, is questionable. The experiments of Wöhler should be extended to members subject to stresses in opposite directions before any formulae which so materially affect the unit stresses are employed.

In comparing the weight of one of the 408 feet channel spans of the St. Lawrence to the 400 feet span of the Plattsmouth bridge, it might be said that the former will weigh fully 400,000 lbs. more than the latter.

Mr. Bouscaren's statement with regard to the fixing of the points of contraflexure in the shore arms of the Kentucky River Bridge, to preclude a reversion of strain, is only correct after the bridge was swung complete. During the erection a reversion of strain must occur in the shore arms, and was provided for in the Kentucky River Bridge by adding sufficient section in the chords to allow the erection to proceed as a cantilever. It is easy to see that a large percentage of the metal in the chords near the points of contra-flexure of the Kentucky River Bridge had to be introduced, which was not required after the bridge was completed. This fact is what led Mr. Smith to fix the point of contra-flexure where the use of extra metal for erection as a cantilever would be avoided, as he did in the Minnehaha cantilever in 1881.

In reply to Mr. Tate's question:—"What is the maximum stress developed in the cantilever arms during erection?" The maximum strain per square inch is developed in the cantilever arms next to the flanking (balancing) spans; and occurs in the curved portion of the top chord in the second panel from the pier. Here the stress amounts to 20,900 lbs. per square inch when the cantilever is built out, with the traveller and hoisting engine standing at the end of the arm.

The maximum unbalanced load which the arms from the centre pier may safely bear during erection, and before any connection with adjacent arms is made, depends solely on the width of the base which is used for erecting that portion over the centre pier. There is nothing in the construction of the trusses themselves to give any base whatever; thus nothing else remains but either to use one or two temporary cribs, so as to give the necessary base, or to employ false work immediately next to the pier on both sides in line of the bridge. The latter method is the one which has been finally adopted by the Dominion Bridge Co. It might here be said that it was Mr. Smith's intention to use one or two cribs in line of the bridge to assist in balancing that portion over the centre pier, until the final coupling was made.

In regard to Mr. Dawson's statement in referring to the formulæ used for calculating the stresses in the continuous girders it might be said that, there is no possible objection to using these formulæ as long as they are known to be correct. They are derived directly from the "Theorem of Three Moments," and they certainly simplify the work very much, when using concentrated loads. Mr. Dawson's distinction between continuous girders and cantilever bridges is too sharp. A cantilever bridge such as the Niagara is simply a continuous girder, with fixed points of contra flexure. The cantilever principle is simply a step forward in the science of engineering, from the continuous girder. Mr. Dawson's objection to using pin connected trusses for continuous girders, owing to their unsatisfactory condition for expansions due to temperature, would not hold if expansion rollers are provided where needed, and if also provision is made for the strains produced by the friction of the rollers themselves. These same provisions would have to be made in any form of girder, whether rivetted or pin connected. Mr. Dawson calls attention to the rapid variation of the depth of the trusses of the swing over the Lachine Canal, as to its effect in the calculation of the strains, inasmuch as "I" the moment of inertia is assumed as constant. He also cites the fact that the 396 feet draw span of the Sault St. Marie Bridge with its top chord at an inclination of 1 in 12, gave no appreciable evidence of an error in assuming "I" the moment of inertia of the cross section to be constant, inasmuch as the diagram of forces closed.

The fact that the diagram of internal forces closes does not prove the assumptions made in regard to the Theorem of Three Moments to be correct. In fact, any external forces whatever may be assumed to be acting, and as long as they balance, they may be applied to a structure of any form, and a diagram of internal forces which also balance may be obtained.

The assumption that "I" is constant involves an error in obtaining the reactions only, which is entirely on the safe side, as previously stated; but no amount of inclination in the chords of the draw span would prevent the diagram of internal forces from closing as long as the external forces are balanced.

The method used for annealing the steel bars for the St Lawrence Bridge is the same practically as used by all manufacturers in the States, namely, heating the bars to a low cherry red in a gas furnace, the flame not striking the bars. The temperature is not a high one, as the bars take, perhaps, a whole day to become properly heated, when they are drawn out on a sand bed, and allowed to cool under the sand. The results obtained by the Edge Moor Iron Company shew that the bars may be allowed to cool without being covered, but it would certainly be preferable to allow them to cool in sand or some similar material. The effect of annealing is to restore the molecules to their normal conditions, and to make the metal more ductile and homogeneous. The extensive experiments made by the Edge Moor Iron Company on the steel bars for the East River Bridge shew that annealing reduces the ultimate strength and increases the ductility. The eye-bars used in the St Lawrence Bridge are made by the Kloman process; that is, the metal in the head is rolled thicker than the body of the bar, which leaves a lump on each end of the bar, from which the head is forged under a steam hammer.

The Rankine formula for compression members is certainly a modification of Gordon's formula, but the introduction of the least radius of gyration in place of the diameter is such a vast step in advance of the Gordon formula, that the Rankine formula now stands alone.

The Gordon formula is an empirical formula, framed to suit the experiments of Mr. Eaton Hodgkinson, made in connection with the building of the Conway and Britannia Bridges. Now, when the Gordon formula is applied to other sections than those used by Mr. Eaton Hodgkinson, the results are not correct. Why? Simply because in the Gordon formula there is no variable dependent upon the Moment of Inertia of the cross section, a very important element, when it is remembered that a long column must be designed to resist flexure as well as direct thrust.

Mr. Burr's objection to the double intersection type of truss must also hold good for any ordinary discontinuous span. Why the web strains in this form of truss should be uncertain within limits ranging from 10 to 25 per cent. Mr. Burr does not make clear. With long panels, such as those used in channel spans of the St Lawrence Bridge, quick transitions of alternately heavy and light concentrations, from one system to the other, cannot take place. To be sure, a single system would have been desirable, if other conditions could have been ignored. A single system would have required very much longer panels, which would have made the curves in the chords a series of straight lines, the effect of which would be anything but pleasing to the eye. Longer panels would have necessitated using built stringers in the place of rolled beams, an objectionable process in this country as rolled beams are very much cheaper than built beams.

Mr. Burr says:—" It is undoubtedly a simple operation to assign "definite duties to each system and to compute the resulting stresses, "but the latter possess largely imaginary values in any of the web members." If Mr. Burr will examine the diagrams of Mr. Moore he will find that where the two systems do combine they are united by an equalizing link, the direction of which is fixed, not arbitrarily, but by working back from a neutral point in the span where the shearing force is zero, for a position of the load which is known to give the maximum. This operation is carried out independently for each system. A mean, which is the resultant of the maxima, fixes the direction of the equalizing links. They are held in position by proper construction, and prevent any ambiguity in the value of all the stresses calculated thereafter.

If Mr. Burr would give his formulæ more clearly, that is, the formulæ which he says should have been used for calculating the moments and shearing forces for the continuous girders in the St. Lawrence Bridge, it might be possible to make a comparison, with a view to determine exactly how much error is involved in assuming the beam to be straight between supports. If there are any formulæ that are more accurate, and at the same time as practical as those that were used, it would be of interest to know them. There is no structure in existence in which the formulæ Mr. Burr gives have ever been employed.

It has been shewn with sufficient clearness that distortions must take place in the members themselves, in a structure where the diagonals are held by a pin to the post at the centre. It is a matter of simple computation to determine exactly where the diagonals cross the post when the truss is cambered. In the 240 feet deck spans, the point of intersection of the diagonals with the post is exactly $\frac{1}{4}$ in. below the middle of post when the truss is cambered. The diagonals do sag where they are free to sag, but this is altogether another consideration. The practice of fixing the diagonals to the posts, at their middle, is comparatively a new one, but it is only necessary to look among the more recent structures, built in the United States, to establish its popularity.

26th May, 1887.

Mr. T. C. KEEFER, C.M.G., President, in the chair.

The discussion upon M. Schaub's paper on "The St. Lawrence Bridge Superstructure" occupied the evening.

9th June, 1887.

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

The following candidates have been balloted for and duly elected as

MEMBERS.

THOMAS OLIVER BOLGER.
HERBERT CHARLES BURCHELL.
WILLIS CHIPMAN.
ARTHUR EMILE DOUCET.
HIRAM DONKIN.
PETER GRANT.
MALCOLM HUGH MACLEOD.
CHARLES PERCIVAL METCALFE.
JULIUS W. SCHAUB.

ASSOCIATE MEMBERS.

HENRY BANNISTER.
HUGH WILSON.
HARTLEY GISBORNE.

ASSOCIATE.

ROBERT GILLESPIE REID.

STUDENTS.

JAMES FITZGERALD.
ROBERT TODD LOCKE.

THE WARMING, VENTILATING AND LIGHTING OF RAILWAY CARS.

By J. D. BARNETT, M.C.Soc. C.E.

A more unsatisfactory question than that of railway car heating and ventilation it would be difficult to find. Not only do car designers disagree, but the passengers have ideas and wishes so diametrically opposite, that a satisfactory solution does not at present seem possible. Do not expect it from the author, who will esteem himself happy if he succeeds in conveying a fairly clear idea of the problem, and of those recent attempts at its solution approaching nearest to success.

The problem, considering the wide and rapid variations of a North American climate, is certainly a double one, although experience and the Patent Office records shew that each factor is usually attacked singly; and at first it will perhaps be better so to look at the subject.

The requisites of a good heater are:—

(*a*) That it give out heat sufficient in amount.

(*b*) That it be safe from fire risk, scalding, &c.

(*c*) That it be frost proof.

(*d*) That it be controllable without too much attention.

(*e*) That if it be part of a continuous system, it may be detachable without rendering it useless, and that it may have a variability of from two to fifteen cars.

(*f*) That its heat be distributed equally throughout the car, and close to floor.

Ordinary stoves are wanting only in *b* and *f*, and Spears encloses his hot-air stove in a close-woven, heavy wire netting, slightly elastic, yet strong enough to fill requisite *b*; stoves manufactured from wrought-iron—instead of thin, cheap cast iron—having common-sense doors, and located in centre of length of car, come very near satisfying all requirements.

Steam heating—at low pressure—with the heat supply located in a portion of the train not occupied by passengers, fills all requisites except *c* and *e*, the more recent inventions being endeavours to meet these particular requirements.

The Martin system receives its steam supply from the locomotive. It has, for distribution, one through or continuous train pipe under each car, with a metallic double-ball-coupling and expansion-sleeve for connection at each end, and a double vertical line of piping (for heating purposes) on each side of car below seat level, having, however, no provision for keeping car warm when it is not attached to locomotive, or coupled up to station steam warming pipes, or to external portable boiler. Similar crude attempts at steam warming have been made ever since Stephenson's day. The metallic flexible coupling for the through pipe appears to be its distinctive feature; but it is open to doubt if a claim for originality could be sustained if this patent were subjected to legal test. (See historical notice in "The Artizan," July 1st, 1863, page 147.)

The cost of equipment is $200 for engine, $200 for ordinary cars, and $250 for sleeper and parlour cars.

The Sewall and Emerson systems appear at many points to be identical. They draw their steam supply from the locomotive, and use a hot well under the car to receive the water of condensation. Below the well a fire is placed when the car is standing detached, the car heating pipes being arranged so as to give independent circuit with this reservoir boiler. The auxiliary source of heat—be it coal fire, oil lamp or gas jet (and all have been used)—is dumped, or otherwise dispensed with, as soon as the car is to be coupled up with train, thus meeting requisite *b*.

Many-ply rubber-hose is used to allow of adjustability in the continuous couplings. The expense of renewing each hose may amount to $3 or $4 per year. Sewall has a simple and effective metallic hose coupling, locking by gravity, and readily separating when cars become detached, which will permit of a free interchange of cars with foreign railways on through runs. Emerson has apparently not given this most important point any special attention, and each car with his equipment, having an independent outlet by pet-cock for the excess of steam and water, it causes with this arrangement, a vapour to rise, sometimes obscuring the windows, and the annoyance of a constant drip of water has been noticed. Sewall has a small opening in through steam pipe to atmosphere at end of last car only, the excess of water in hot well under each car being discharged intermittently by self-acting trap.

The continuous circulation and its control (when car is detached and fire is put under hot well), cannot be said to be perfect with either system, Emerson having to use a second series of pipes on car roof to act as a condenser or cooler, while the Sewall slowly loses its wate supply, due to the permitted escape of steam through a pin hole a end of the continuous pipe.

The pounds of steam condensed to water per car per hour ar variously given, the independent tests (far too limited in number shewing higher figures than those given by the patentees. The C., M & St. P. Railway obtained an average of 75 lbs. at temperatures between 20° and 40° above zero; but, even, their careful experi ments will not permit an approximation to the weight of steam require with high winds, and temperatures from 20° to 30° below zero. It ma be deduced from some experiments with these systems, and a loco motive with a boiler so large that it is not generally worked up to it maximum capacity, that 1 lb. of soft coal burnt in its fire-box wil radiate an amount of heat equal to 2 lbs. of anthracite burnt in th car; therefore, after allowing a margin for fuel used when car i detached from locomotive, the total or annual cost for fuel, when th rolling stock is fully equipped for steam heating, will be but one-hal that now paid for hard coal, ranging at present on various railways from $35 to $55 per year per car.

There is no information as yet, nor can any be obtained until nex winter, as to the continued action of "traps" in getting rid of loca condensation at extremely low temperature.

Hot water heaters—that is to say, the contained coil and vertical boilers of Owen, Baker, Smith, Johnson, Coughlan, Salmon, etc.—fill all requirements, except "*b*" and "*c*," and various schemes have been tried and suggested to overcome these defects, such as enclosing the whole in a metal safe with self-shutting doors, or making the water-crown of stove boiler of thin cast-iron, so that it shall, in case of accident, instantly fracture, thus drowning the fire, or arranging that derailment open a reservoir of chemicals which shall discharge into and kill the fire. The dead weight of the safe and its contained stove would be dangerous in time of collision; self-quenching arrangements cannot be depended upon if left disused, say for twelve months; and it is possible that the escaping vapours and acids might prove quite as dangerous to life as hot cinders would.

Exhaust steam from the locomotive cylinder and from the brake air-pump have been slightly experimented with as a source of car heating; but the water carried in suspension is so large in amount and so difficult to get rid of, as to discourage any hope of success in that direction, in Canada, unless it be by the use of the William's patent, recently experimented upon by the Central Vermont Railway, in which the old pipes employed in single circuit with a hot water heater are utilized. The single circuit is broken, and the pipes on each side of each car are connected under the platform by flexible hose, so that there is opportunity for complete circuit down one side of train and back the other, when the two hose under platform of last car are coupled together.

Exhaust steam from the locomotive, from the air-pump, or from the vacuum-pump, is admitted at forward end of this pipe circuit, and a vacuum pump is attached at return end (also on locomotive). It is claimed that the vacuum pump will clear the pipes of all vapour or water of condensation, however many convolutions or "pockets" there may be in the whole circuit.

Its main defect is its complete dependence on the locomotive (or other detached boiler) for heat, and its dependence on the pump to prevent failure by frost.

Mr. D. H. Neale, New York, writes (since the "advance proof" of this Paper was issued) that a train heated by exhaust steam from the locomotive has been running between Glasgow and Aberdeen for the last two winters, with very satisfactory results, using a cast-iron radiator of a simple form under each seat. When the locomotive is first attached to the train line, steam is turned on until the coaches are warmed, after which a small portion of exhaust steam is found quite sufficient to keep up a comfortable temperature.

Stoves underneath the car frame have been used; but the supply heat—with the hot air system—is not always adequate, and the gases combustion are liable to get into the hot-air flues. With these defec and a first cost about double that of a similarly equipped car with inte nal stove, the risk from fire is not removed, and cars so fitted have i accidents been destroyed by fire. External heaters for hot water o steam are more effective, but the fire risk is not removed—it is only i part lessened.

The Gold system is practically a storage, rather than a continuou heating system, and has been used only on suburban railways (900 cars A $3\frac{1}{2}$ in. wrought iron tube is almost filled with brine (water and salt then sealed up and laid horizontally within a 4 in. steam pipe, so th when steam is admitted into the annulus between the two tubes, it n only radiates externally but heats up the contained brine, thus charging a reservoir, which when steam is cut off continues the radiation b parting slowly with its rapidly absorbed heat, so that, for instance, wit an external temperature just at freezing, a street car will retain a comfortable warmth for two hours. To suit ordinary train service it is pr posed that the reservoirs shall be charged when the locomotive is runnin down grade and has steam to spare. The defects of this system ar a difficulty in obtaining flexible couplings for high pressure steam, an the risk of scalding in case of accident; and the fact that failure o locomotive would eventually result in freezing out the passengers, prevents it being considered a practical scheme for long through runs or fo isolated branch trains.

VENTILATION.—Having continuous steam-pipes throughout the car the question of ventilation in winter is not a difficult one, a few smal inlets close to pipe, with wide-open exhaust-ventilators in roof, giving free exit, are conditions fairly conducive to health and comfort.

The many and variously designed stoves, with passages in or around them, through which air is forced from Cowl or Bellmouth on top o roof when train is in motion, and thence through hot air flues provided with foot registers the length of the car, have not proved a success being deficient in heat and at the same time making the air too dry. Heat radiated, is far more comfortable and healthy than heat delivered by convection.

The *minimum* supply of fresh air required to keep a car carrying 6 passengers in sweet and healthy condition is 1,000 cubic ft. per minute, and the more this amount can be increased (without inducing draughts) the better.

For summer service a narrowing opening at front end of car under
tform hood will no doubt admit enough air when car is moving; but
is not sufficiently diffused, a draught being felt about the 4th or 5th
w of seats, which fine wire screens or adjustable louvre boards fail to
t rid of. A roof cowl, of almost any pattern, open to front of train,
ll force sufficient air in, and it can be distributed at various points in
iling, sides or floor, according to the number of distributing pipes and
justable registers used, but the air there collected is far from pure,
e dust not only annoying the passengers, but settling in the pipes,
d eventually choking up the passages. Fine wire screens reduce
e air pressure out of all proportion to the dust they exclude, and have
effect on smoke, sulphur, etc., from engine, which is apt to trail over
e train, especially in woody country and in cuttings. Thirty-three
ars ago air was so forced through water-spray, the resultant inky
lour of the water proving that it performed its work well; but the ap-
ratus occupied too much space, and in damp weather the car was too
ist for comfort. Ruttan of Cobourg passed the air over water. This
oved not so effective, but the car was dryer; yet his system collected so
ny impurities in the purposely contracted passages, that it was not
ed with success on long trips. A double roof with the open space
tween, bell-mouthed at each end, and the lower roof perforated, will
t as efficiently as a distributing flue in securing full admission of air
nd a double roof insures a cool ceiling), but it is no nearer to secur-
g clean air and much increases the fire risk. A fan, worked from
r axle, drawing its air supply through gauze-covered opening in the
le of car, passing it over an ice box, distributing it around top of car
om a 6 in. tube and exhausting through the floor, has worked well when
e car was running at full speed; but when going slow or climbing
ades it did not give sufficient supply, and passengers were provoked
break the windows which (necessarily in this as in all artificial systems)
d been fastened down. It should not be forgotten that all similar
hemes result in a car being oppressively close when it is not in motion.

There are several patents for taking air in front of the engine, warm-
g or cooling it there as required, and forcing it to each car through a
ntinuous train pipe by an independent steam motor. The bulk size of
e apparatus involved will probably discourage experiment in this direc-
on until all other possible expedients have failed.

For purifying the air there seems be no scheme equalling that of W. D
ann, who says, " taking my cue from nature's provision in the human
se......I have adopted a 'nose' through which all air is obliged to.
ss. This consists of a mass of 'excelsior' (fine wood shavings like
ir), held loosely by spindles of wire, and kept moist by the melting

of ice over it......the air being first discharged directly on the surface o a large pan of water, the product of the melting ice."

Lighting.—The existing sources of artificial light are candles, oil, ga (coal, oil, water), and electricity. Candles are wanting in brillianc cleanliness and safety; and are not now used. Oil has been roundl abused in the public press and in some State Legislatures; nevertheles mineral oil of 300° fire or flash test is, all things considered, a safe sourc of light—absolutely so if there be no other source of fire in the car tha the lighted lamp itself. Certainly there are but few, if any, cars d troyed by fire in summer, when the increased train service partiall balances the fewer hours per night that lamps have to burn, and if stea warming be adopted all trains would, in winter, be as safe from fire ris as they now are in summer.

Coal-gas carried within wrought iron reservoirs, under a pressure c about 230 lbs. per sq. in., gives a brilliant light, and a reservoir 10 f long by 1 ft. diameter will hold sufficient gas to run a 5 ft. burner 5 hours, or the car for 10 hours. The first cost of fixed plant for com pressing and storing coal-gas is heavy, varying from $2,300 to $18,00 per station (not including cost of gas producers), and there is a larg daily expense in running the plant in addition to a serious loss of ga when it is under compression, due to its condensing into a troublesom gummy liquid, which interferes with the action of all the mechanica fittings and the self-acting pressure reducing valve, as well as with th efficiency of the small distributing pipes.

The Pintsch system gets rid of some of these troubles by using ga manufactured from crude petroleum, or other natural hydro-carbo which, in addition to being less sensitive to low temperatures, to loss b compression, and to gummy condensation, gives a clearer white light o higher illuminating power; the economy resulting from the use of thi system compared with that of coal-gas is marked. It has but one draw back, viz., that each charging station must be equipped with a complet gas *distilling*, as well as gas compressing apparatus, otherwise, special ga storage tanks on wheels must be regularly transported to the distribut ing points, from the central manufacturing and compressing depot English experiments shew that colza oil costs per lamp per hour 1.2 cents, and the Pintsch light only ·652 cents.

In electric lighting there have been experiments with primary (or chemi cal) batteries, secondary (or storage) batteries, independent dynamo, an dynamo taking its power from a revolving car axle. A dynamo deriv ing motion from an independent engine is costly, requires the con stant attendance of a skilled man, and is useless when detached from th train; hence the attempt of Messrs. Houghton & Stroudley and others, who combined a secondary battery with a dynamo driven from a car axle, their action alternating, or even if required supplementing each other, the mechanical details being so arranged that the batteries could not play back into the dynamo when it was running at slow speed; the axle could also revolve in either direction without interfering with the efficiency of the combined apparatus, the whole of which was carried in the guard's van. It is recorded, that trains so equipped, made on the Brighton Railway 2,352 trips in 11 months without failure; but at the present date this Company are reported as experimenting with the Pintsch gas light.

The system of electric car lighting, of which we have most exact information, is the Julien secondary battery; it has much less dead weight than the Plante, Faure and other early patents, and it can be charged from any electric source. Its standard cell has 19 plates and weighs 27 lbs., or, with rubber box and connections 34 lbs. In order to find the total weight required per car, divide the desired candle-power of the lamp by 2, and this will give the weight of battery per lamp-hour. Thus 16 c. p. lamps require 8 lbs. of battery, and 10 lamps 80 lbs., or per night of 10 hours 800 lbs. Allowing 20 per cent. for contingencies the ten 16 c. p. lamps for one night's duty call for 960 lbs. weight of cells, or with connections 1,200 lbs. per car extra weight to be hauled (as a minimum).

The cost, as submitted by the Julien Co. in their recent offer to the New York Central Ry. Co., and actually charged to the Wagner Car Co. for equipping the "Olga," is

60 cells at $13	$780
Wiring, boxes, and lamp fixtures	150
Total cost	$930

The daily cost, using the figures obtained from the Boston and Albany Railway, is

60 cells at $13 = $780, depreciation at 30 p.c. =	$234.00
24 lamps at 85c. = $20.40, each lamp lasting 2 months, 6 renewals at $20.40 =	122.40
Charging battery 365 days at 75c. =	273.75
Interest on $9.30 at 4 p.c. (cost of installation) =	37.20
Total cost of 24 lamps per year	$667.35
Cost of 24 lamps one day	1.83
Cost of one lamp per day	.76

The batteries will probably last longer than 3 years, although actual experience with them covers little more than 2½ years; the negative plates never give out, and the positive plates have not yet done so, whatever the violent motion inseparable from railway travel may yet result in.

The weight of this installation will exceed one ton, and should the exigencies of train working require that a second set of cells be kept for charging, while the other set are in use, the cost for a car as fully lighted as the "Olga" would exceed $1,700.

The N. B. Railway have artificially lighted a train performing much tunnel service by electrically charging an insulated central rail, with which circuit to coach lamp wires is made automatically by wheel coming in contact with the raised rail at entry into tunnel. The rail drops and circuit is broken at exit from tunnel, thus the lamps are alight only when train is within tunnel.

To sum up:—it may be said, that if boiler-power can be supplied, there are no great difficulties under average conditions in heating a train by steam supplied from the locomotive. Boiler power in midwinter on any other than short local runs is, however, rarely in excess of absolute needs, and if boilers large enough are built the locomotive will be so much heavier as to probably call for the strengthening of bridges, &c. If compressed gas be used for lighting, it can readily be adapted as a source of heat, in connection with any system of steam circulation or water pipes.

Ventilation, in winter when steam pipes are used, taking air supply through sides of car close to pipes, and keeping exhausts open in raised roof, is easily accomplished. In summer it is different, and some artificial means for supplying, cleansing, and distributing a large amount of air is necessary. Such schemes will not work if passengers have the option of opening side windows, thus destroying the artificial currents. There are strong objections to machinery, as it must not be recognized as such by the passengers, be too expensive, require too much attention, or be liable to derangement.

It is known to all familiar with the plenum system of ventilation (air forced in by fan)—as adopted for the Houses of Parliament and for Public Buildings at Washington—that it is not satisfactory, although the conditions are much more favourable to success than those limiting the ventilation of trains.

Induced currents by air-jets worked from the brake air-reservoir, may yet accomplish this work satisfactorily.

The ejectors would be very small and distributed over the whole area of the coach at such points as experiment may determine, and acting on the contained air within the coach by suction would permit of the fresh air being received both summer and winter at the same point, iz., at *sides* of coach where it can be obtained (without special filtering) n the purest condition. In winter these ejectors would not be required.

If each passenger is to be allowed to do what is right in his own eyes, t is probable that side windows hung so as to swing vertically, instead f to lift horizontally, would keep out more of the cinders, etc.

For lighting, oil and oil gas are safe enough, and ignoring the question f interest on the heavy first cost of the equipment, the actual daily out-ay for gas would probably be less than for oil (taking all breakages of amps, etc., into consideration).

Electric lighting—cool, safe, and pure—is as yet somewhat uncertain in effect, too expensive in first cost, and calls for too highly paid skill in attendance, to be generally adopted.

Not only for economy in the use of light, but also for cheerful effect in daytime, the internal "finish" of cars should be in light coloured woods, and with the object of lessening fire risks, the "finish" should be, where possible, in wood rather than in woven fabrics.

Cars wholly framed in metal, whatever be their relation to fire risks, are not likely to be a success for passenger service, because of the difficulty in deadening the annoying vibrations and noise incident to motion.

The last few months have been prolific with car heating patents, many of which could not yet be said to have reached the experimental stage. One attempt by Mr. Wilder kept the old hot water heater and its pipes intact, but an additional wrought iron drum was added under the sills, to which the water circulation pipes were coupled, so as to make the drum part of the coach circuit. A through train steam-pipe from engine (by branch under each coach) admitted steam into a coil within the drum, thus heating up the water and putting it into circulation throughout that coach. When coach was detached and tanding, the heater could be lighted up, and circulation maintained as at present.

DISCUSSION.

Mr. H. Wallis. Mr. Wallis remarked that the warming of railway cars is a subject to which, on this continent especially, much attention has been given.

The use of ordinary stoves has been unsatisfactory, from the difficulty of maintaining an equable temperature, and in first class coaches, at any rate, they have, on most railways, given place to various systems of diffusing heat through the medium of water at a temperature of about 212° Far. The hot water system with independent heaters is, no doubt, a considerable step in advance of the stoves, perhaps as much so as the stoves are in advance of the foot warmer used in Great Britain and other milder climates; but like the stove, it has one serious objection which has existed since its inception, and has become prominent, and made the question of car warming of vital importance, during the past winter. The lamentable accidents in which the car heater has figured so conspicuously and unfortunately, and to the use of which the lives of many sufferers are believed to have been sacrificed, has brought into prominence a crop of arrangements or systems, many of which the author of the paper has fully described. These systems seek to establish a central source of heat in the fire box of the locomotive, and thus to reduce the number of disastrous possibilities to a minimum.

That the principle is a correct one, there can be no doubt.

During the past winter, on several railways, steam has been successfully used with some of the systems mentioned, and most of those present have seen the same in operation on the New York elevated railways. While, however, the principle appears sound, the working out of the same is attended with difficulty. The one central source of heat may fail and in a northern climate with storms of snow and spells of intense cold, the result may be but a remove from that which the system is intended to avert.

Clearly then there must be auxiliary sources of heat, and the system which most successfully combines the two (that is, the Central and Auxiliary) will find most favour with the officers of railways. It is too well known that the maintenance, in proper working order, of devices, which are used only in cases of emergency, is difficult; and this fact, and the apparent necessity of such a device, is the great drawback to the use of steam from the locomotive.

The question of first cost is an important one, and this would suggest the use of the piping forming the present generally adopted hot water system.

The further difficulty which may arise from the inability of the locomotive to furnish the necessary steam, in long through trains, will have to be met either by a reduction of train load or an increase of the power of the engine, which in either case is serious, having regard to the radical nature of such a change on rail ways fully equipped at present.

The author's estimate of economy to be derived from the continuous system is rather a high one.

The mean temperature at Montreal for the six winter months, from November to April inclusive, is, as nearly as possible, 20° Far. (See Prof. McLeod's meteorological reports), and if the water of condensation amounts to 75 lbs., at temperatures ranging from 20° to 40°, an evaporation say of 6 lbs. of coal, which is fair locomotive practice during winter, would account for 13 lbs. coal per car per hour, or about 7 per cent. more than that actually now used for haulage.

Making due allowance for the preparation of the cars a reasonable time prior to their occupation, the consumption of coal for the year, that is, for the six winter months during which coal would be used, would be 8 tons, or say $30 per car.

In a continuous system of heating, the constant interchange of cars between railways, makes a universal coupling essential, and before much headway can be made such a coupling will have to be agreed upon. The coming winter will no doubt see much done by way of experiment to solve this important question.

As long as such a difference of opinion exists on the part of railway travellers, as to what constitutes comfort in the shape of ventilation, it would seem hopeless to insist upon the adoption of devices, whose object can be rendered nugatory at the will of the individual.

Those who hold somewhat extreme views on this question are apt to mistake rise of temperature for imperfect ventilation.

The railway car of this continent is of a construction to be easily ventilated. The end doors, the side and upper deck windows, all form excellent passages of ingress and egress for the air, which can be admitted in greater or less quantity, as required.

In car lighting, one advantage in using oil is that a high fire test oil may be obtained (some 300° flashing point) at a reasonable price. Such oil will not cause a fire, though it would feed one started from another cause ; and in illuminating power it is equal at 20c. per gallon to gas at 45c. per 1000 cubic feet. An ordinary car roof lamp of the double type burns from 2 to 4 oz. of oil, and a highly lighted car, therefore, only costs 25c. per hour for its light.

There is no doubt excessive comparative wear and tear of lamps; but with all this there is a great margin of cost in favour of oil, which is one of the good things nature has provided.

Mr. A.T. Drummond. The subjects, especially of the heating and lighting of railway cars, which Mr. Barnett discusses, have received more than usual attention from the public during the last few months, in consequence of the terrible disasters at White River Junction and Dedham.

With regard to the heating of cars, the popular verdict, without doubt, favours heating by steam derived from the locomotive, as being absolutely safe from the dangers of fire in the event of collision or other disaster. The system also produces an uniform, pleasant heat, under easy control. The inventor of the Baker heater contends that he can furnish a self-acting furnace, which can be charged with coal in New York, and will not require to be opened for recharging or any other purpose until such a distant point as Chicago is reached. He also contends that such a furnace can be made so strong and be so securely guarded, as to resist fracture, and retain the coal in case of any accident whatever. This, in Mr. Drummond's opinion, is not possible. It is not the ordinary, if the term might be used, but the extraordinary accidents, where the complete collapse of the cars is probable, that have to be most guarded against. No stove, however strong, or however well cased in an iron jacket, is altogether proof against the effects of such disasters and the very weight of the stove is an element of danger when it is displaced by the overturning of the car at the embankment or bridge, o by the collision. Nor is a heater suspended under the car a less sourc of danger. What must be avoided is any system which, in the case of th complete collapse of the car, would permit of live embers being scattere broadcast over the car furnishings and debris.

Whilst, however, the popular verdict is in favour of steam derived fron the locomotive, the railway manager has not only its practicability bu its economy to consider. Its practicability is now becoming less a experiment, and more a certainty. There are still some minor difficul ties which further experience will readily overcome. Various railwa managers and superintendents, after actual trial, have testified in it favour, and the superintendent of motive power on the New York, Lak Erie and Western railway goes even so far as to say that "unless th outside temperature is below zero, warming a train of cars by steam o a railway of an average gradient, will not increase the draft on the loco motive one per cent.; the size of the train has nothing to do wit it." As to its cost, the result of the enquiries made by the Massachu setts and New York Board of Railroad Commissioners appears to prove that it is little, if any, more expensive than present methods. Abundant warmth, it was shewn by continuous experiments, was obtained even when the temperature was 20° below zero, and only a moderate pressure was required, ranging on one railway from 2½ lbs. to 5 lbs. when the thermometer varied between 5° and 13° below zero. The Intercolonial Railway authorities fear, after the experience of the past winter, when trains were snow-bound for several days, that cars heated by steam from the locomotive might be placed at a grave disadvantage if detained in a snow drift. It is, however, impossible to foresee every such contingency, and even for the ordinary heaters it is not usual to carry several days' supply of coal.

It is said that the Boston and Albany through New York train is heated from the locomotive in twenty minutes, and it is claimed by the Martin System people that eight cars can be thus heated without any loss of power to the locomotive. On the other hand, they also claim that when once a car is properly heated, it will remain comfortable for at least half an hour after being cut off and side-tracked. These are important points regarding which some further experience is needed.

The subjects of lighting and heating must, however, be considered together by railway managers if accidents from fire are to be prevented. It is merely taking away one risk of fire, if steam from the locomotive is employed as a heating agent, whilst oils or even gas are still retained for lighting purposes.

Mr. Drummond does not agree with Mr. Barnett, that for lighting cars, oils or oil gas are safe enough, and that mineral oil of 300° fire test is absolutely safe, if there is no other source of fire in the car than the lighted lamp itself. Though claimed, it has by no means been established, that a sudden shock to the car would necessarily at once put out all such lights in it, and thus quickly remove the source of danger. There is some evidence to the contrary. Now, the swaying of a Pullman sleeper, in the event of its being precipitated from the track, would be liable to bring inflammable material like curtains and bedding into contact with the lighted lamps, and if they should take fire, such fire would find increased fuel should the oil have become scattered over the car by the breaking of any of the lamps. It may be argued that the occurrence of extraordinary accidents is assumed, but it is these very extraordinary cases that have most to be provided against, as when they occur, the loss of life is greatest.

Gas is open to a similar objection in case of collision or derailment, and it has this greater objection that, if the reservoir of highly compressed gas should be burst open by the shock, as is probable, a large amount of very explosive material would be let loose.

The only absolutely safe means of lighting, at present known, appears to be the electric light, and considerations of expense can alone prevent its general adoption. It does not add to the heat of the car, is under immediate, easy control, has the advantage of cleanliness and freedom from unpleasant odours, and gives a steady, agreeable light. The first cost in fitting out a car with it, is considerable, in fact, much more than it should be. In railway economy, however, safety should be a consideration long prior to that of expense.

Mr. McIlwain.

Mr. McIlwain fully endorses the remarks of Mr. Barnett, regarding the difficulty of obviating all the objectionable features of car heating and lighting, and having taken up this question, has much pleasure in giving some of his experience. He has made a number of tests with the object of finding a system of heating and lighting, that combined safety with efficiency and economy.

In all the experiments, where the heating of the cars was effected by burning coal, whether the heat was diffused by means of hot water steam, hot air, or by direct air contact and radiation, a practically indestructible fire pot was employed. He found that this kept the coal from being scattered, if upset or detached in case of accident; but the combustion products escaping through the air openings, necessary to maintain combustion under normal conditions, are of such a high temperature as to ignite wood or debris piled on the fire pot. In one instance, the sides of the fire pot set the wood, upon which it had fallen, on fire.

Water calculated to extinguish the fire automatically, in case the stove is upset, could not be relied upon under all the different conditions that may exist in a wreck. Fire extinguishing devices, that automatically generate carbonic acid, are not safe, and also not as effective in cooling a bed of incandescent anthracite as they would be in extinguishing a wood fire.

Further, whoever has witnessed the terrible rapidity with which carbonic acid destroys human or animal life would object to the introduction of a carbonic acid extinguishing device. The presence of a large mass of red hot anthracite seems almost incompatible with safety.

Steam heating would abolish all danger of fire in case of accident; but the difficulties this climate offers to the mechanical execution of this plan, seem almost insurmountable, and if accomplished, the drain on the Locomotive, and the cooling down, if a car is detached from the train, add further troublesome features, not yet fully overcome.

Mr. McIlwain is now testing a device invented by a German Chemist, which promises well if it proves successful in practice. He hopes to be able to speak more positively on this in the near future.

Regarding the lighting of cars, he concurs with Mr. Barnett that 300 per cent. test oil is practically safe (as there are no authenticated cases where life has been lost or property destroyed in railway accidents, caused by the use of oil of this description), and with some of the modern burners, an illumination of the car can be produced that cannot be excelled by the electric incandescent.

The simplicity and absolute reliability of oil lighting is another strong point in its favour. The electric incandescent in railway cars has made such a poor show, especially in view of reliability and economy, that it can only be considered to be in its first experimental stage.

Secondary batteries lose their efficiency readily, and this with their enormous weight and first cost has greatly diminished the adoption of the storage system.

Dynamos want attention and power, and more of both than the light they furnish is worth.

Chemical batteries consuming zinc have been mentioned and advertised as being the true electric generator for car lighting; careful tests have shown it to be much more expensive than oil lighting, in fact entirely out of the question, as far as practical work is concerned.

He does not look upon gas lighting in as favourable a light as Mr. Barnett. Oil has a freedom from complicated construction and plant that may get out of order; oil is independent of any definite source of supply, always ready, can be handled by the brakeman or porters, is just as safe as gas, and if there is a difference of price in favour of gas, it is so small as to be of no consequence in view of the many desirable qualities oil possesses.

The extended interest and research, that have been caused by the deplorable loss of life in last winter's accidents, will no doubt result in methods of heating cars, much more safe than those now in use.

Ventilation.—After trying almost every known device for ventilating cars, all of which have failed in the one important feature, i.e., in giving the same (or nearly so) amount of ventilation when the car is standing still as when moving, Mr. McIlwain has arrived at the conclusion that the coming system of ventilation to be successful, must be one that will fully give the necessary amount of fresh air circulation under all conditions. This can, in his opinion, be accomplished by automatic arrangement, whereby in warm weather, when the car is at a standstill, the ventilators will be open to their fullest extent, and gradually reduced as the momentum of the train is increased, until at last the minimum amount of air required to properly ventilate a car will be admitted only, and the reverse as the speed is reduced. Inventive ingenuity will be adequate to accomplish this, when it is found that the ventilation of railway cars is as important as automatic draw-bars, or continuous power train brakes.

Mr. G. Gibbs. Mr. Gibbs, of the Chicago, Milwaukee and St. Paul Ry., fears that he can at present add little of value to the published accounts of their experiments last winter. These were very far from complete, on account of the limited range of temperatures encountered. The highest recorded temperature at which test was made was 40° Far., and the consumption of steam was 70 lbs. per car per hour. At 30° the amount rose to 85 lbs., and at 10°, 100 lbs. Except at these temperatures no reliable figures can be given. A "heating-up" test, however—standing—at 10° below zero was made, and it took 285 lbs. of steam per car to bring the inside temperature up to 70° Far., and three hours time. If the total condensation is divided by three, 95-lbs. is obtained as average consumption per car per hour. At present there hardly seems sufficient grounds for deducing from this figure one for running test under same temperature condition, as the further loss of heat due the motion of train would much depend upon the build of the coach, the principal losses occurring from leakage and not from conduction.

It would be exceedingly interesting to be able to work out an approximate law for steam consumption at various temperatures. Mr. Barnett suggests in a letter that the condensation may increase in a geometrical rather than arithmetical ratio with temperature fall. Mr. Gibbs is inclined to doubt this, however; in fact, he hopes that the condensation will not be as great even as in inverse ratio of temperatures. He has been led somewhat to this conclusion from the fact that considerable heat must be wasted at the moderate temperatures of the tests, while with care at low temperatures much of this would be saved, at the expense of good ventilation, however.

Running over some of the points made in Mr. Barnett's excellent paper:—

He entirely agrees with him in what he says, in reference to stoves, encased or otherwise, or other individual heaters outside or in; also in regard to use of steam from exhaust of locomotive cylinders, air-pumps, etc. He has maintained that one of the most vital points connected with continuous steam heating was in dealing with the water of condensation. The rapidity with which water issuing hot from parts of a locomotive will freeze in the severe Northern climate, is almost inconceivable; and he, therefore, lays great stress upon the perfect action of the "trap" used, and would give it the least possible work to do by using the dryest steam.

He has been in favour of wholly metallic couplings between cars, but after some experience with these, believes that the purpose can be more satisfactorily accomplished, by securing flexibility by the use of stout steam-hose, having couplings arranged to permit of very readily replacing a broken hose by an extra one always carried at hand.

In practical train operation, there are certain to be some complications introduced by use of continuous heating ; but Mr. Gibbs feels convinced that the operating department can deal with these, if it is supplied with a mechanically good arrangement. As might be naturally supposed, the arrrangements on the market at present are far from perfect or well thought out.

There is a good field for inventors in this direction, to devise a simple coupling, traps and means of regulating radiating surface for varying degrees of cold, and, as far as possible, for needful ventilation. Beyond this, the so-called "systems" amount to nothing, and the expectation that railroads will pay exorbitant prices for the privilege of using what is already theirs is certainly doomed to failure.

His company is about to embody in a new arrangement being prepared for next winter, a scheme for good ventilation, but the details have not been sufficiently worked out yet to be made public.

Mr. Gibbs agrees with Mr. Barnett in his remarks about use of 300° fire-test mineral oil for lighting. He considers it perfectly safe from the danger of setting the car on fire, under any condition of collision wreck, provided no other source of fire is at hand. The difficulty of inflaming the grade of oil is well known to any one handling it, and the slight shock necessary to put out all lamps using this oil can be easily determined by experiment.

Mr. Barnett, in reply, said the estimated economy in fuel by steam-warming was based upon experiments carried out with locomotives hauling short trains, (therefore, having light fuel consumption per sq. ft. of grate surface, and excellent evaporation per lb. of soft coal burnt), and in districts to the south and west, where the average temperature was milder than in the Province of Quebec, but not so mild as to result in any appreciable reduction in the amount of hard coal used in keeping heaters alive night and day.

The explanation of this apparent anomaly is in the fact that hard coal is not readily combustible, and will not keep alight when in contact with a cooling metallic surface, unless a certain intensity or activity of combustion is maintained in excess of that absolutely required for heating purposes, thus occasioning a waste in the use of hard coal that locomotive steam heating would probably avoid.

Also, aside from the higher market price of hard coal, its evaporative duty, when burnt under similar conditions, is but 74 per cent. of that achieved by soft coal. (See author's paper April, 1886, in Proceedings Canadian Institute, Toronto.)

The desired universal coupling will probably be found in the Sewell patent, if it can be effectively cleared of the water of condensation. Whether this be so or not, it is at present the best coupling offered for light steam pressures.

Mr. Gibbs very properly qualifies his belief that the water of condensation (at present the only satisfactory measure of the amount of heat taken from a locomotive) will not—at extremely low temperatures—increase even "in inverse ratio," by saying, that the free movement of air through the car required in his experiments at medium temperatures would not be allowed in winter. Granting that a restriction may be to some extent permissible, there is no physical reason why the air in a car should not be changed as frequently in mid-winter as at any other season when artificial heating may not be required. The demands of a healthy body are practically the same in all seasons, although in mid-summer we may desire positive draughts because of their cooling influence.

The difficulty of inflaming high grade mineral oil may be tested any time by dropping a mass of saturated cotton waste, when in full blaze, into a barrel of 300° oil, with the invariable result of the oil putting the fire out at once. There is no authenticated case of such oil being the primary cause of destruction by fire of any car in any railway accident on this continent.

Mr. Drummond is correct in saying that a heater suspended underneath the car is no less a source of danger. The P. & R. Ry. have had at least two coaches so equipped burnt up in accident, and the B. & E. Ry. one.

The statement he quotes, that steam warming will not increase the draft on the boiler one p.c. cannot be sustained. A coach to carry 60 passengers requires from 126 to 140 supl. ft. of pipe surface for steam, or 200 ft. for hot water, with an average temperature of 160° F. Where steam is used for the warming of domestic dwellings, despite the facts that walls are thick, and double windows and doors are used, the condensation averages $\frac{1}{3}$, often raising to $\frac{1}{2}$ a lb. per ft. per hour; and it is self evident that a coach having its doors often opened, and a large glass surface to radiate heat, will suffer a much greater condensation. Using, however, the small figure of a $\frac{1}{2}$ lb. per sq. ft., the condensation over 140 ft. will total to 70 lbs. per hour, or per 10 coaches 700 lbs., which is 1 p.c. of 70,000 lbs., equivalent to an evaporation of 7,000 galls., and the burning of more than 5 tons of coal per hour. If 2,000 galls. are to be evaporated, the locomotive must not stop during the hour, so that its artificial blast may draw air enough through the small grate to consume this large amount of fuel.

That steam, at such low pressure as 2 to 5 lbs., will warm a train, or that the fractional opening of an ½ in. valve will pass steam enough, is no proof that the consumption of steam is small in quantity, or that there is no loss of power to the locomotive; all tests of the definite amount condensed contradict this statement.

It is the heavy expense and necessity for skilled attention that will restrict the use of the Electric light on trains. Even when primary batteries are used as a source of electricity for equal candle power, the cost is equivalent to coal gas at $3.25 per thousand feet; there is a possibility of risk to life, for it is not yet proven that a charged storage battery—or even a primary battery—is not a source of danger to passengers at time of a passing thunder storm.

It may be remarked that in all discussions on the cost of lighting by Dynamo, worked from coach axle that have come under Mr. Barnett's notice, the factor of expense involved in giving motion to the machine is ignored, it being tacitly assumed that the resistance to the train is not increased, although a Dynamo so coupled up, is a most effective electric brake.

The extreme cost for lighting the "Olga" is qualified by the consideration that it is to some extent an advertisement, its 24 electric lamps when all alight giving 384 candle power, 120 candle power being enough to permit reading in any part of an ordinary coach. This may be obtained by 8 oil lamps, using argand burners of 15 candle power, which is about the quantity of light given out by a first-class argand student lamp. The consumption of about one pint of oil per hour will develope 120 candle power.

There may be risk in the presence of reservoirs of compressed gas in time of accident; but although the Pintsch system has been used in Germany since 1770, and 40,000 vehicles are now equipped with it, no case of injury to life or property in time of railway accident is attributed to it.

Mr. McIllwain's statement as to lack of success in electric lighting is probably limited to experiments made on this continent; the Pacific Railway Co. having made more than any other railway, and the Co. is still experimenting.

That special ventilation is not required when car is standing, is open to question. It is often asked for by passengers, and the conditions of the problem are such as to scarcely justify elaborate machinery or extensive outlay to attain perfect ventilation, only when the coach is in motion. If train motion is to be a factor in the equation, the outlook at present suggests but a qualified success in the supply of fresh air at low train speeds.

At the conclusion of the discussion on Mr. Barnett's paper, Professor Leeds, of Harvard University, described a method of water purification with special reference to aeration, precipitation and mechanical filtration.

END OF PART I, VOL. I.

OBITUARY.

Thomas Guerin was born in the Glen of Aherlow, county Tipperary, Ireland, A.D. 1818, and died in Montreal on Saturday, the 7th May, 1887. He received his education in Trinity College, Dublin, and came to Canada in 1843. He was appointed lecturer in Mathematics and Natural Philosophy in McGill College, in 1847. The following year he was married to Miss Mary Maguire, of this city. Having studied law, he was admitted to the Bar of Montreal in 1852, but preferring scientific pursuits he never practised law, but devoted himself to Civil Engineering. He was on the engineering staff of the Grand Trunk Railway from the time of its location to its completion. He then located the Piles Railway and the first section of Lake St. John Railway. Mr. Guerin now went abroad for some years, and during this time was resident engineer on the Guines and Matanzas R'y. in Cuba, located and constructed the Launceston and Deloraine Railway in Tasmania, and several other roads and bridges for the Government of Victoria. Returning to Canada in 1864, he received an appointment on the engineers' staff of the Department of Public Works, which he held for nine years, and then resigned to become resident engineer on the Oakland Harbour Improvements for the United States Government. Mr. Guerin competed successfully for a prize offered by the Chili Government, for the best means of measuring and distributing water for irrigation purposes, and invented a module, which was extensively used in irrigating the land in Chili and Peru before the late war. He also invented a sewer and sink trap to prevent the escape of sewer gas. Mr. Guerin returned to Canada in 1880, and from that time to the date of his death was connected with the Department of Public Works. From time to time he has contributed papers of professional interest to various engineering journals.

Mr. Guerin took great interest in the formation of the Canadian Society of Civil Engineers, and was elected a member at the preliminary meeting, held on Jan. 20th, 1887.

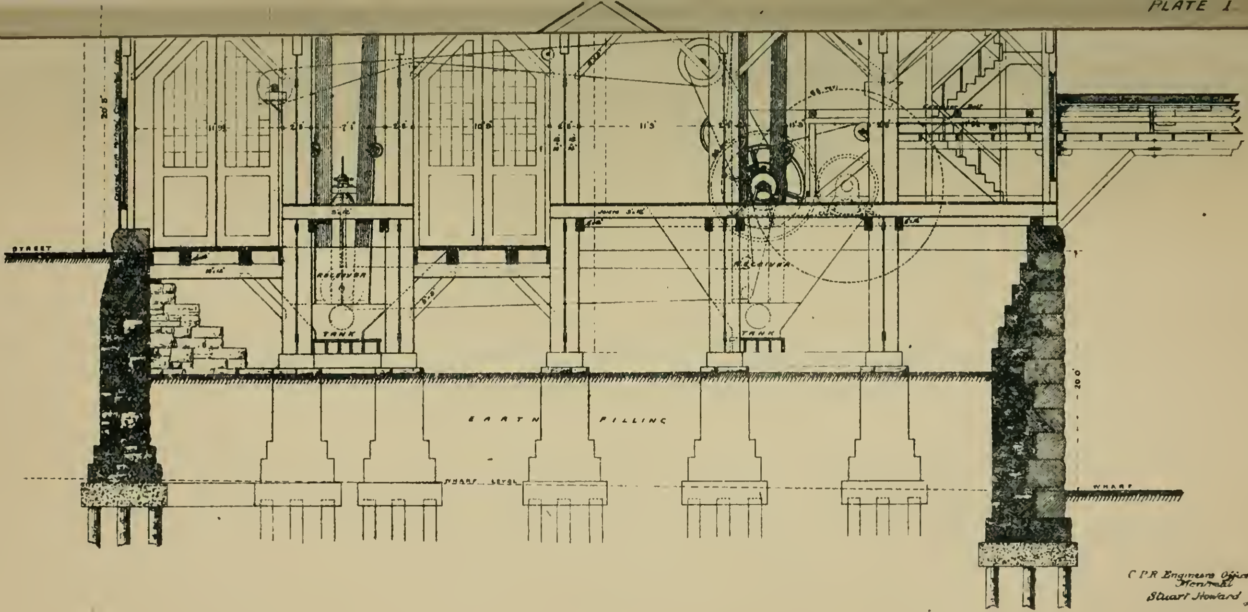
His profession was a labour of love to him ; his mental attainments were cultivated by long years of constant study, which had made the paths of science easy and pleasant to him ; and when death came, it found him busy in the faithful performance of his duty.

Like many men of refined temperament, he was of a retiring disposition, but his rare gifts commanded the admiration of those who had the good fortune to know him. He was distinguished for a nobility of character rarely met with. Decided in his principles, strong in his reasoning, a faithful member of the Roman Catholic Church, he was ever amiable and just to all. He leaves a widow, four sons and one daughter to cherish his memory.

INDEX TO THE TRANSACTIONS.

1887—MARCH TO JUNE.

PLATE I



C P R Engineers Office.
Montreal.
Stuart Howard del.

·C·P·R· ELEVATOR

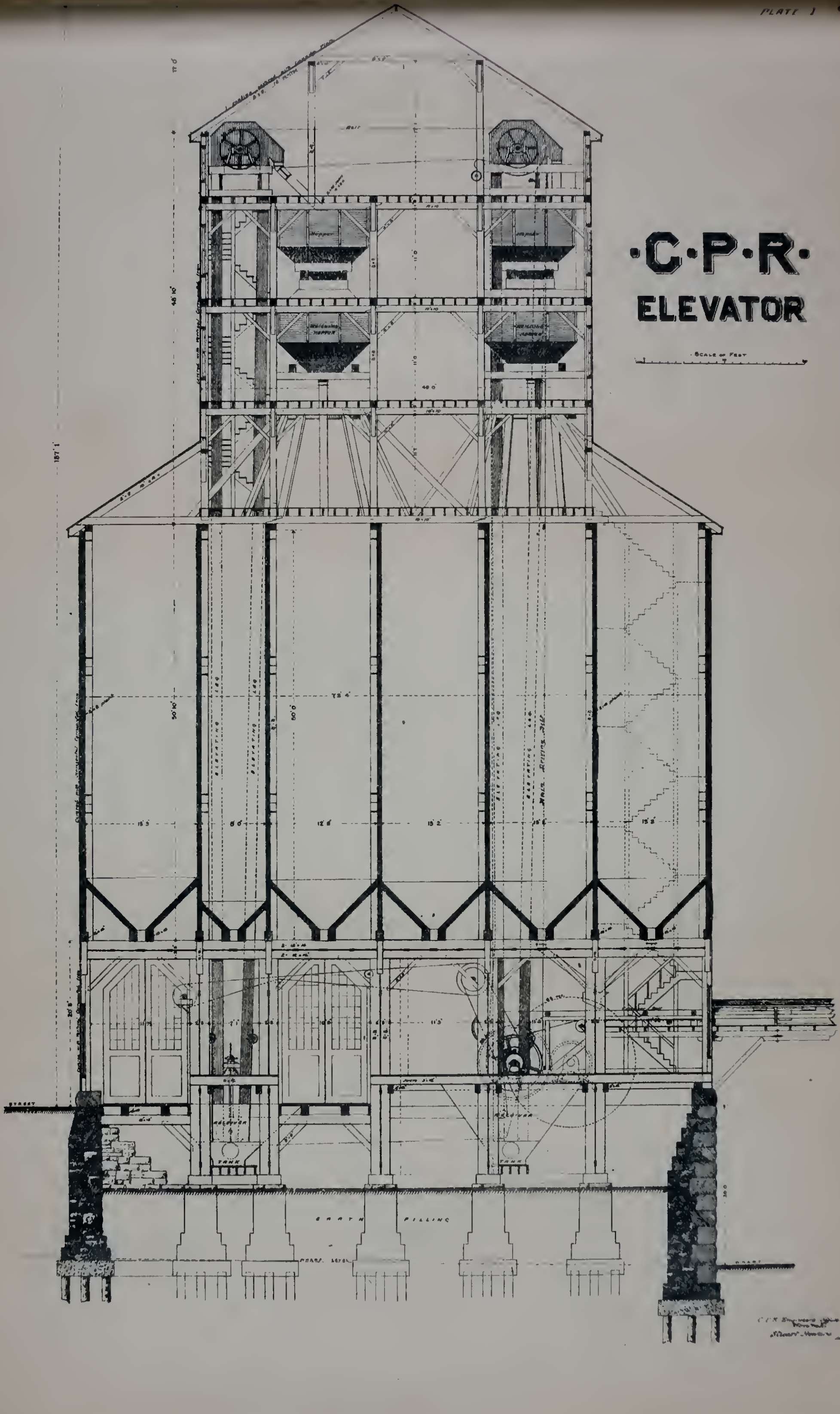
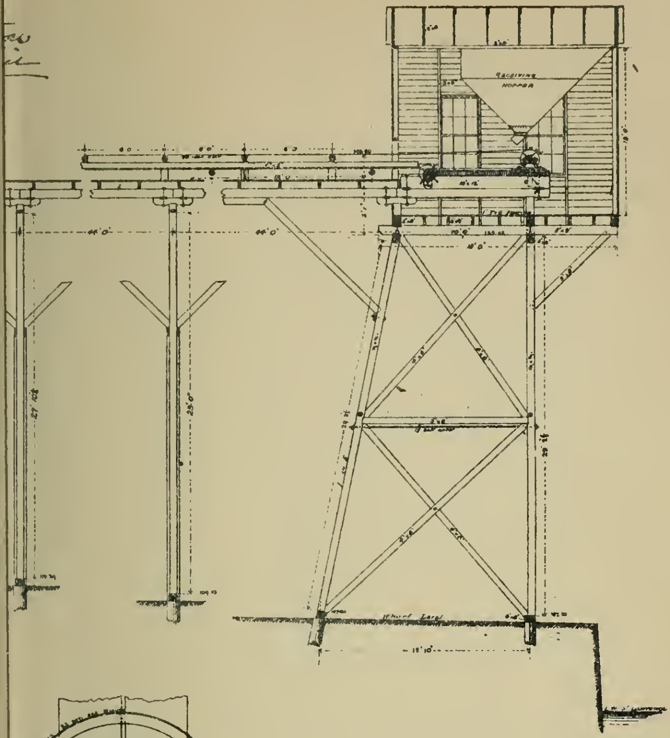
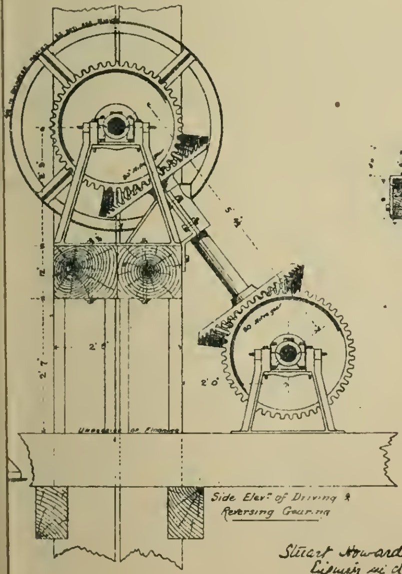
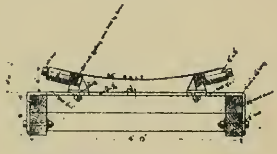
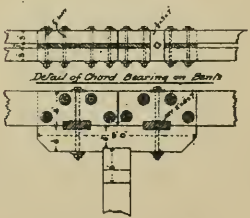


PLATE 2





Side Elevⁿ of Driving & Reversing Gearing

Frame for Curving Belt



Detail of Chord Bearing on Bank

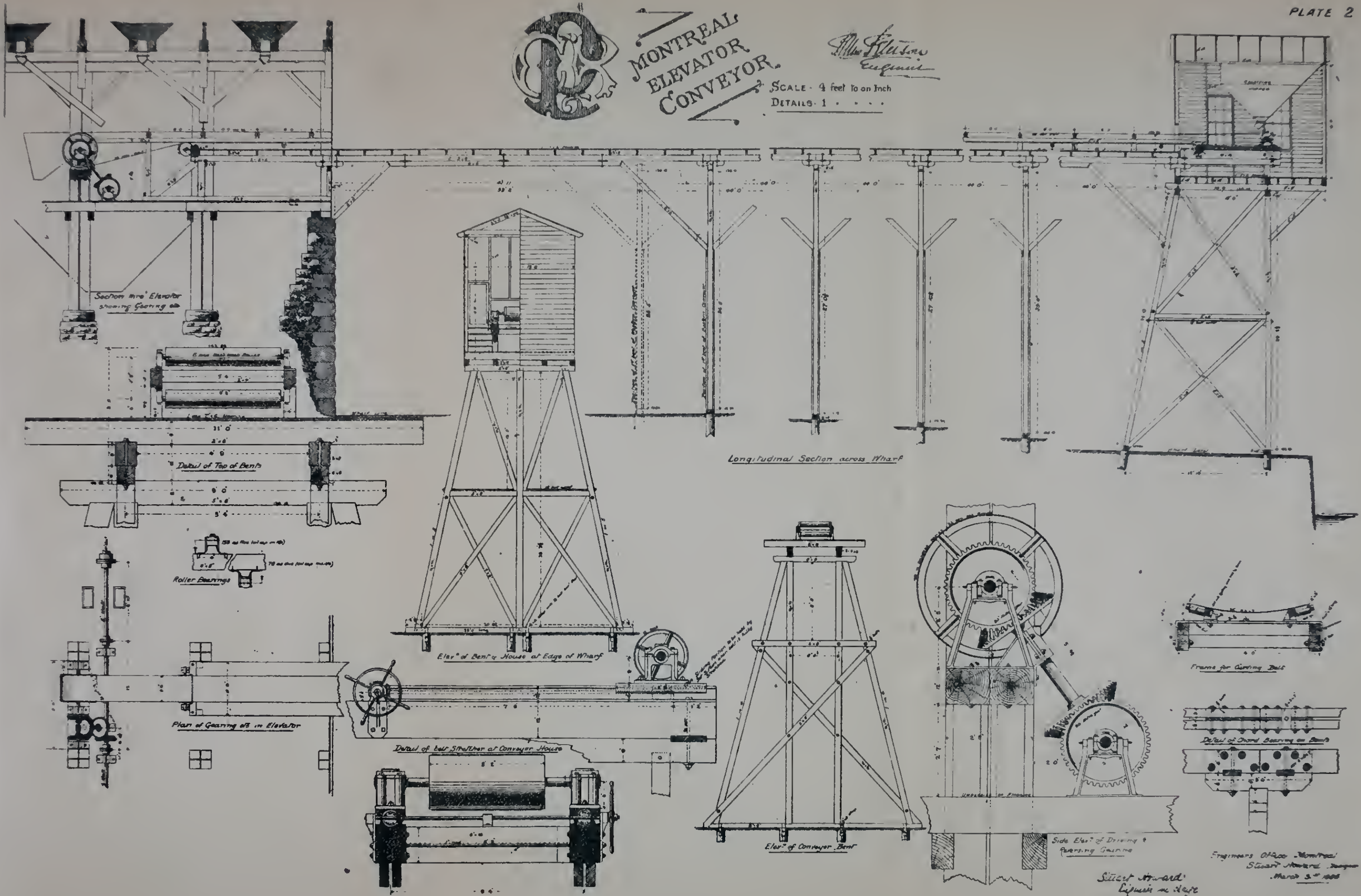
Engineers Office. Montreal
Stuart Howard. Designer
March 31st 1888

Stuart Howard
Engineer in charge

PLATE 2

MONTREAL ELEVATOR CONVEYOR.

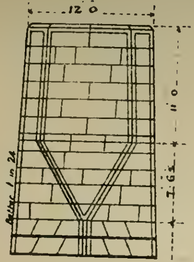
SCALE · 4 feet to an Inch
DETAILS · 1 · · · ·

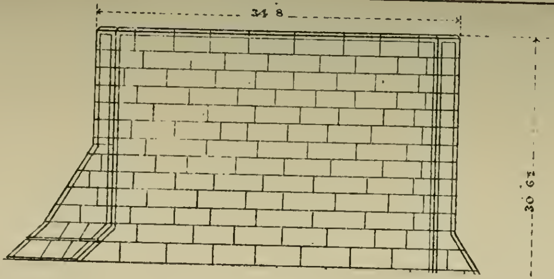


Engineers Office Montreal
Stuart Howard Engineer
March 3rd [illegible]

Stuart Howard
Engineer in Charge

PLATE 3





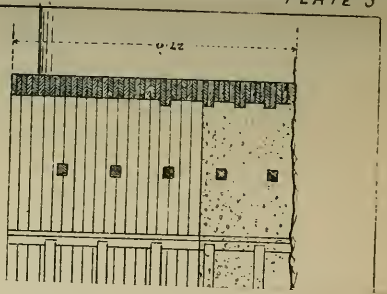
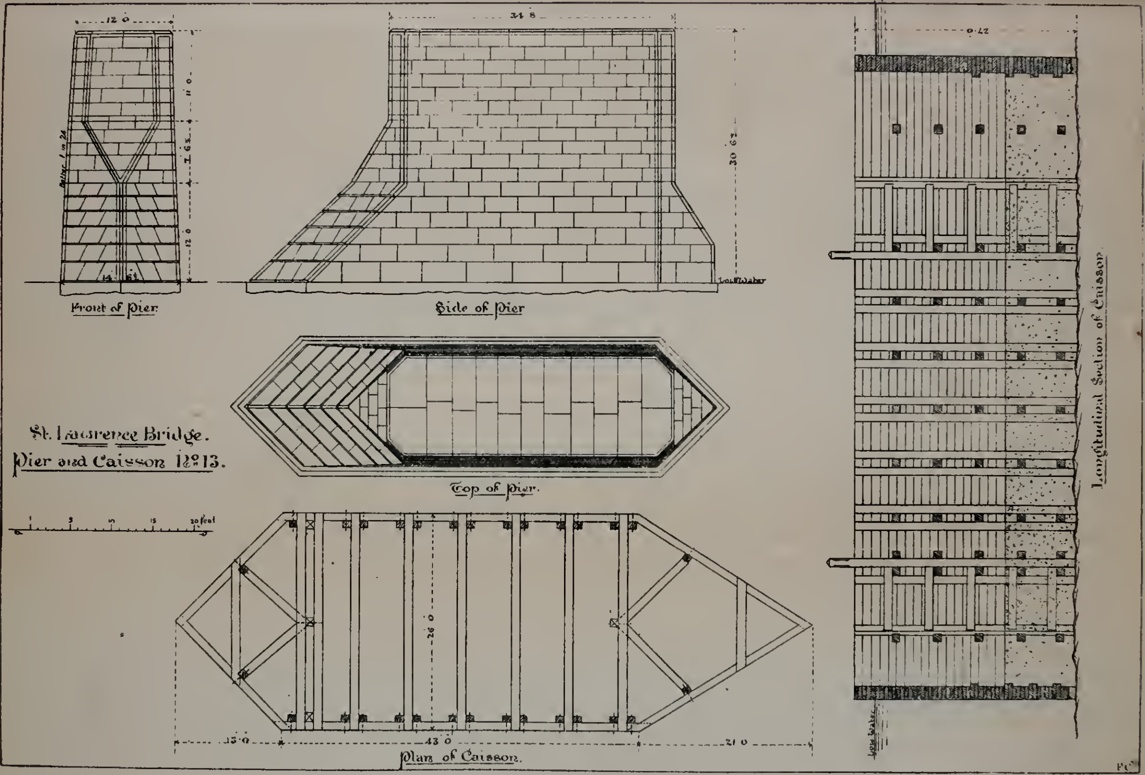


PLATE 3



St. Lawrence Bridge.
Pier and Caisson No. 13.

Front of Pier.

Side of Pier

Top of Pier.

Plan of Caisson.

Longitudinal Section of Caisson.

chine. P.Q., Canada.

C. Shaler Smith Cons. Engr.
Frank D... ore Chief Asst. Engr.
in cha... ulations and details.

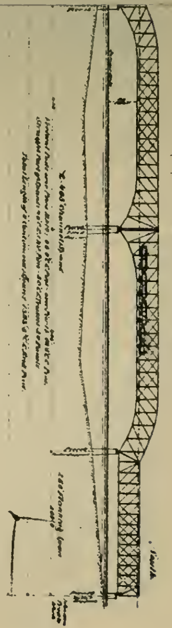
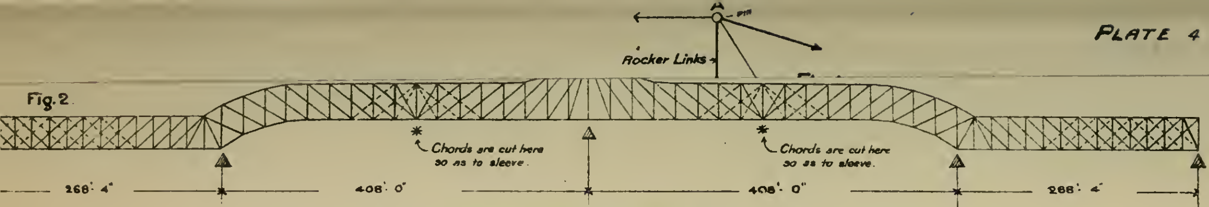


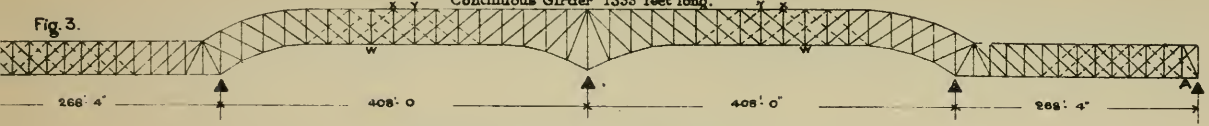
PLATE 4

Fig. 2.



Continuous Girder 1353 feet long.

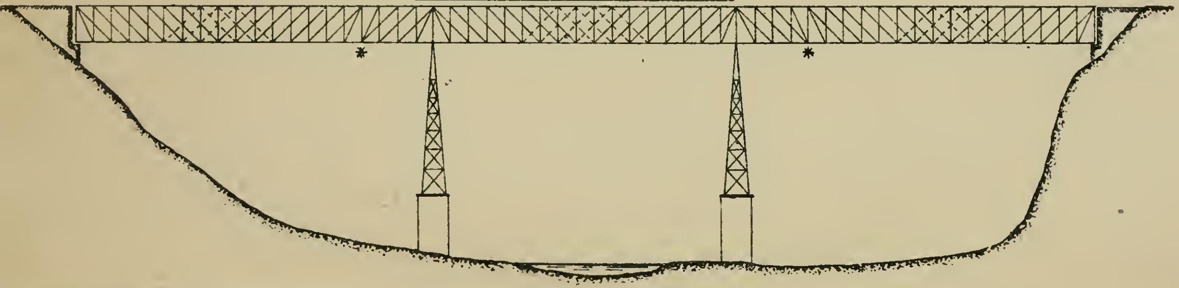
Fig. 3.



KENTUCKY RIVER BRIDGE.

Length 1138 feet, Height 276 feet.

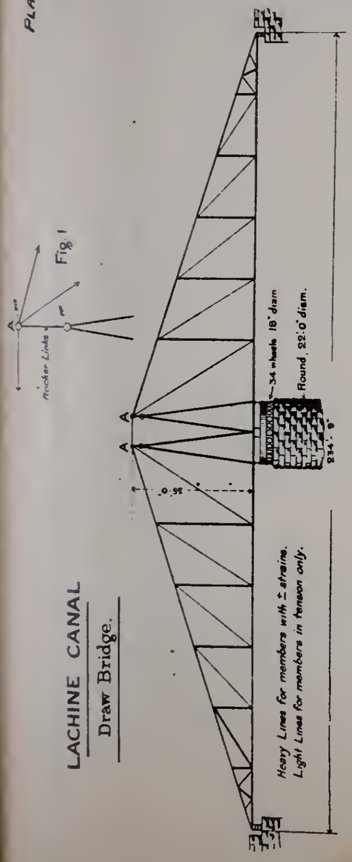
Fig 4.



* Indicate Points of Contra-flexure [fixed].

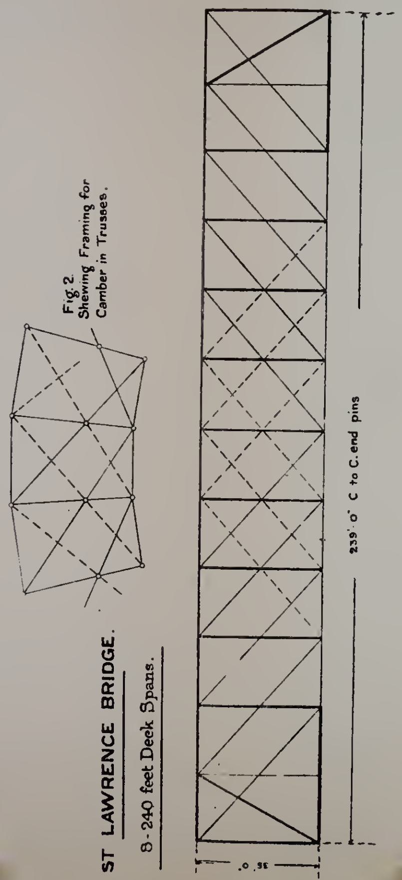
St. Lawrence River. Steel Bridge over Lachine Rapids – A. & N.W. Ry. at Lachine. P.Q., Canada.

PLATE 4



LACHINE CANAL

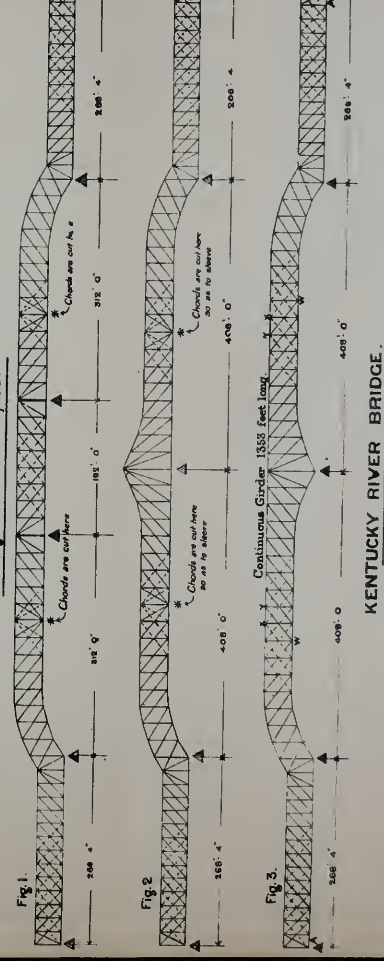
Draw Bridge.



ST LAWRENCE BRIDGE.

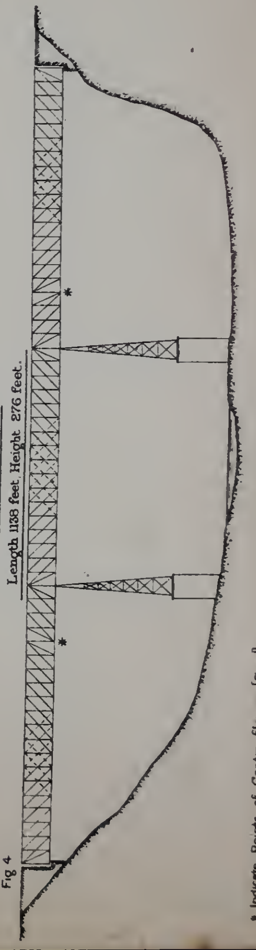
8-240 feet Deck Spans.

PLATE 5



ST LAWRENCE BRIDGE.

Designs for Channel Spans.



KENTUCKY RIVER BRIDGE.

Length 1138 feet. Height 276 feet.

* Indicate Points of Contra flexure (Fixed).

Issued January 1888.

TRANSACTIONS

OF

The Canadian Society of Civil Engineers.

VOL I. PART II.

OCTOBER TO DECEMBER

Montreal:
PRINTED FOR THE SOCIETY.
By John Lovell & Son.
1887

CONTENTS.

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 ncorporators 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.

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 a every crossing of a timber; it was dubbed to an uniform surface befor 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 alternat sides of the plank.

The masonry of the lock walls was built of dressed limestone lai in hydraulic cement. The principal cut face stones and gate quoin were of the best gray limestone, obtained at the St. Vincent de Pau quarry, below Montreal. The remaning stones were obtained at Oak Point, near Belleville, O. The gate or hollow quoins were 5 ft. lon 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 o 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 angl 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 fo the lock-gates.

In building the lock-walls, the four hollow or gate quoins were firs laid, and in each a check 2 feet long, 19 ins. by 19 ins. was cut t receive the ends of the mitre sills. The recess quoins, chain-well sill and stop log grooves were then laid. At each end of the lock chambe walls, two stop log grooves, 3 ft. apart, 1 ft. wide, $15\frac{1}{2}$ ins. deep at th base, were cut into the face and carried up plumb, making them at th top 4 ins. deep. All the principal face stones having been placed i position, the backing was laid, an equal proportion being built on eithe side each day. In rear of the walls, at 15 ft. centres, counterforts 6 f long and 3 ft. wide were built throughout the chamber up to a heigh of 18 ft. The recess abutments were 50 ft. long, and 6 ft. fro each end a chainwell 2 ft. square of cut face stone, was formed t connect with each inclined tunnel below. The position of the chamber recess walls and counterforts being fixed, wing walls on the nort 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 1½ 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. 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. Evans.

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. **Mr. Henshaw.**

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.

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. Mr. Dodwell

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.

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 Mr. Peterson.

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.

r. 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.

EUGENE RODOLPHE FARIBAULT.

STUDENT.

FRANK MCMASTER.

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 the 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.

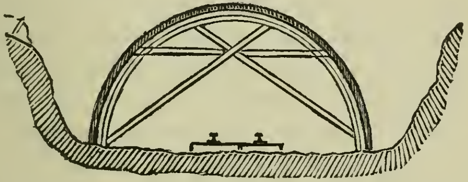
per cubic foot. The greater the velocity of a slide, the heavier the snow composing it becomes, owing to its being more compacted than when the slide travels slower.

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.

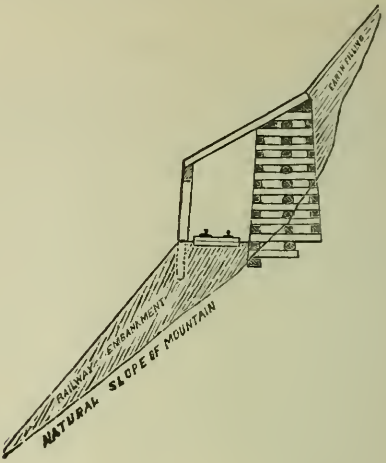
DISCUSSION.

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.

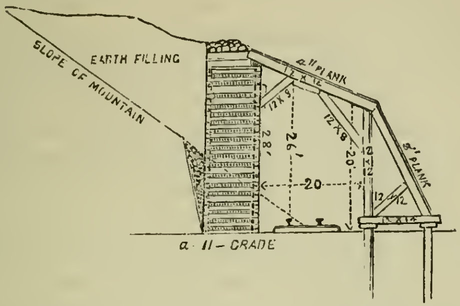
Mr. Smith. Mr. T. Vernon Smith stated that the snow-sheds in the Beaver Valley, where the track is benched into the side of the mountain, with an elevation of perhaps 2000 feet on the right-hand side going west, and a descent of 700 and 800 feet to the river on the left hand, consist of a heavy crib-work 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 Mr. Henshaw. 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, 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 in 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				

Ir. 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. 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 $2\frac{1}{2}$ mills per pound, or \$5 per 2,000 lbs.
47.83 cts. = $191\frac{3043}{} \times 2\frac{1}{2}$ 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 × $2\frac{1}{2}$ 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 petroeum 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, whicl 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 thi Railroad, has drawn from a year's consumption on 143 locomotives, i 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 ess 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 or railway spring work were run with petroleum for six months. The ystem 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 $2\frac{3}{4}$ cents per gallon, to compare avourably with Anthracite coal, and at about $2\frac{1}{2}$ cents per gallon to ompare with Nova Scotia coal. The price of oil in this market today is about $4\frac{1}{2}$ cents per gallon.

The burner which was used in this instance is here for your inspecion. It was found advantageous to keep the oil in the main supply ank at a temperature of about 80° F., in order that the oil might reach he burner in a thoroughly thin and fluid condition, otherwise the parafine 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 passin away up the flue unburnt, in the form of brown smoke.

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

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

That gigantic corporation, the Standard Oil Co., in some parts c the U. S., where they have a larger product of petroleum than they ca market, are offering their fuel oil to manufacturers and fuel user generally, at 65 cents per barrel, or say $1\frac{1}{2}$ cents per gallon, with guarantee that 150 gallons (i. e., $1.85 worth) are equal to 1 ton o 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, nothin but fuel oil is used. In these works about 5,000 tons of bars of stee per annum are re-heated and worked up into railway springs, and superior burning device has been adopted, of which a tracing i submitted for inspection.

After an experience of three years, it has been found, on the average that 152 gallons of oil (Am.) at $2\frac{3}{4}$ cents per gallon, worth $4.18, ar equal to one ton of Lehigh coal at $5.00 per ton (2240). In additio to this, the entire expense of coaling up furnaces, clearing out ashes carting ashes away to dumping ground in distant parts of the city, an the handling of coal is saved, which is estimated to amount to $800 pe annum. Under date of October 29, Mr. Schoer, Superintendent o the Keystone Spring Works, Philadelphia, states as follows:—

"We think we save 20 per cent. by the use of fuel oil at $2\frac{3}{4}$ cents pe gallon, as against Lehigh coal at $5.00 per ton. In addition to that w get a better product from our furnaces, on account of the entire absence o sulphur in the oil; we also get more heat from our furnaces in a give time, on account of the furnaces not being checked and cooled dow 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 lelivered within the retort, the under side of it being heated to assist n volatilizing the oil, the combined vapours or gas passing through and round the regenerative metal burners, where combustion took place. arious styles of burners are shewn, and were experimented with. he heating of the retort could be accomplished by waste heat, or by lame from burners fitted in its base, taking their supply of gas from he upper part of the retort.

The result was unsatisfactory; the conversion of oil to gas appeared o be imperfect; probably the wax gathered, and closed some of the assages; the air admitted internally was in volume not a fraction of hat was required, and that admitted externally (or around the sides f the retort) had a cooling effect upon it, and as this air had no fair pportunity 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 hat the evaporation of water was low, the products of combustion ensely black, depositing soot thickly, and that they were pungently ffensive in odor.

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

The analysis of Ione coal clearly indicates its poor quality, but as nly a rough approximation to the calorific value of even *good* fuels can e made from the information given by simple analysis, much less can he 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 hould be, according to Mr. Clement, four times that of C. H. coal, but t is only 2.88 times.

Inferring that the oil is measured by the U. S. gallon, and that it as a s. g of .85, its thermal value per unit weight compared with Ione oal 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. 5 cents, and oil 55 cents, that is, they are as 1 to 2·2. In other words, he 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 ($\frac{96·5}{88·0}$=1·09) 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 aseous state when combined with coal, so that the formula is untrustorthy for both constants used. Hence the necessity for such practical ests as those carried out by Mr. Clement, who it is hoped will tell ore about the type of spray-jet used, and its actual location, about he boiler, the shape and size of furnace, and, if possible, the temperaure of the escaping products of combustion in the smoke-box; also if ny part of the furnace—especially that on which spray and flame ould impinge—were faced with fire-brick; and lastly, the amount of ir supplied to the furnace; as the total absence of smoke, and the ower steam pressure obtained when oil was burnt—when compared ith other petroleum experiments—lead to the inference that an excesive supply of air was admitted, that it was cold, and perhaps admitted lose to furnace sheets, or perhaps that the temperature of the steam assing through the injection jet was too low to produce the maximum ffect.

Certainly oil fuel had the poorest effect on the Piedmont, with a low-ressure steam jet to feed the oil into the furnace; and there can be no oubt that the mechanical work done in giving motion to the oil and hanging it into spray would further condense the steam, so that it ould enter the furnace as a vapour, not as a gas. It is because ork is performed by the jet, that *super-heated* steam for injection gives 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. . Urquhart. (A copy of his drawing is appended to this paper, ee Plate VII. C.) It is practically the standard apparatus for elivering fluid fuel in Southern Russia, not only in locomotive and tationary service, but also in the steamships plying to and from its orts. In such an instrument there is the least possibility of carbon olidifying to coke and choking the mouth of the nozzle. In most ther forms of spray nozzles it is at times necessary that the oil flow hould be cut off and steam at full pressure turned through the oil assage, with the object of clearing it by blowing out all collected npurities.

The practice usually followed in raising steam from cold water, if ressure cannot be borrowed from a companion boiler to work the spray njector, is to light a wood fire in the furnace, which is kept going until team of just sufficient pressure to start the injector is developed, after hich the wood fire is dispensed with. Many engine-houses are now quipped with a continuous steam pipe having suitable branches and ouplings to all stills, so that if one boiler is alive any or all others using uid fuel can be raised from cold water to a full head of steam in wenty minutes, while it ordinarily occupying two hours to do this with ituminous 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 nto gas in a separate retort, and delivered into combustion chamber mixed with hot air.

Mr. Brown

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 ines.

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 trongly 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 n 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 osts 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 he future, but not sufficiently imminent to cause any anxiety as to the depreciation of their property by its sudden adoption.

Mr. Henshaw.

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 uperior to coal for industrial purposes, particularly where it is desirable to maintain a regular temperature, as in smelting, etc. It saves 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,

A PARTIAL BIBLIOGRAPHY OF PETROLEUM.

BY J. D. BARNETT, M.CAN.SOC.E.

(Items 1 to 18 are from Appendix to Harrison Aydon's Paper on Liquid Fuel: Minutes Proceedings Inst. C.E., (Eng.) vol. 52, p. 196.)

1. Adams, Col. Julius W. Report to the Trustees of the Petroleum Light Company of experiments made at the Morgan Iron Works, New York, on Petroleum as Fuel. 1865.

2. Gesner, A., M.D. A Practical Treatise on Coal, Petroleum, and other Distilled Oils. 8vo. Plates and Cuts. New York, 1865, Bailliere.

3. Richardson, C. J. Petroleum as Steam Fuel. Journal of the Royal United Service Institution, vol. IX, p. 70. 1865.

4. Selwyn, Capt. J. H., R. N. Petroleum as Steam Fuel. Journal of the Royal United Service Institution, vol. IX, p. 62. 1865.

5. Parliamentary Paper, No. 503. Petroleum and Shale Oil. Copy of a Report of the experiments that have been conducted at Woolwich Dockyard, with the view of testing the value of petroleum and shale oils as substitutes for coal in raising steam in marine boilers. 10th August, 1866.

6. Rankine, W. J. M. On the Economy of Fuel, comprising Mineral Oils. Journal of the Royal United Service Institution, vol. XI, p. 218. 1867.

7. Dorsett, G. Liquid Fuel. Dorsett's patent apparatus for applying it to steam boilers and furnaces generally. Tract, 8vo. Vol. CLXIV. London, 1868.

8. Paul, B. H. On Liquid Fuel. Journal of the Society of Arts, vol. XVI, p. 400. 1868.

9. Selwyn, Capt. J. H., R. N. On Liquid Fuel. Transactions of the Institution of Naval Architects, vol. IX, p. 88. 1868.

10. Selwyn, Capt. J. H., R. N. Further information on the employment of Mineral Oils as Fuel for Steamships. Journal of the Royal United Service Institution. Vol. XXI, p. 28, and vol. XXI, p. 119. 1868.

11. Selwyn, Capt. J. H., R. N. On the Progress of Liquid Fuel. Transactions of the Institution of Naval Architects. Vol. X, p. 32. 1869.

12. Sainte-Claire, Deville H. Mémoire sur les propriétés physiques et le pouvoir calorifique des Pétroles et des Huiles minérales. Comptes-rendus des Séances de l'Académie des Sciences, Paris. Vol. LXVIII, pp. 349, 485 and 686. Also see vol. LXVI.

13. Sainte-Claire, Deville H., and Dieudonné, C. De l'emploi industriel des huiles minérales pour le chauffage des machines, et en particulier des machines locomotives. Comptes-rendus des Séances de l'Académie des Sciences, Paris. Vol. LXIX, p. 933. 1869.

14. SELWYN, CAPT. J. H., R. N. On Liquid or Concentrated Fuel. Transactions of the Institution of Naval Architects. Vol. XI, p. 160. 1870.

15. SELWYN, CAPT. J. H., R. N. On Liquid or Concentrated Fuel. Journal of the Society of Arts. Vol. XVIII, p. 543. 1870.

16. DR. PAUL'S Report of the Trial of the SS. "Retriever."

17. PROFESSOR THURSTON'S Investigations.

18. DR. ANTILL'S Treatise on Shales, &c.

19. WRIGHT, WM. Oil Regions of Pennsylvania. 8vo. New York, 1865.

20. ANTISELL, THOMAS. The manufacture of Photogenic or Hydrocarbon Oils. London. Appleton, 1859. 8vo.

21. Petroleum as a Steam Generator in Marine Boilers. (Isherwood) Reports. United States Bureau Steam Engineering. 1867-70.

22. FAIRNIAN, E. ST. JOHN. Petroleum Zones of Italy. 8vo. Spon. 1868.

23. URQUHART, T. Petroleum Refuse as Fuel in Locomotive Engines. Proceedings Inst. M. E. No. 3, 1884, p. 272.

24. RANKINE, W. J. M. Economy of Fuels comprising Mineral Oils. 8vo. London, 1867.

25. Petroleum Fuel Spray Injectors (various). "Engineering" (periodical). June, 22-9, 1883. pp. 518 and 600.

26. ROSS, O. C. D. Petroleum and other Mineral Oils applied to the manufacture of Gas. Minutes of Proceedings Inst. C. E., vol. 40, p. 150.

27. ROSS, O. C. D. Air as Fuel, or Petroleum, &c., utilized by carburetting air. Spon.

28. AYDON, HARRISON. Liquid Fuels. Minutes of Proc. Inst. C. E., vol. 52, p. 177.

29. BRUNTON, R. H. Paraffin and Paraffin Oils. Minutes of Proc. Inst. C. E., vol. 66, p. 180.

30. MANSFIELD, C. B. Application of Hydrocarbons to artificial illumination. Minutes of Proc. Inst. C. E., vol. 8, p. 207.

31. BARRET, M. Combustion of Petroleum Oils. Annales du Génie Civil. January to April, 1874 (Abstract in Minutes of Proc. Inst. C. E., vol. 39, p. 412).

32. WURTZ, PROF. H. (of Zurich). Eames Petroleum Furnace. "Engineering and Mining Journal," New York, Aug. 7, 1875, pp. 122-128 (Abstract in Mins. of Proc. Inst. C. E., vol. 42, p. 336.

33. WURTZ, PROF. H. Fuel and its use. Dingler's Polytechnisches Journal, Band. 219. 3 pp. 185-202 (Abstract in Mins. of Proc. Inst. C. E., vol. 43, p. 399).

34. VASILIEFF, F. Oil wells of Baker-Gorny Journal (Russian Mining Journal, Sept., 1885. Partially translated by W. Anderson). Minutes of Proc. Inst. C. E., vol. 83, pp. 405-414.

35. ASHBURNER, C. A. Product and Exhaustion of Oil Regions. Transactions of American Inst. Mining Engineers. Sept., 1885.

36. Report on Petroleum. United States Congressional Doc., 51, 39th Congress, 1st Sess. Vol. 8. Feb. 26, 1866, p. 39.

37. Derrick and Drill, 8vo. New York, 1865.

38. Wrigley, H. E. Petroleum in Pennsylvania. 8vo. Harrisburgh, Pa. 1875 (Pennsylvania 2d Survey).

39. Peckham, S. F. Petroleum, its products, technology and uses. 4to, 1882.

40. Petroleum Oils. Paper before the American Chemical Society, printed in American Chemist, June, 1876.

41. Report Royal Commission on the Quantity of Coal in the United Kingdom. Blue Book, 1872.

42. Crookes and Rohrig. Treatise on Metallurgy, 8vo. vol. 3. London, 1870.

43. Percy Dr. J. Metallurgy (Fuel). Last edition. 1875. 8vo.

44. Chandler, G. F. Petroleum as an Illuminator, 8vo.

45. Sadtler, S. P. Hydro-carbon compounds. 8vo. Harrisburgh, 1875. Pennsylvania 2d Survey. (See also Am. Journal Science and Art, vol. 10, p. 59, 1875, and Popular Science Monthly, vol. VII, p. 754. 1875.)

46. Full information on Pennsylvania Petroleum is given in the various reports issued by the Second Geological Survey of Pennsylvania. See Reports.

Q, Q^2, Q^3, Q^4, for references to oil rocks in Beaver, Lawrence, Mercer, Crawford, Erie and South Butler counties.

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

See R, R^2 for descriptions of oil rocks in McKean, Elk and Forest counties.

See V, V^2 for notes on the oil rocks of North Butler, and Clarion counties.

See H^2 for oil boring at Cherry Tree, Cambria county.

See G^5 for oil boring in Wayne county.

47. Barff, Arthur. Petroleum as Fuel. Journal of the Society of Arts, 1880. Vol. XXVIII, pp. 761-811.

49. Clarke, N. B. Petroleum as a source of emergency power in warships. Journal Franklin Inst., May, 1884, p. 341.

49. Warren, C. M. On Chemistry of Petroleum. See papers in American Journal of Science and in Chemical News. 1863 to date.

50. Shorlemmer, —. Chemistry of Petroleum. Quarterly Journal Chemical Society, vol. XXV, p. 425. Also American Chemist, vol. II, p. 454.

51. Pelouze, Cabours, Berthelot. Chemistry of Petroleum in Annales de Chimie et de Physique. Paris, 1863 to date.

52. Attfield, John. On testing Petroleum. Chemical News, vol. XIV, p. 257.

53. Calvert, F. C. On testing Petroleum. Chemical News, vol. XXI, p. 85.

54. Chandler, C. F. On testing Petroleum. American Chemist, vol. II, p. 409.

55. Abel, F. A. On testing Petroleum. Chemical News, vol. 35, p. 73.

56. Peckham, S. F. Bibliography and Monograph on Petroleum in Reports of 10th Census U. S., 1881 (exceptionally complete).

57. For general discussion, history, probable sources, amount of supply and theories of formation, see the works and various contributed papers of T. Sterry Hunt; J. F. Carll; C. A. Ashburner.

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.

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 what-"ever may be necessary to accomplish said object; but shall not im-"pede 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 sub-"mitted to the Secretary of War for his approval.

"This Act also provides that the bridge, at the option of the corpo-"ration 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 brickwork, 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 2½ miles to 3¾ miles per hour, at stage of 92. The calculated rate of current at stage of 100·0 is 4⅓ 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............	61¼	0	15 3/10
	Same, shaken down, microscopic grains of sand	74	1	2½
" 2	Two feet from surface, 4″ thick. Clay, organic matter and fine sand..................................	74¼	1	2 1/16
	Same, shaken	81¼	1	4 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 12/16
	Same, shaken down..................................	81¼	1	3 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

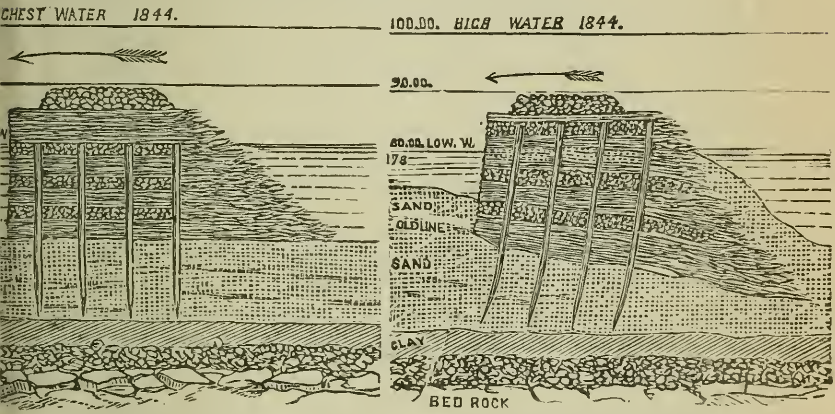
From the above figures it is not difficult to account for the formation of bars in slack water, independent of the shifting of the sand.

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 $3\frac{1}{2}$ 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 necsssary 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 enormons 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.

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

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

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

The subject of construction on sandy or alluvial soils has long gaged the speaker's attention. During a seven years' residence in the rth of Europe, he has examined with interest a number of works; but ough admiring their massiveness, and the skill shown in their conuction, he has always been oppressed by the almost universal sameness idea implied in their design. Smiles tells us that the first engineer England was brought over from Holland, and we find that to the esent day, when works of the kind we are speaking of are desired, ople still go over to Holland to study the antiquated structures of nturies ago, or their copies. Why? Because they are orthodox, the ork of the old masters; as if science had not progressed since their ne, or as if their knowledge of it left nothing valuable to be discoved. The result has been rather to condense and crystallize old ssiliferous 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 iver, would be a very costly operation, quite beyond the means of rdinary capitalists. What really was done was to build a dyke with he deliberate intention of having its face undermined, but with breadth nough to secure it in its place until the face had sunk upon the underiined bottom and thus form a protection against further erosion, and his its elastic construction enabled it, so far as we know, to do very ffectively.

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

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

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

To explain how this may be done would take up far too much me, and is foreign to the object of the present remarks, which are only itended to draw attention to the value of Mr. Killaly's paper, as pointig onward to still higher conceptions of what may be done in carrying it 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 han two points of support can be had, or the beam is not long enough o 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 he 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 munici-ality represented in its city council by illiterate men, to allow an ngineer or architect to build a retaining wall of sufficient strength, ufficiently thick at bottom to hold out as it should do for its natural ife against the horizontal thrust and overturning tendency of the naterial behind it, often so liquid—or rather so fluid—when composed f quick sand or of earth diluted with water, that it must be assimilated n stress to that of water pressure for purposes of calculation.

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

There are other defects to be guarded against, as the bulging out of alls of certain structures, by the stress of vaults and arches when not unteracted either by a proper thickness of wall or by the strength-ning thereof by buttresses, or by loading from above by adding to the eight, or by applying iron ties to counteract the spreading tendency. gain it is hardly necessary to speak of the very bad effect of the pearance of a corner pier of any building, when as is often the case 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 abov quantity. A cubic yard of the stone used for sinking the crib weighed $1\frac{16}{100}$ long tons, so that it took about 334 tons to sink a tida harbour crib block. As each crib block was sunk, it was backed u with large rubble stone and clayey materials, the backing taking th 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 $8\frac{1}{4}$-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 $12\frac{1}{2}$ 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 $7\frac{1}{2}$-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 $\frac{1}{4}$ 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 $2\frac{1}{2}$ 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 $26\frac{1}{2}$ feet below low water, and ubsequently filled with concrete.

These cribwork blocks differ somewhat from those employed in the onstruction of the tidal harbour quay wall of the Louise embankment. The face, instead of being composed of longitudinal full timbers and ntremise filling pieces, in alternate courses, is made up altogether of full timbers, which are halved on to the dove-tailed heads of the cross ies; 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, nstead of the hoarding of 3 inch planks; these piles are placed in posiion 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 $20\frac{1}{2}$ 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 $1\frac{1}{2}$ 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

rea enclosed is dredged out to 32 feet below low water, and a bottom
f concrete, composed of the same materials and in the same proportions
s that used in the cribwork blocks, put in over the entire area,
r a depth of 12 feet, the sand bottom having been first covered with
anvass. When placing concrete in the cross wall crib blocks, a tally was
ept of the number of casks of cement used, and of the number of skips
f concrete (each containing one cubic yard) put down; the cubical
ntent of the concrete space in each crib was also calculated.

From the above data, the loss of bulk due to mixing the materials,
nd also the shrinkage of the concrete due to consolidation when placed
the work, can be deduced. Each batch of concrete before mixing,
ntained 29.32 cubic feet of aggregates, made up of 4.18 cubic feet of
ment, 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
ixed ; these batches measured 20901 cubic yards, skip measure, and
lled in the cribs a space containing 18476 cubic yards. As each batch
ntained before mixing 29.32 cubic feet, and as the number of batches
ixed was 23520, the materials therefore before mixing aggregated
5541 cubic yards. The concrete formed by mixing the above mate-
als measured, before being placed in the work, 20901 cubic yards ;
ere was consequently a loss of about $18\frac{1}{5}$ per cent. in bulk, due to
ixing. Of the materials used to form the concrete, 16.74 cubic feet in
ch batch consisted of broken stone in which the voids amounted to
4 per cent. of the bulk, or to about 9 cubic feet. Had the voids in this
one been filled by the process of mixing, the batch should have lost 9
ubic feet in bulk, or have been reduced from 29.32 to 20.32 cubic feet;
y actual measure, however, the batch only lost $18\frac{1}{5}$ per cent. in bulk
ual to 5.34 cubic feet by mixing, or was reduced from 29.32 cubic
et to 23.98 cubic feet. It would follow from this that either voids,
ual to 3.66 cubic feet, remain in the broken stone, after mixing, or
at the materials have increased in bulk by this amount, during the
rocess of mixing.

In order to ascertain what change in bulk took place when mixing sand
nd cement together, in the proportions used for the above mentioned con-
ete, the writer first mixed dry 864 cubic inches of sand with 432
bic inches of cement, and found that there was no loss of bulk, the
ixture measuring 1296 cubic inches. He then remixed the materials,
dding a small quantity of water, so that the mixture should be of the
me consistency as that used for concrete placed under water, and
en found that the mixture measured 1477 cubic inches, having
creased in bulk by 181 cubic inches or about 14 per cent. Allowing

for this increase in bulk, a batch when mixed would be compose somewhat as follows :—

		cub. ft.	
Original bulk of materials...........................		= 29.32	
Loss due to mixing $18\frac{1}{5}$ per cent....................		= 5.34	23.9
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................			31.0
Lost in voids of stone....................			7.1

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 th process of mixing.

The above result would only be obtained when a small quantity o water was used for mixing. When sufficient water is added to mak the cement and sand into a thick mortar, such as would be used fo 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 o the centre line of the dock. The pressure of the water brings the wo meeting faces together, which thus form a water-tight joint.

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

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

The plan Fig. 13 shews the position and size of the culverts used for ooding the dock, and for carrying off the water discharged by the umps, the arrows marking the course taken by the water during the peration of pumping out. These culverts are circular and are con-ructed of masonry.

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

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

In addition to the main engines, an auxiliary engine is provided for orking the drainage pumps and the caisson hauling machinery. To erate the caisson hauling machinery it must do work equivalent to fting 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 60(gallons 50 feet in one minute.

The following is the general specification for the Portland cemen 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 250(meshes to the square inch, without leaving more than 20 per cent. o its bulk as residue, or through a sieve of 1600 meshes to the squar inch without leaving more than 10 per cent. of its bulk as residue; an must weigh not less than 112 pounds to the imperial striked bushel, o 87¼ pounds per cubic foot. It shall be deposited upon the works a least one month before it is required for use, and at least two tests shal be made; one at the time of the delivery of the cement, and another o the tenth day after delivery. These tests are to be made from sample taken from every twenty-fifth bushel. After having been mixed and cast in moulds as directed, they shall remain in the open air for twelv hours, and then be immersed in water for seven clear days, at the en 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 Briquets.	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	$2\frac{11}{16}$	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	$\frac{49}{1}$	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 he result of experiments made in Germany on the effect of mixing salt vith the water. It was found that concrete made when eight per cent. f salt was added to the water was very much stronger than that made vith pure water when the weather was very cold. Unfortunately no nention was made of the strength of similar concrete made at a higher emperature. The salt seems to have kept the water from freezing onger 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 ribs of concrete were to be placed—a twelve inch pile was far too mall, as the sand would yield under it by being displaced laterally—however, the experiments, if they gave incorrect results, would rr on the safe side.

Mr. Henshaw.

The speaker has not had an opportunity of visiting the works treated f in Mr. Boswell's paper, nor of conversing with any one connected vith them. He has had only the paper to go by, and he hopes that nuch of the severe criticism he is about to utter may be found to have een made under a misapprehension of its statements; yet, the paper eems 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 erm; for it gives a description of things to be avoided, rather han 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 e 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 o 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 $1\frac{1}{2}$ 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=2850 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 instance 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.

THE INTERNATIONAL COLLIERY, BRIDGEPORT, C

Fig. 1.

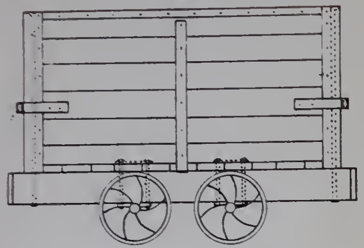


Fig. 2.

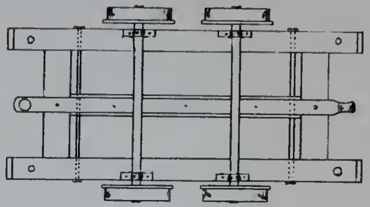
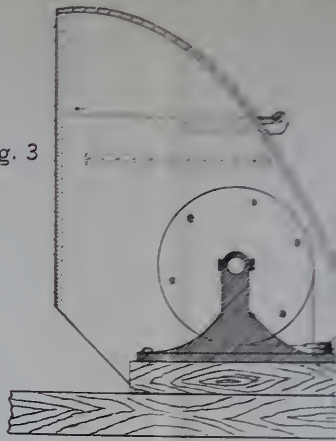


Fig. 3



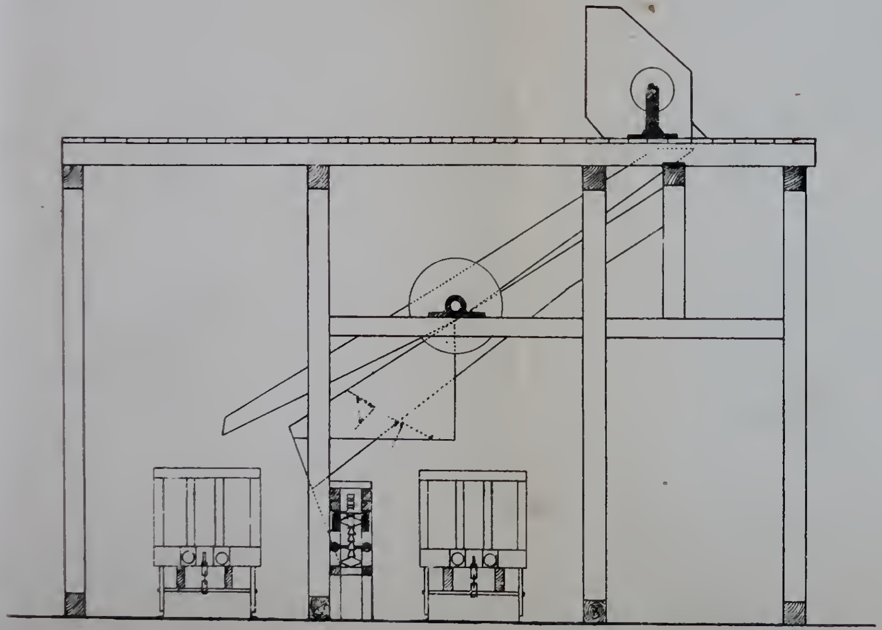
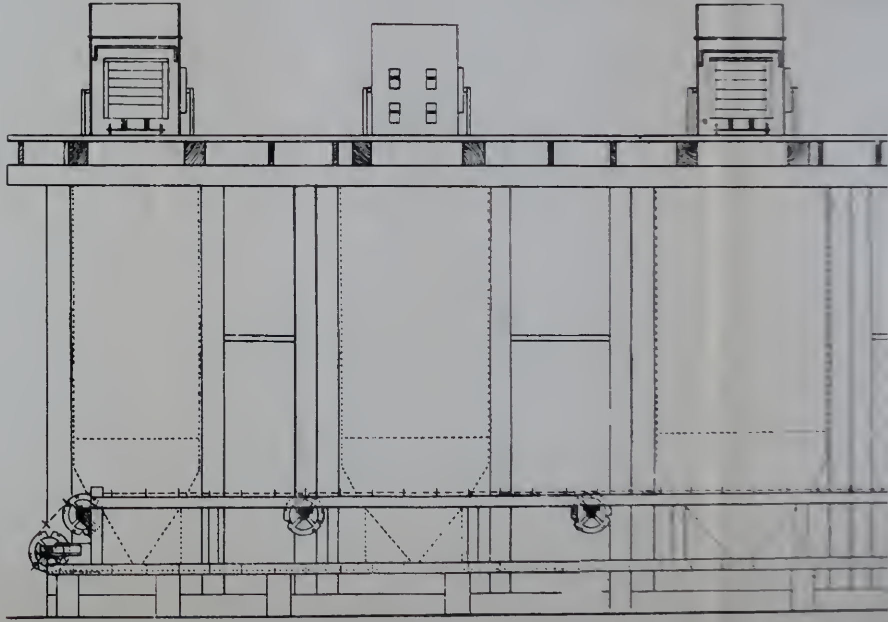


Fig. 4.



F

ONAL COLLIERY, BRIDGEPORT, CAPE BRETON.

Fig. 3.

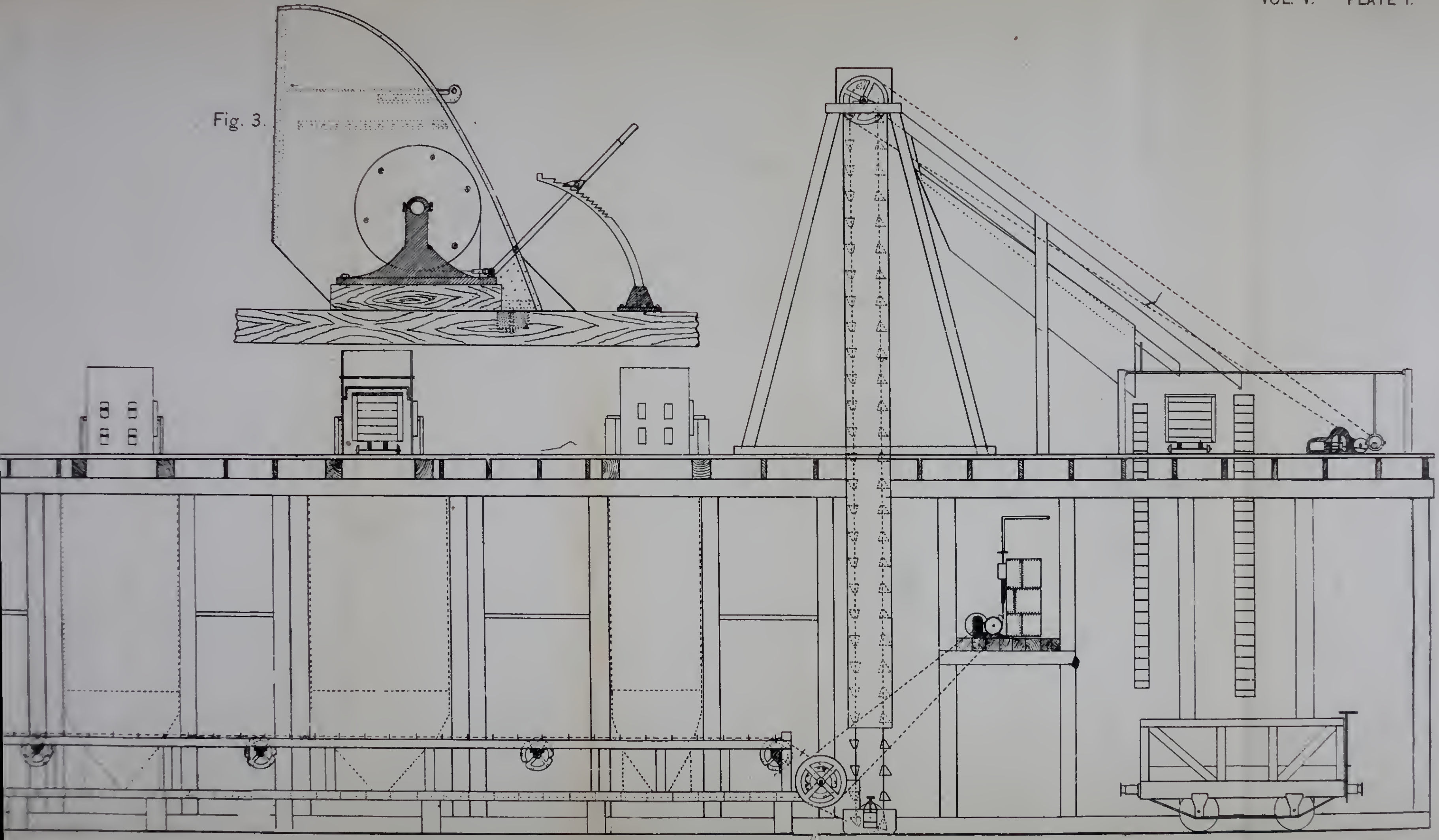
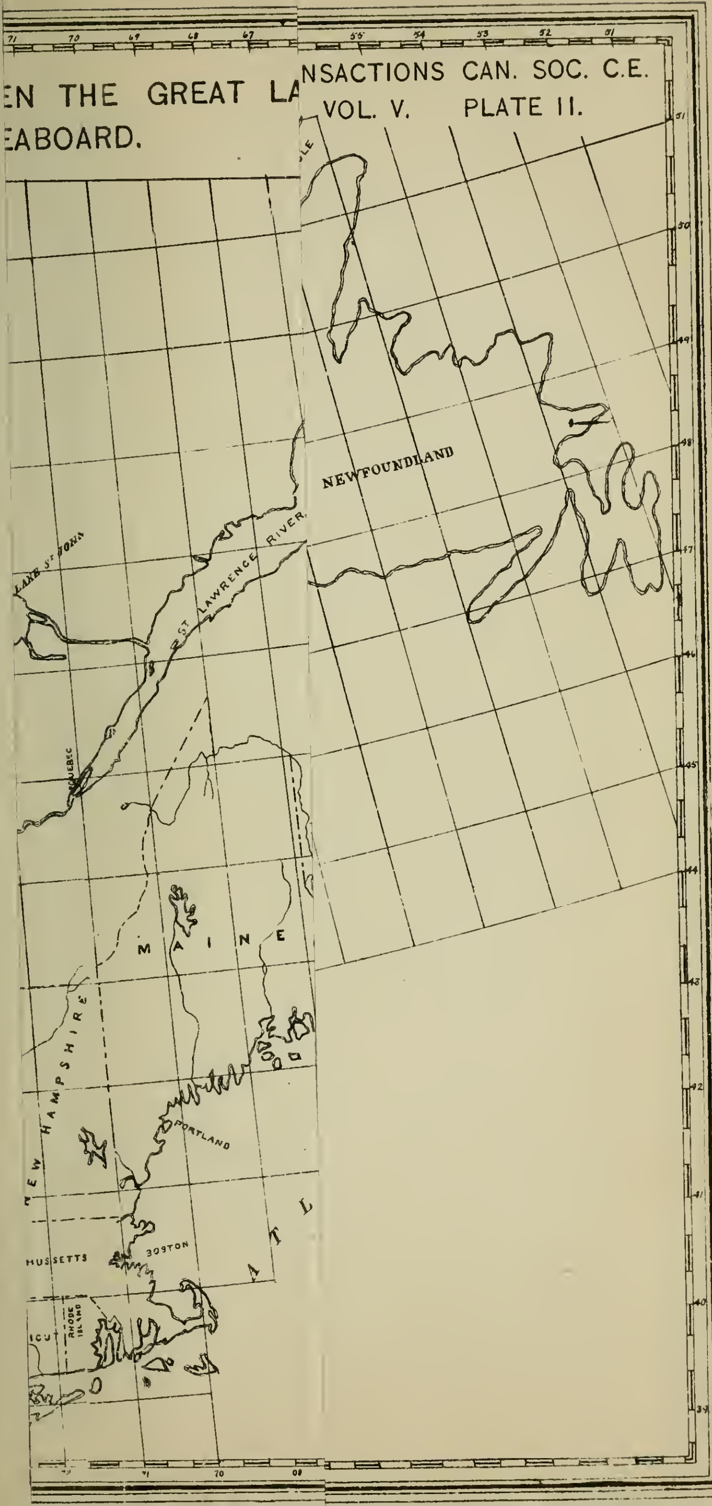


Fig. 5.

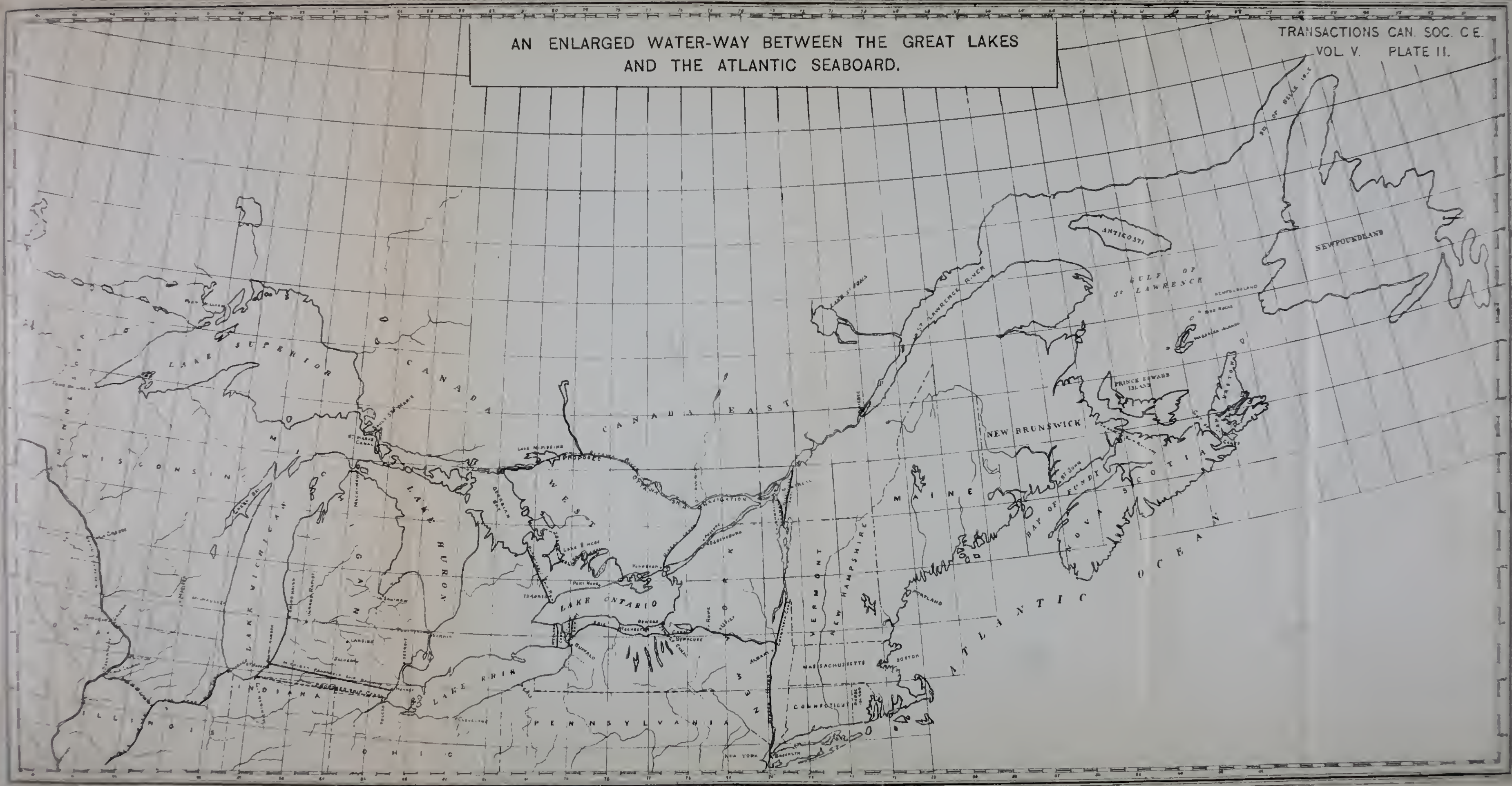
NSACTIONS CAN. SOC. C.E.
VOL. V. PLATE II.

EN THE GREAT LA
EABOARD.



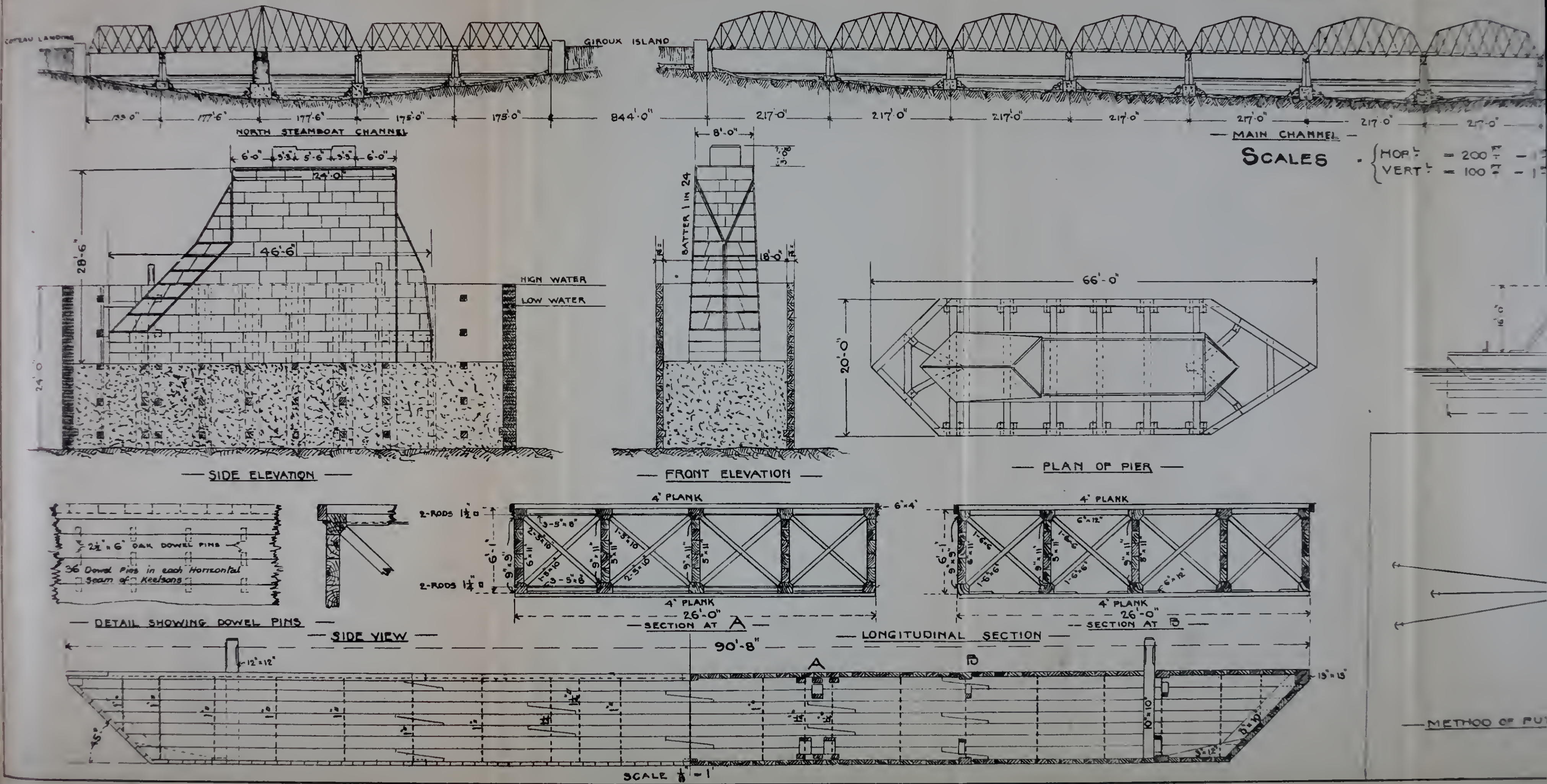
TRANSACTIONS CAN. SOC. C.E.
VOL. V. PLATE II.

AN ENLARGED WATER-WAY BETWEEN THE GREAT LAKES AND THE ATLANTIC SEABOARD.



CANADA ATLANTIC RAILWAY BRIDGE OVER THE ST. LAW

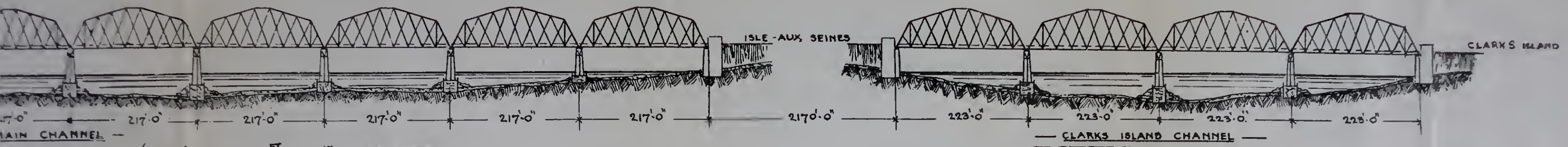
GEO. A. MOUNTAIN, CHIEF ENGINEER.



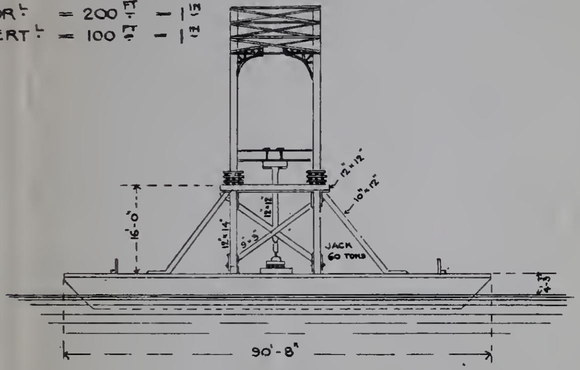
IDGE OVER THE ST. LAWRENCE RIVER AT COTEAU.

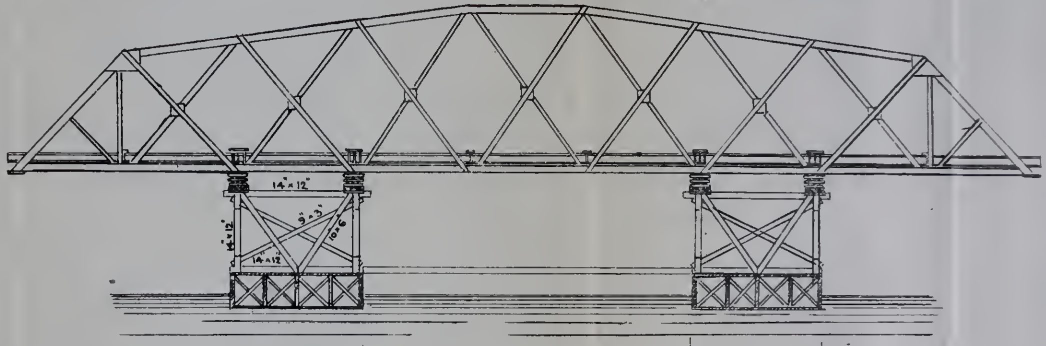
O. A. MOUNTAIN, CHIEF ENGINEER.

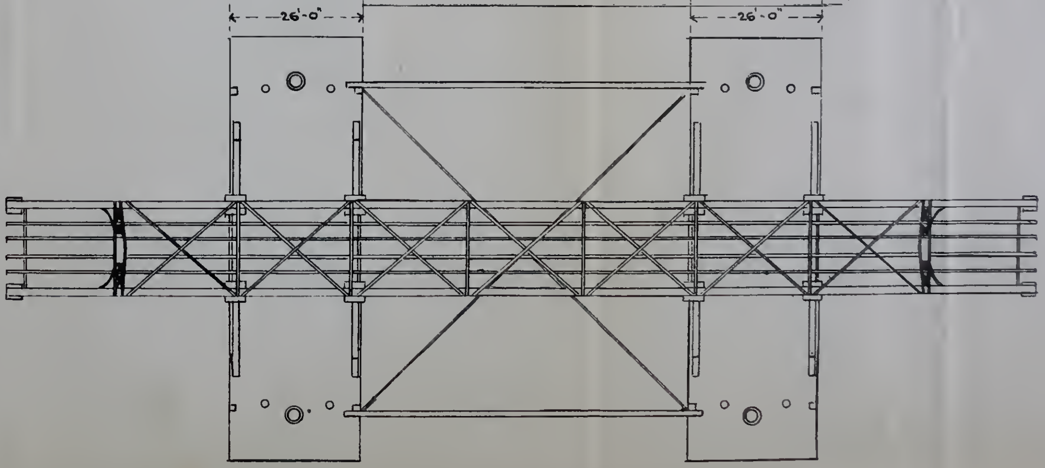
TRANSACTIONS CAN. SOC. C E.
VOL. V. PLATE III.

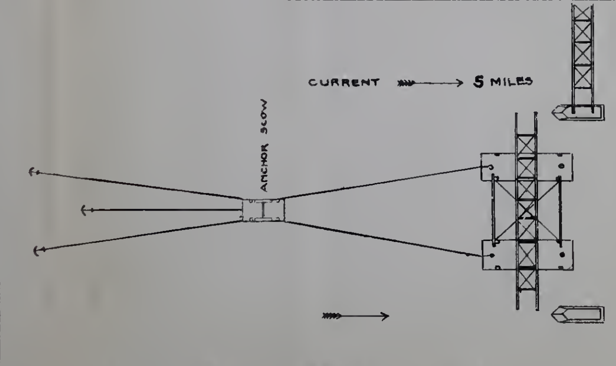


SCALES - HORL = 200 FT - 1 IN
VERTL = 100 FT - 1 IN



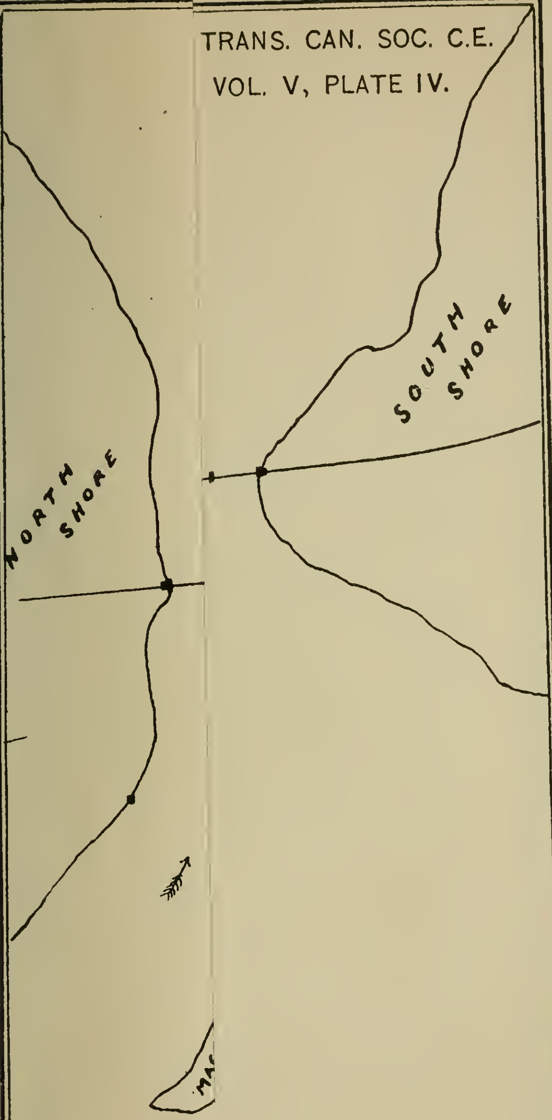






METHOD OF PUTTING SPANS IN PLACE

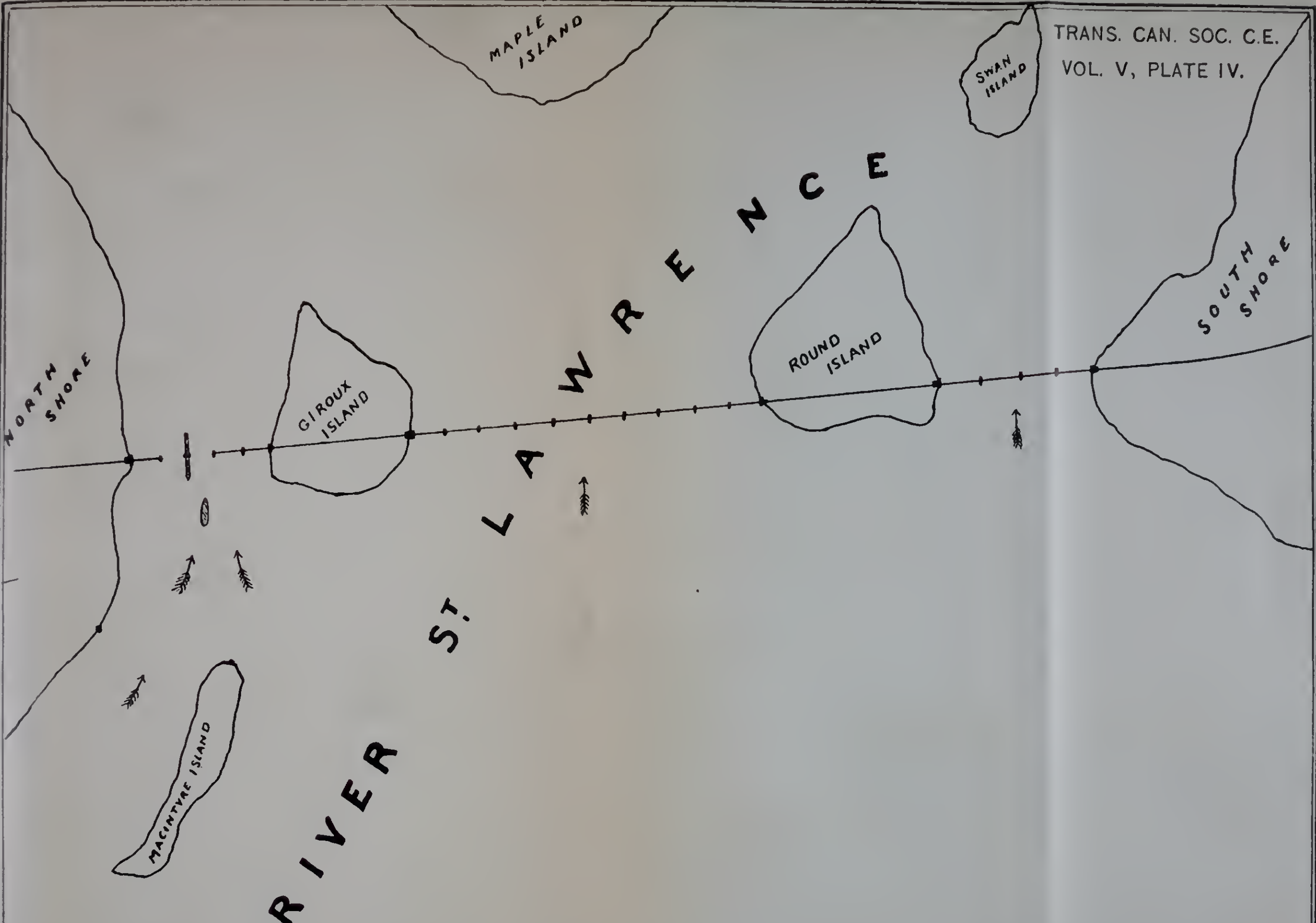
TRANS. CAN. SOC. C.E.
VOL. V, PLATE IV.



ILWAY BRIDGE

COTEAU.

A. MOUNTAIN,
CHIEF ENGINEER.



SITE OF CANADA ATLANTIC RAILWAY BRIDGE

OVER THE ST. LAWRENCE RIVER AT COTEAU.

GEO. A. MOUNTAIN,
CHIEF ENGINEER.

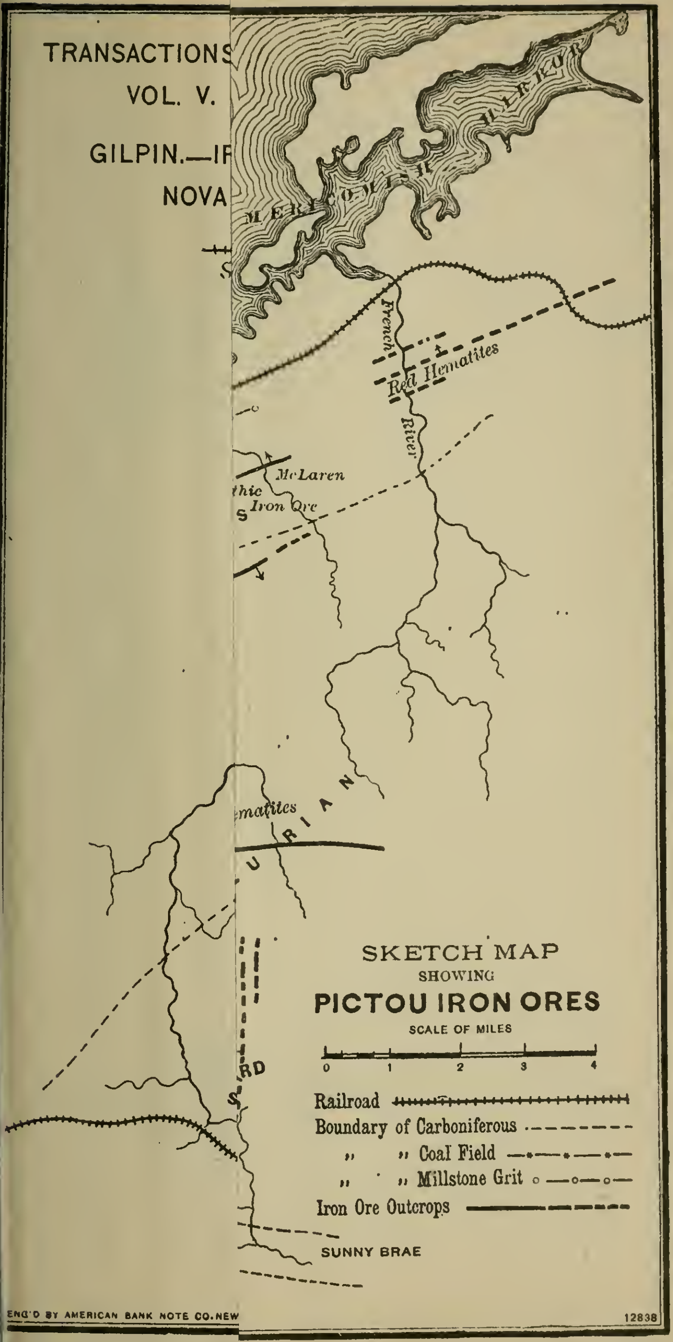
GILPIN —
IRON ORES OF NOVA SCOTIA

TRANSACTIONS CAN. SOC. C. E.
VOL. V. PLATE V.

Sketch Map of
Nova Scotia
Showing Iron Ore
Deposits
Gilpin Jr

TRANSACTIONS
VOL. V.

GILPIN.—I
NOVA



TRANSACTIONS CAN. SOC. C. E.
VOL. V. PLATE VI.

GILPIN.—IRON ORES OF
NOVA SCOTIA.

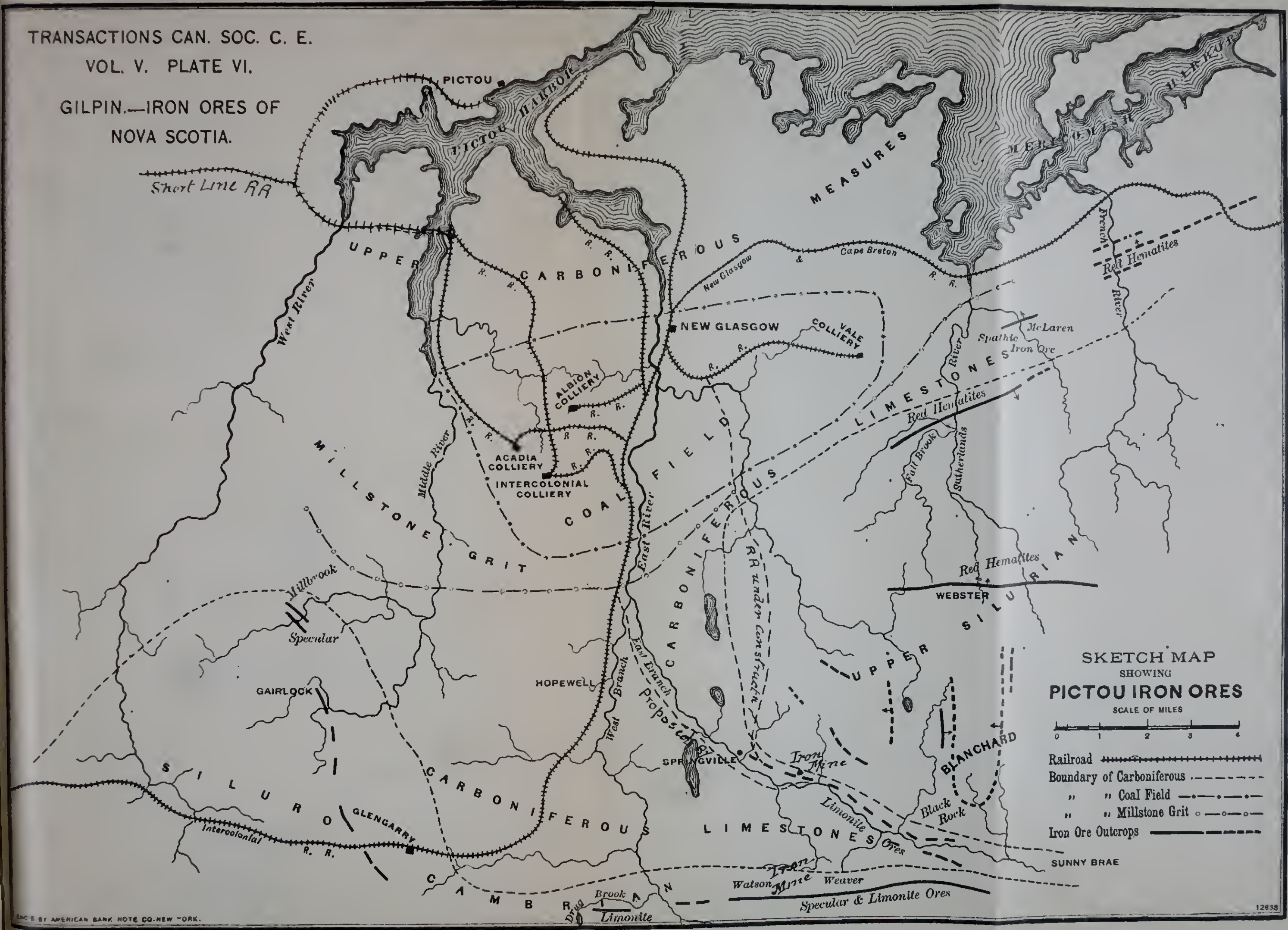


PLATE 6

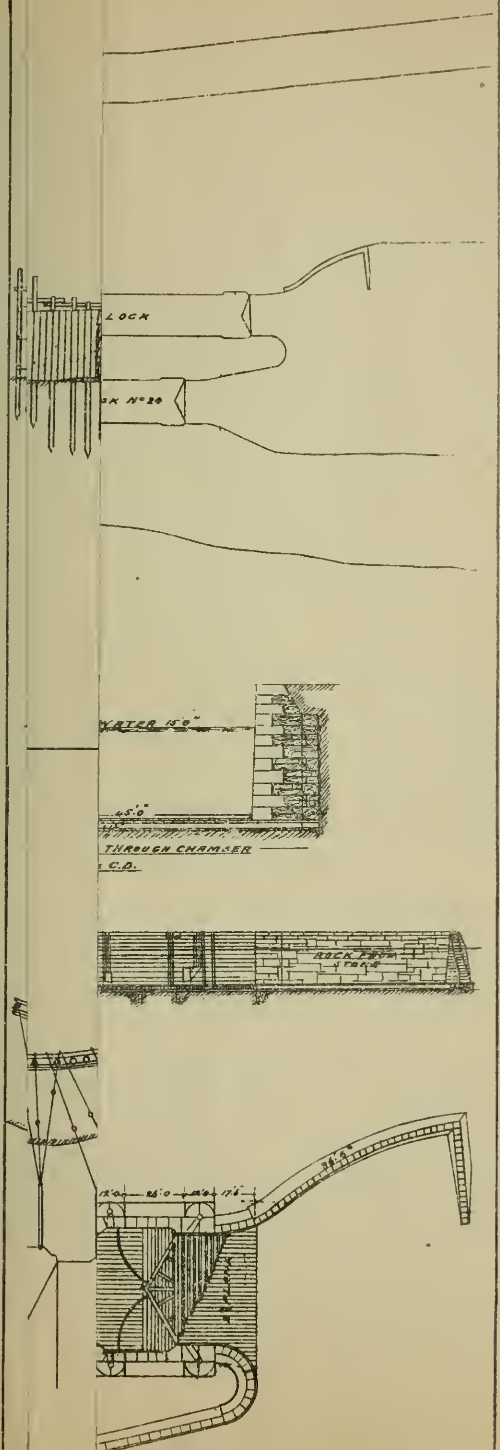
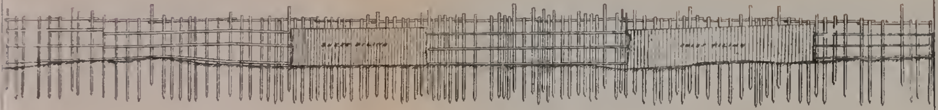

LOCK
K Nº 24
WATER 15'0"
45'0"
THROUGH CHAMBER
C.D.
ROCK FROM STOPS
12'0
26'0
12'0
17'6
34'6"

PLATE 5

RAPIDE PLAT CANAL

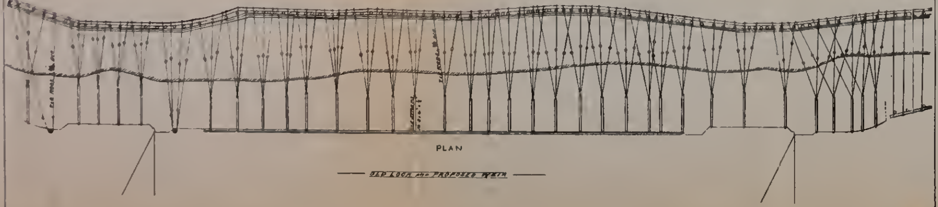
DAM TO PROTECT SOUTH BANK OF LOCK PIT



LONGL SECTION

GENL CROSS-SECTION

CENTRE LINE OF GUARD LOCK



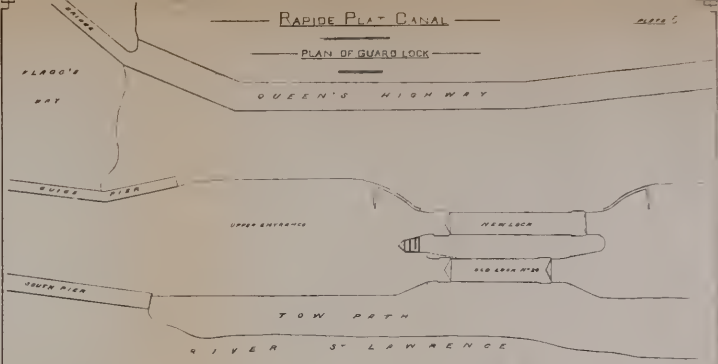
PLAN

OLD LOCK AND PROPOSED WEIR

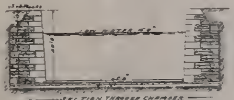
PLATE 6

RAPIDE PLAT CANAL

PLAN OF GUARD LOCK

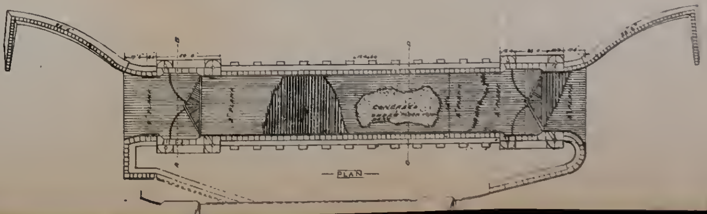


SECTION THROUGH A B



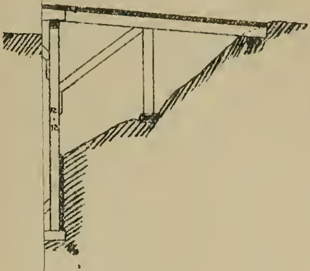
SECTION THROUGH CHAMBER
ON LINE C D

LONGL SECTION

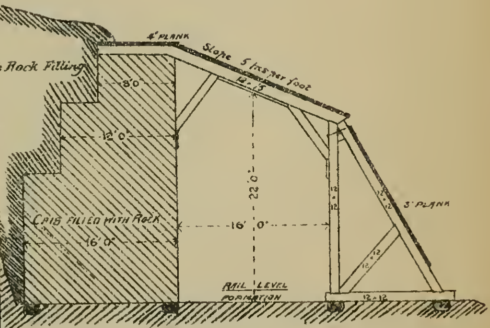


PLAN

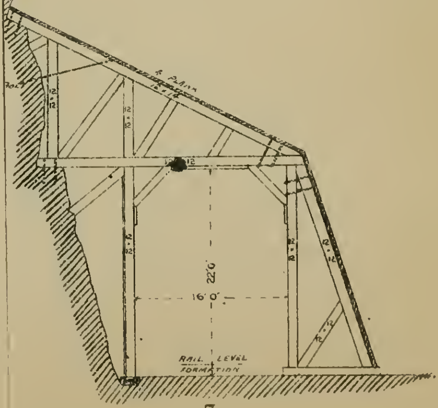
Plate VII.


12
12


12 × 15
4" × 12


4" PLANK
Slope 5 ins per foot
12 × 15
Rock Filling
8' 0"
12' 0"
22' 0"
CRIB FILLED WITH ROCK
16' 0"
16' 0"
12
12
12
12
3" PLANK
12
12
RAIL LEVEL
FORMATION
12 × 12

5

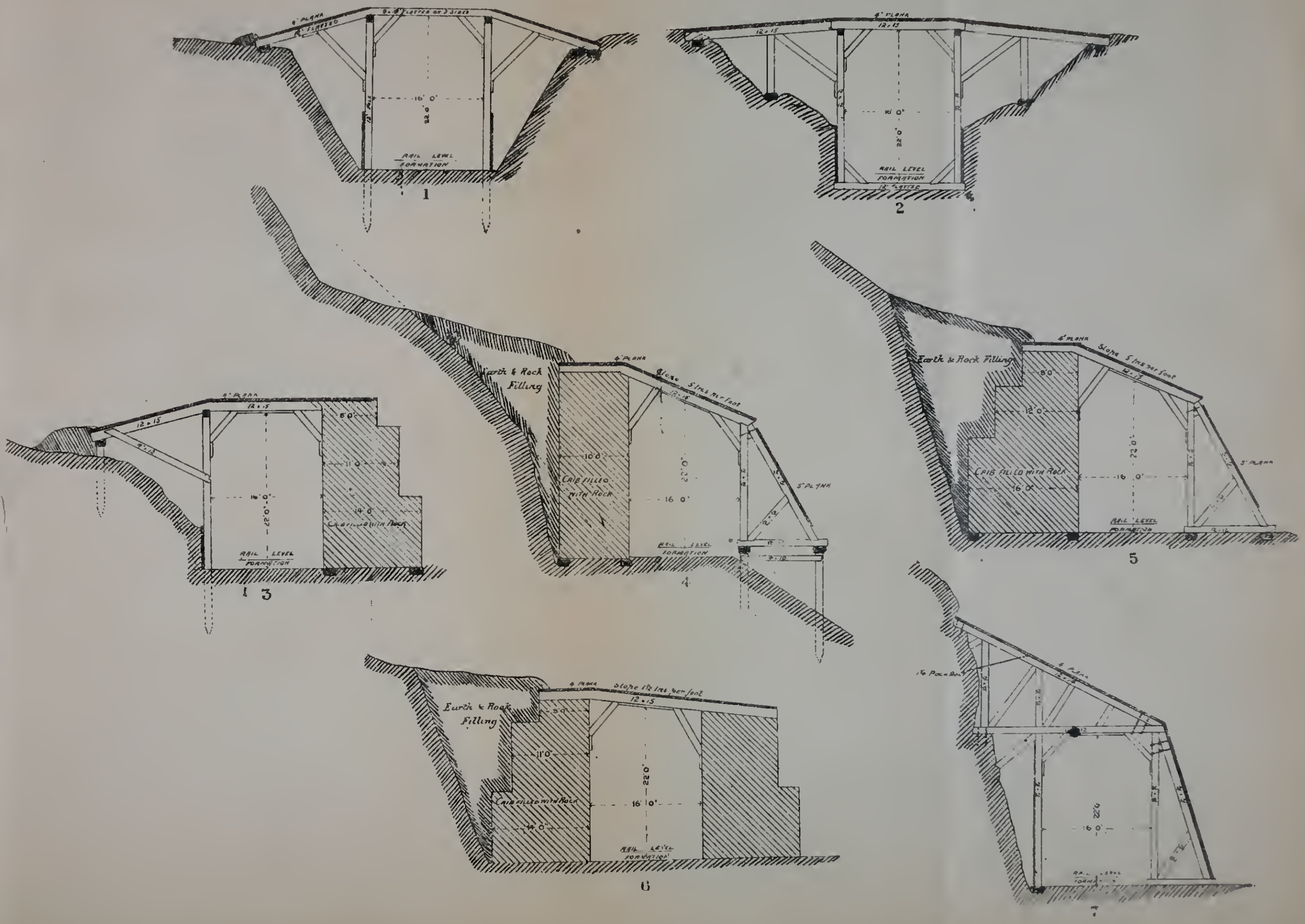

4" PLANK
12 × 14
BOLT
12
12
12
12
12
12
12
12
12
12
12
12
12
12
22' 0"
16' 0"
RAIL LEVEL
FORMATION

7

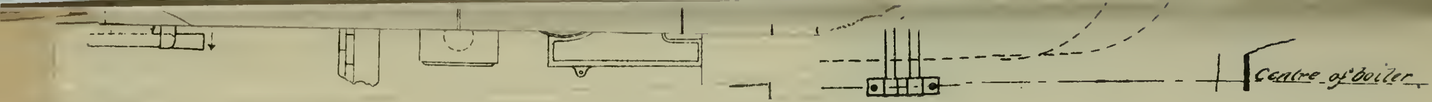
C. P. R.

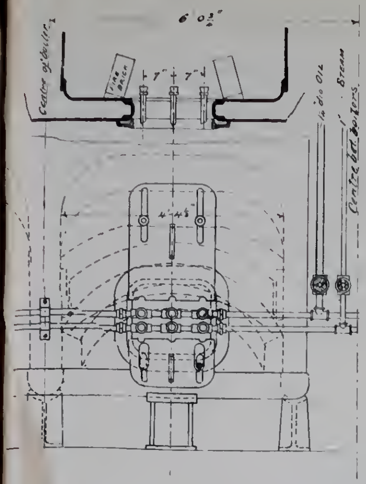
PACIFIC DIVISION SELKIRK SECTION

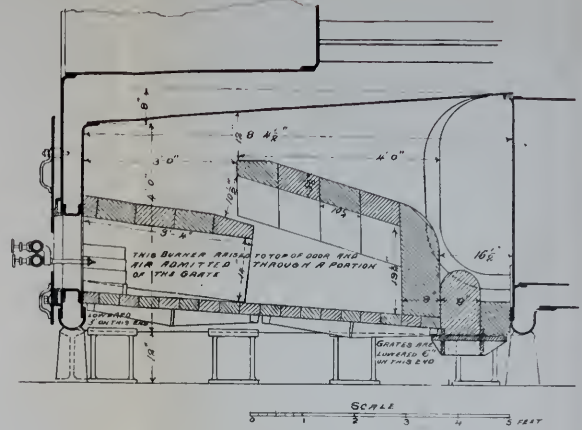
SNOWSHEDWORK: 1886

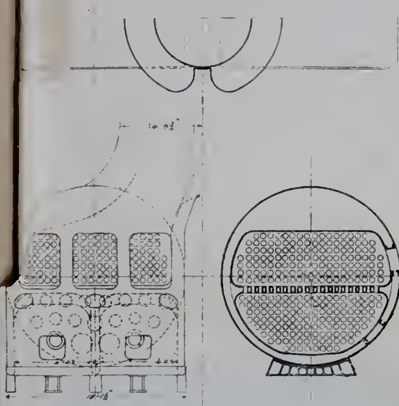


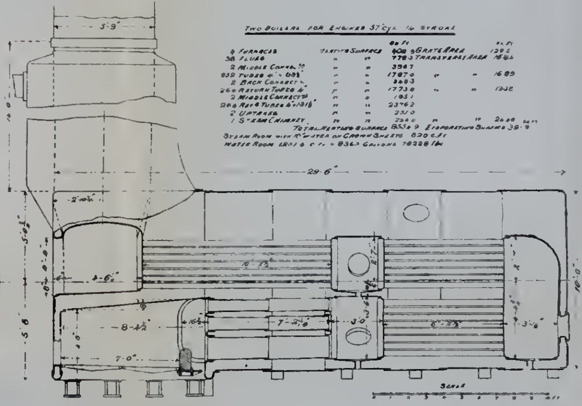
SYSTEMS OF SNOWSHEDS BUILT IN 1886

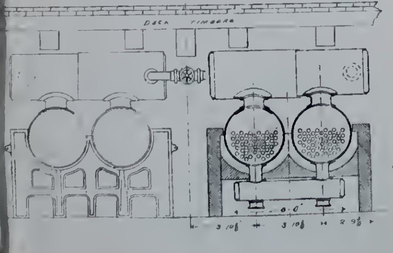

Centre of boiler

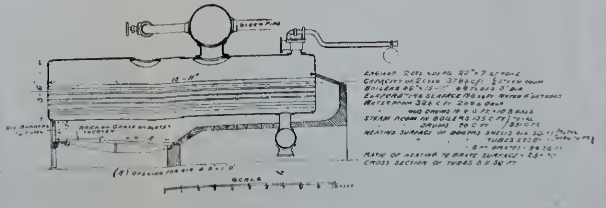

6' 0½"
Centre of Boiler
FIRE BRICK
7"
7"
¾" dia Oil
1" Steam
Centre bet. Boilers
4' 4½"


8"
2' 8 ½"
3' 0"
4' 0"
4' 0"
10½"
10½
3' 4"
THIS BURNER RAISED TO TOP OF DOOR AND AIR ADMITTED THROUGH A PORTION OF THE GRATE
19½
16½
LOWERED 3" ON THIS END
GRATES ARE LOWERED 6" ON THIS END
12"
SCALE
0
1
2
3
4
5 FEET

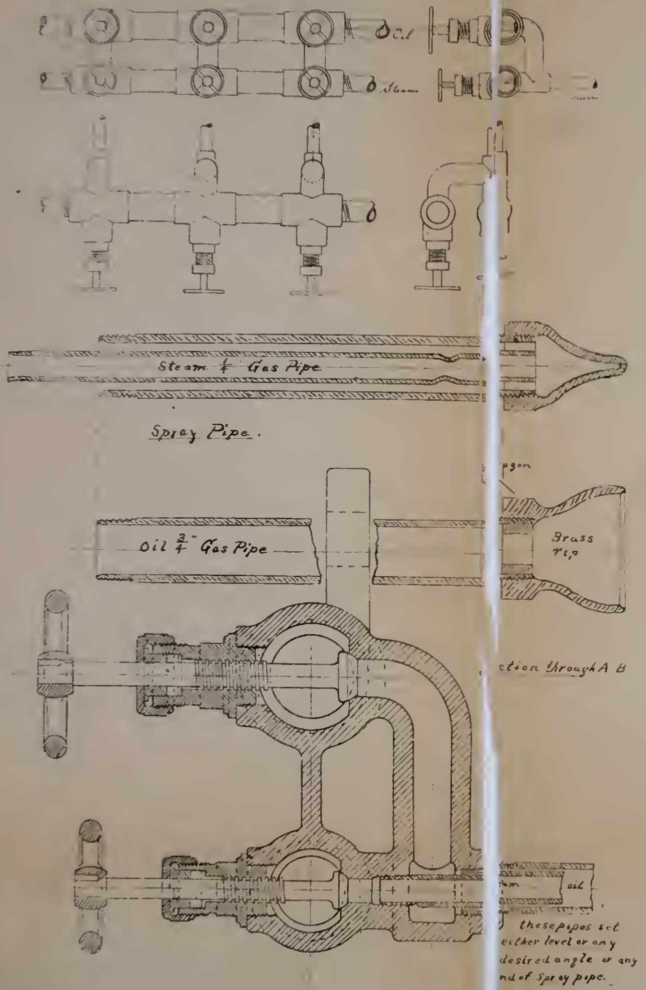

14' 0½"
10' 1½"


5' 9"
10' 0"
TWO BOILERS FOR ENGINES 37" CYL 14 STROKE
Sq Ft
4 FURNACES HEATING SURFACE 402 GRATE AREA 129 5
38 FLUES " " 778 3 TRANSVERSE AREA 16 64
2 MIDDLE CONNECTNS " " 394 7
832 TUBES " " 1787 0 " " 16 09
2 BACK CONNECTNS " " 340 3
264 RETURN TUBES 4" " " 1773 4 " " 13 58
2 MIDDLE CONNECTNS " " 105 1
206 RET TUBES " " 2376 2
2 UPTAKES " " 251 0
1 STEAM CHIMNEY " " 234 0 " " 26 48 Sq Ft
TOTAL HEATING SURFACE 8554 9 EVAPORATING SURFACE 39 9
STEAM ROOM WITH 8" WATER ON CROWN SHEETS 820 C FT
WATER ROOM 1301 6 C FT = 8363 GALLONS 78228 lbs
29' 6"
2' 10½"
5' 0½"
4' 6"
8' 4½"
7' 0"
7' 2½"
16½
3' 0"
5' 8"
10' 0"
3' 4"
SCALE


DECK TIMBERS
6' 0"
3' 10½
3' 10½
2' 9½


STEAM PIPE
13' 4"
3' 6"
OIL BURNERS IN FRONT
BACK OF GRATE OR PLATES TO COVER
(A) OPENING FOR AIR 8 x 1' 0"
SCALE
ENGINES 2 CYL 4 DIAS 22" x 7 STROKE
CAPACITY OF 2 CYLS 378 C FT
BOILERS 48" x 15' 4" 48 TUBES 3" DIA
EVAPORATING SURFACE 136 SQ FT
WATER ROOM 324 C FT
TWO DRUMS 10 C FT
STEAM ROOM IN BOILERS 135 C FT } TOTAL
" " DRUMS 96 C FT } 231 C FT
HEATING SURFACE OF BOILERS SHELLS SQ FT
" " " TUBES
" " GRATES
RATIO OF HEATING TO GRATE SURFACE = 23
CROSS SECTION OF TUBES 8 SQ FT

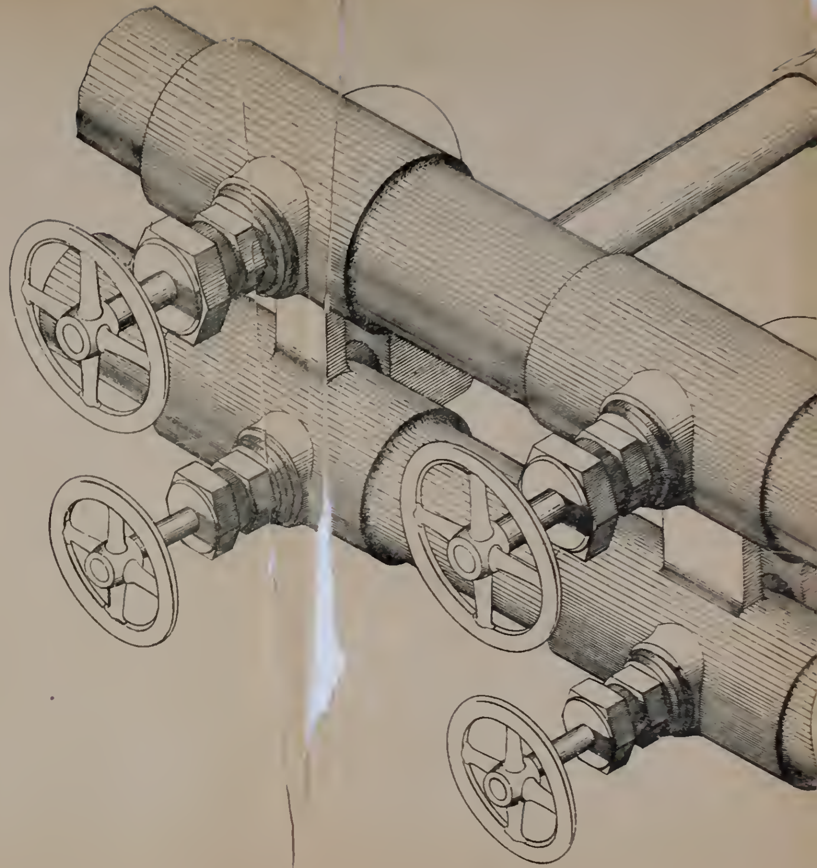
NOTES ON PETROLEUM OIL BURNER.



Spray Pipe.

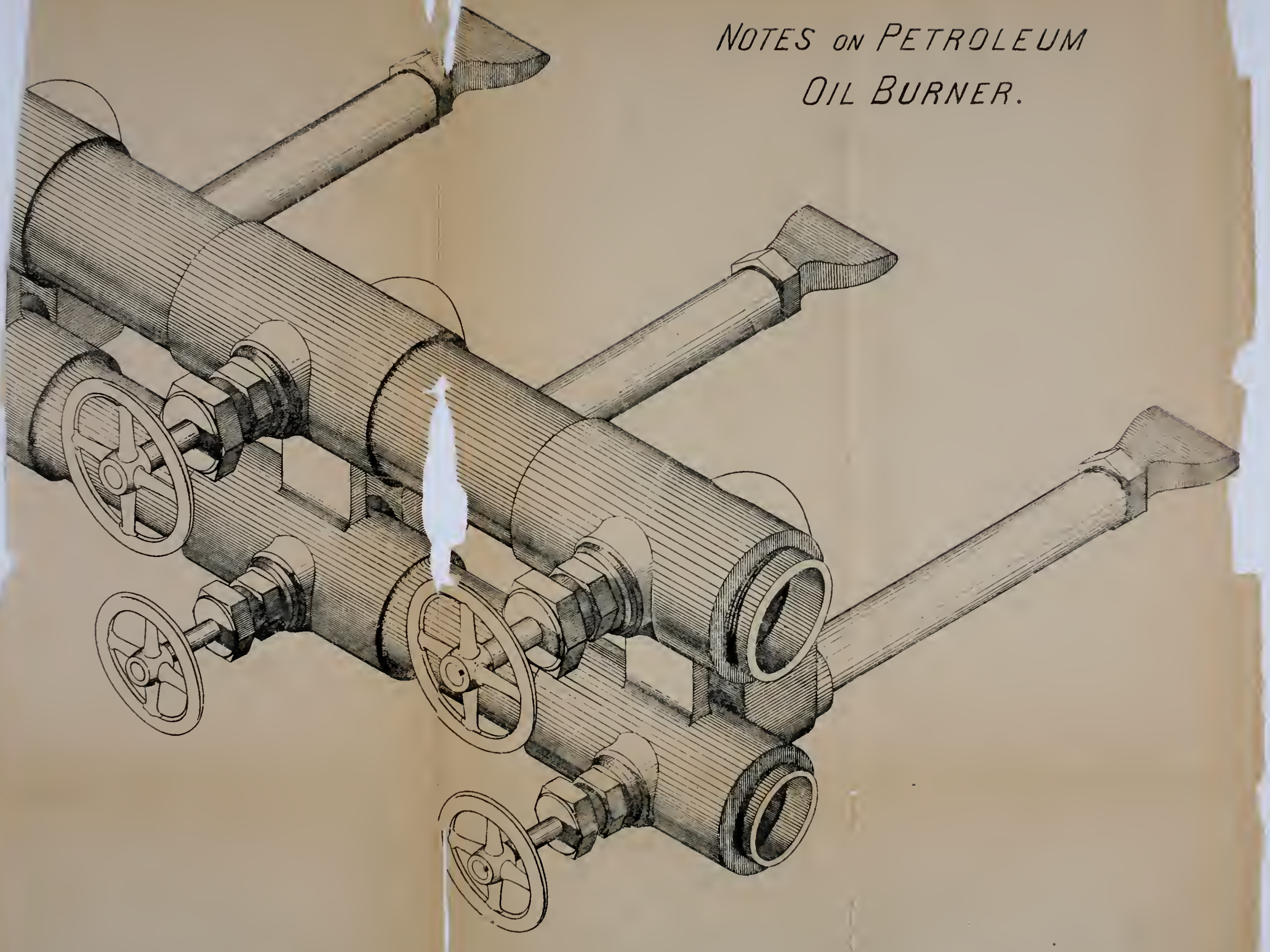
ction through A B

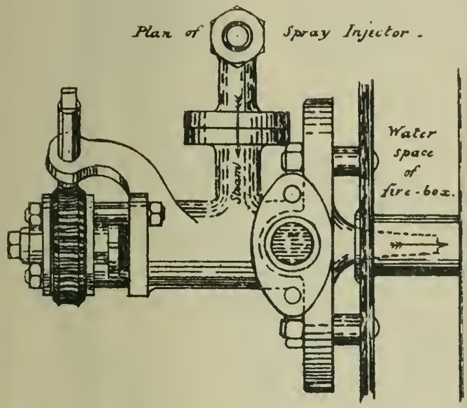
these pipes set
either level or any
desired angle or any
nd of Spray pipe.



THE BURLAND LITHOGRAPHIC CO MONTREAL

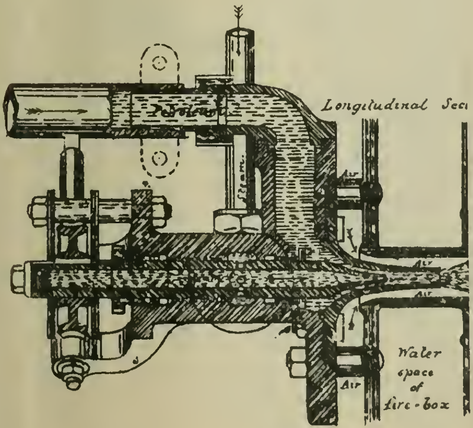
NOTES ON PETROLEUM OIL BURNER.



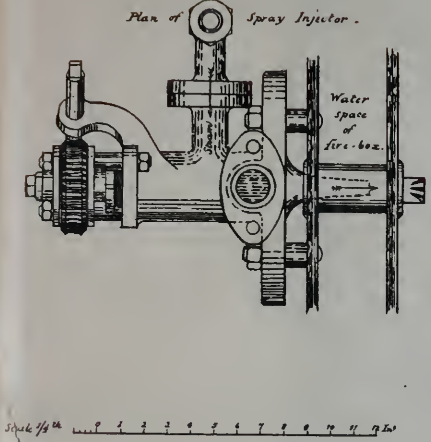


Plan of Spray Injector.

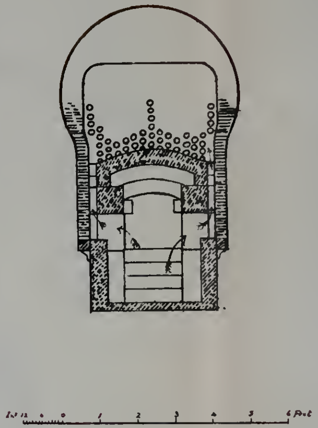
Scale 1/4th 0 1 2 3 4 5 6 7 8 9 10 11 12 In

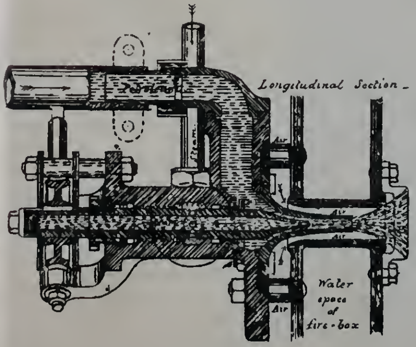


Longitudinal Sec

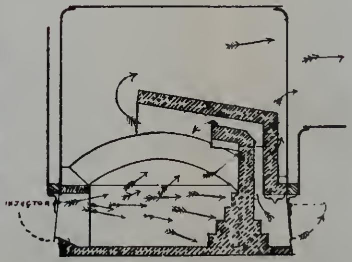


Plan of Spray Injector.

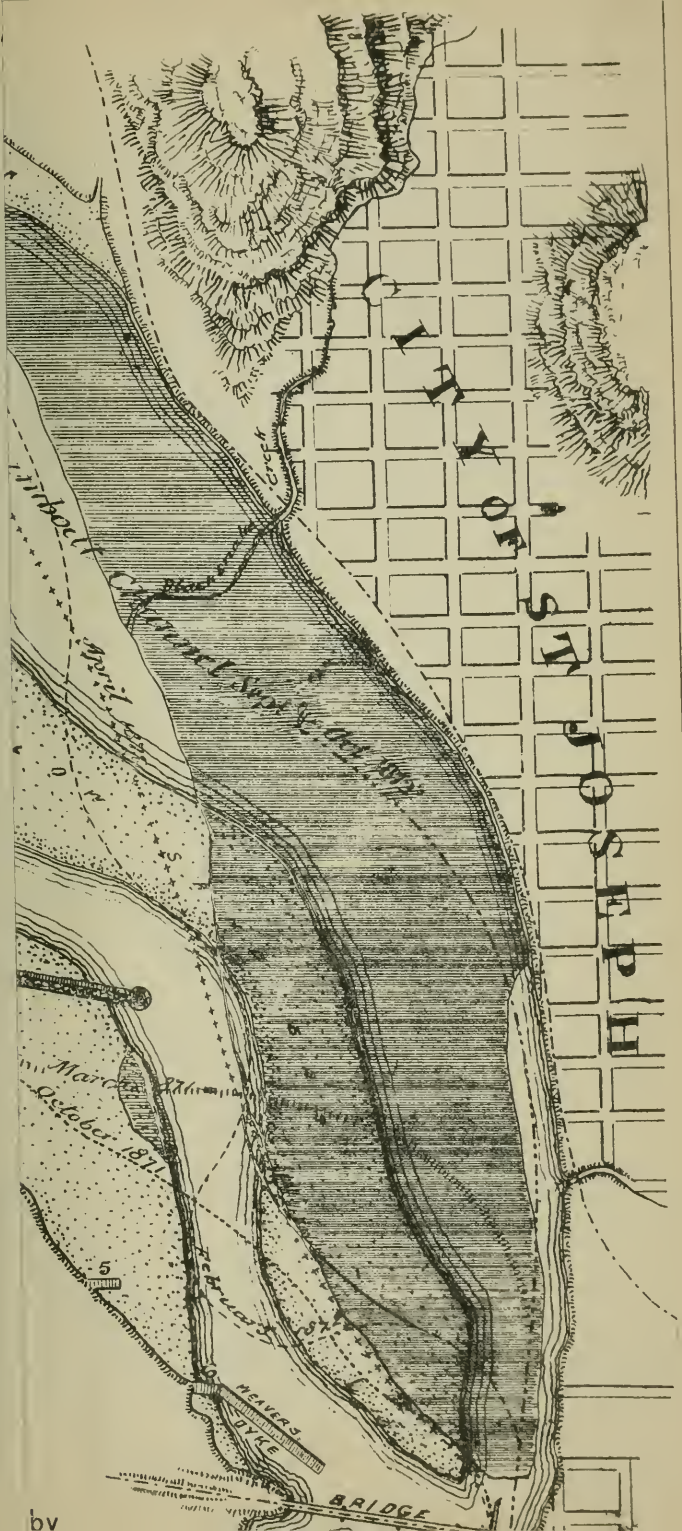




Longitudinal Section.

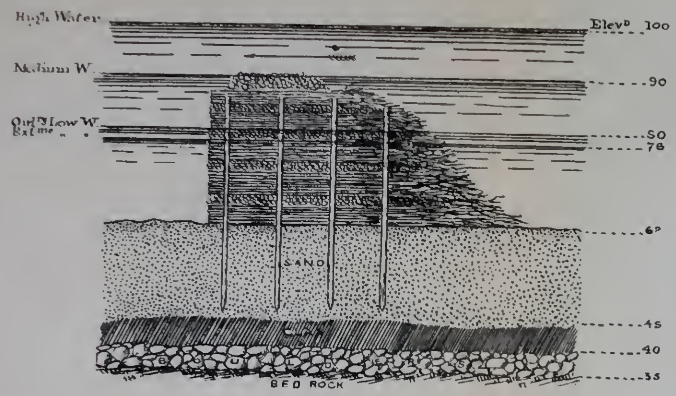


P

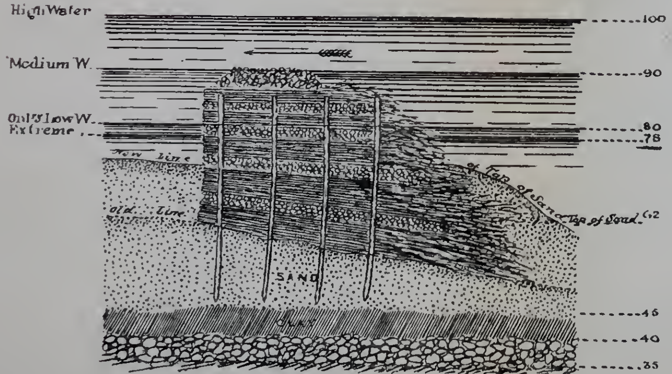

CITY OF ST JOSEPH
Creek
Black
tboat Channel Sept & Oct 1877
April 187
March 1871
October 1871
February
5
MEAVERS DYKE
BRIDGE

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.,

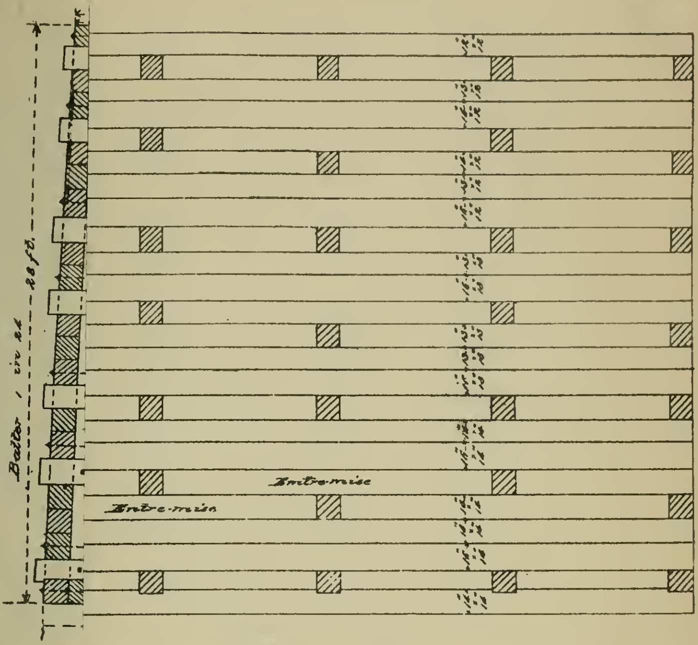
Shewing CHANGES in CHANNEL caused by
DYKES built to DIVERT and CONTROL

PLATE 9.

PART FRONT ELEVATION

F TIDAL HARBOUR CRIB-BLOCK

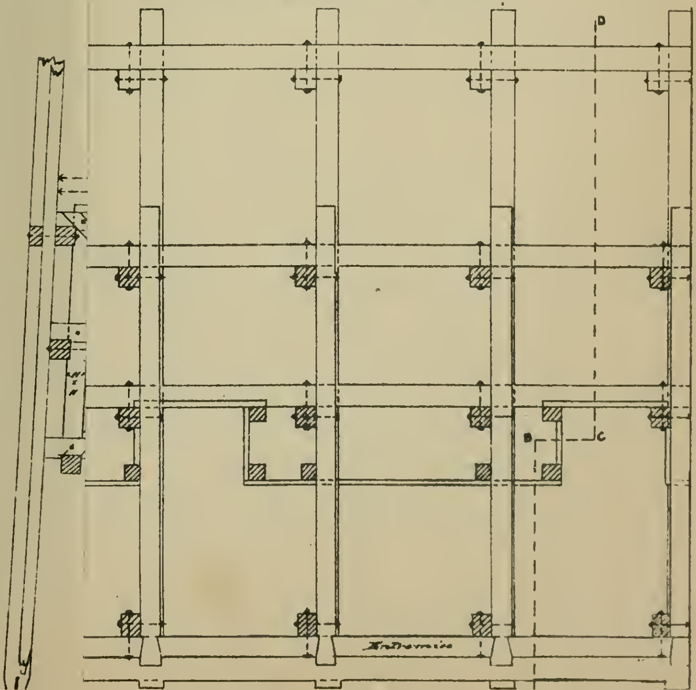
FIG. 4



PART PLAN

OF TIDAL HARBOUR CRIB BLOCK

FIG. 3



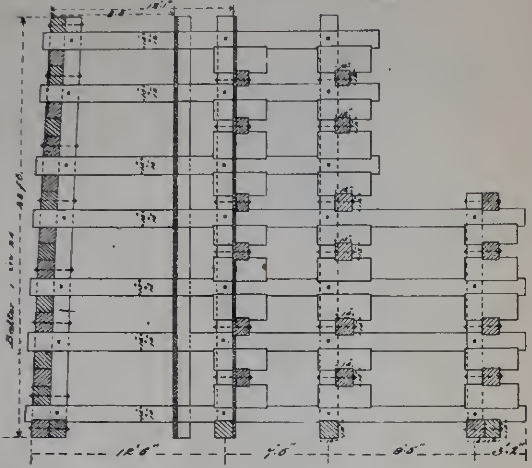
QUEBEC HARBOUR WORKS

PLATE 9.

TIDAL HARBOUR CRIB BLOCK

SECTION AT ABCD

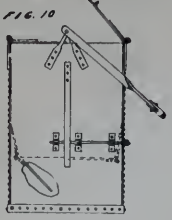
FIG. 2



CONCRETE SKIP

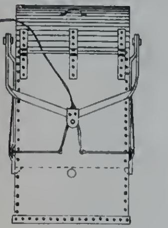
Side View showing spring and Cam rod

FIG. 10



Side View of Spring with Cross Section of Cam-rod

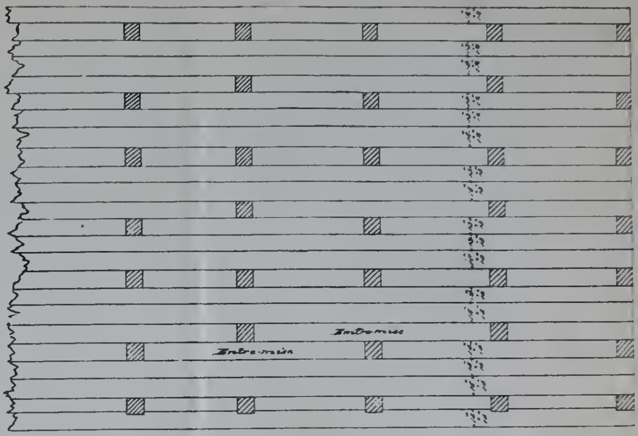
Side View showing Trip-rods



PART FRONT ELEVATION

OF TIDAL HARBOUR CRIB-BLOCK

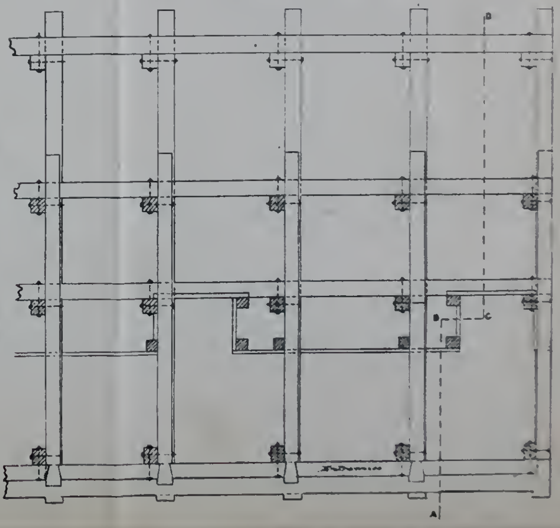
FIG. 4



PART PLAN

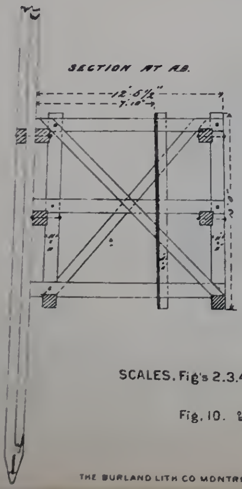
OF TIDAL HARBOUR CRIB BLOCK

FIG. 3



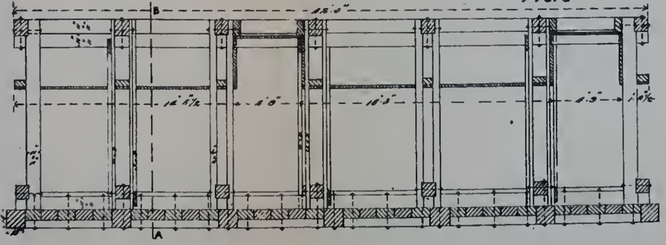
WET DOCK CRIB BLOCK

SECTION AT AB.



PLAN

FIG. 5



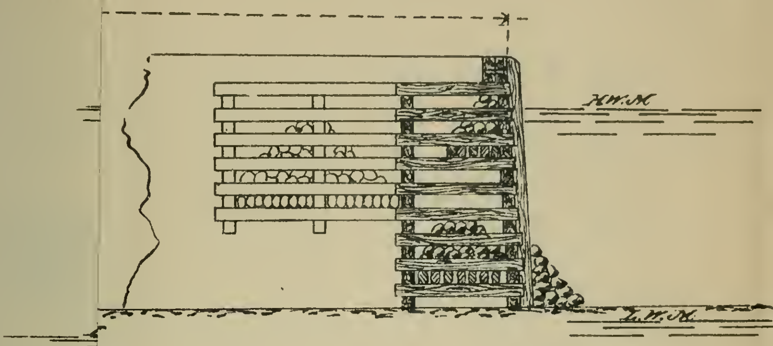
SCALES. Fig's 2.3.4.5 0 1 2 3 4 5 10 15 FEET

Fig. 10. 0 FEET.

THE BURLAND LITH CO MONTREAL.

A.

FIG. 6



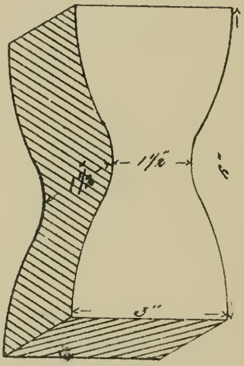
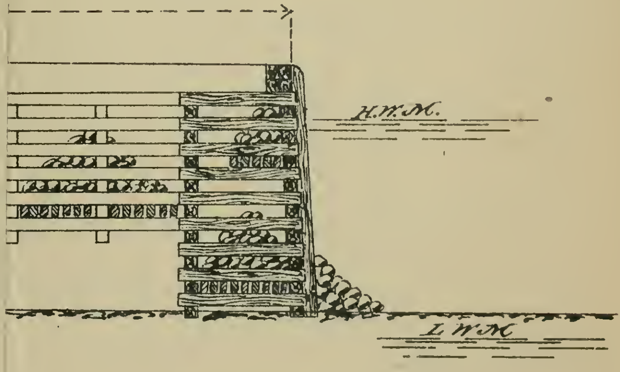


FIG. 17

FIG. 7



CALE. 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

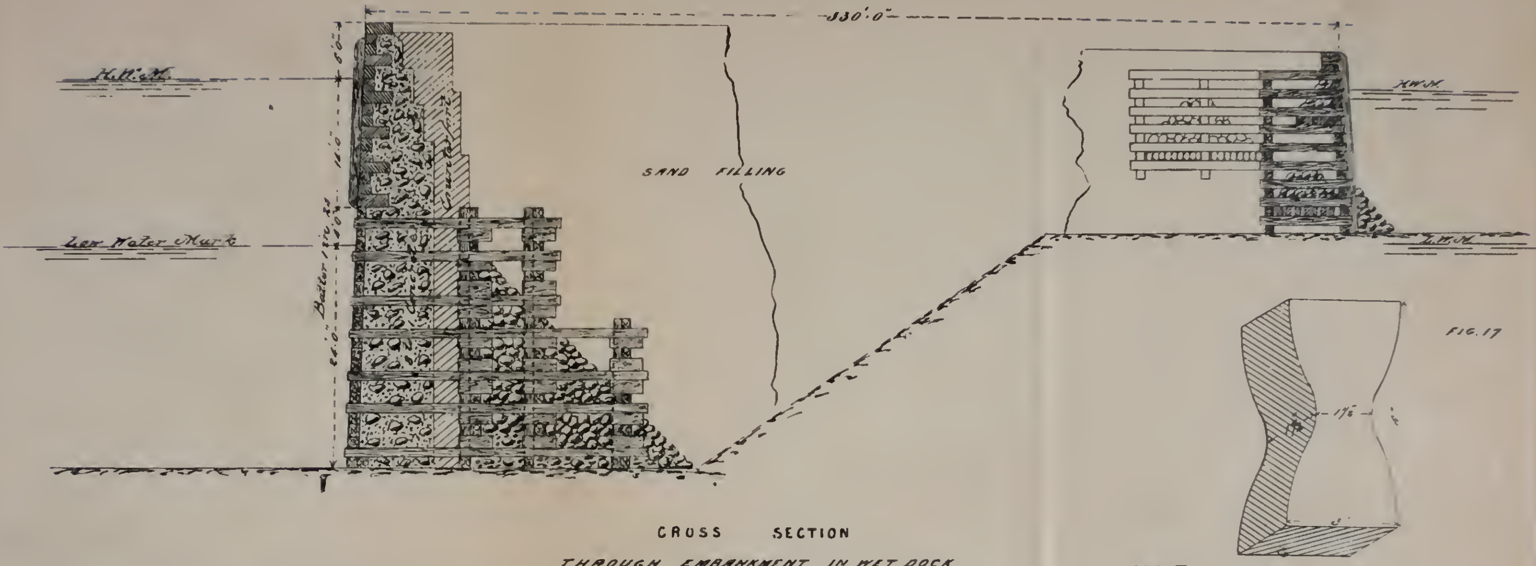
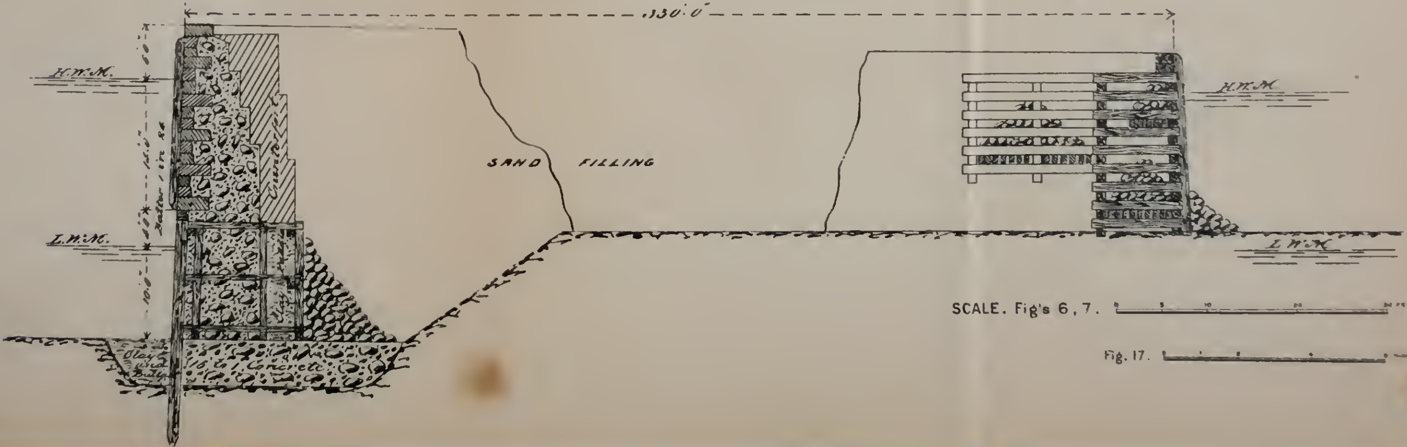


FIG. 17

CROSS SECTION

THROUGH EMBANKMENT IN WET DOCK

FIG. 7

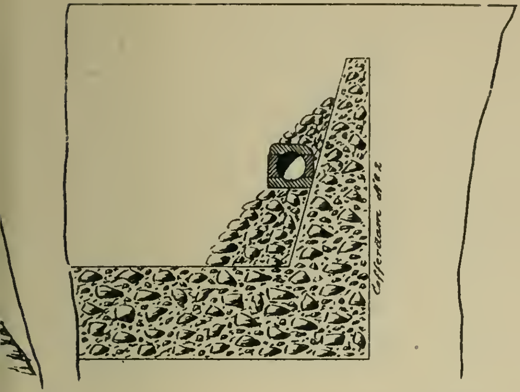


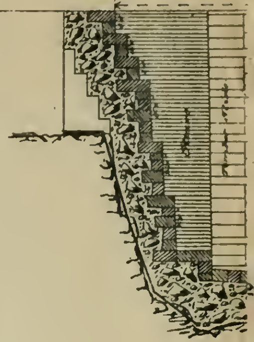
SCALE. Fig's 6, 7.

Fig. 17.

GRAVING DOCK

QUEBEC HARBOUR WORKS





SECTION ON E.F.

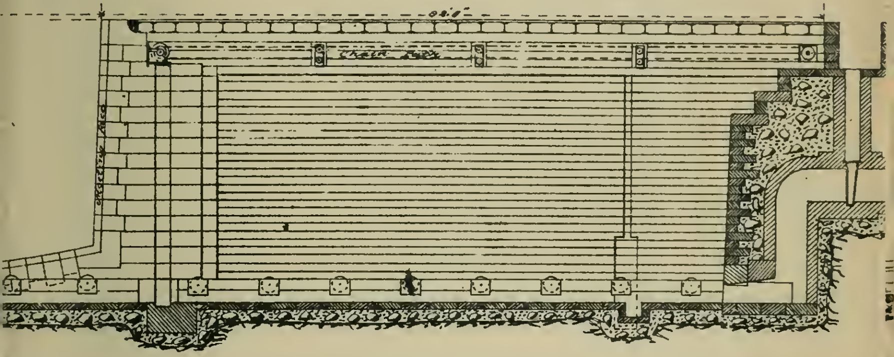


FIG. 13

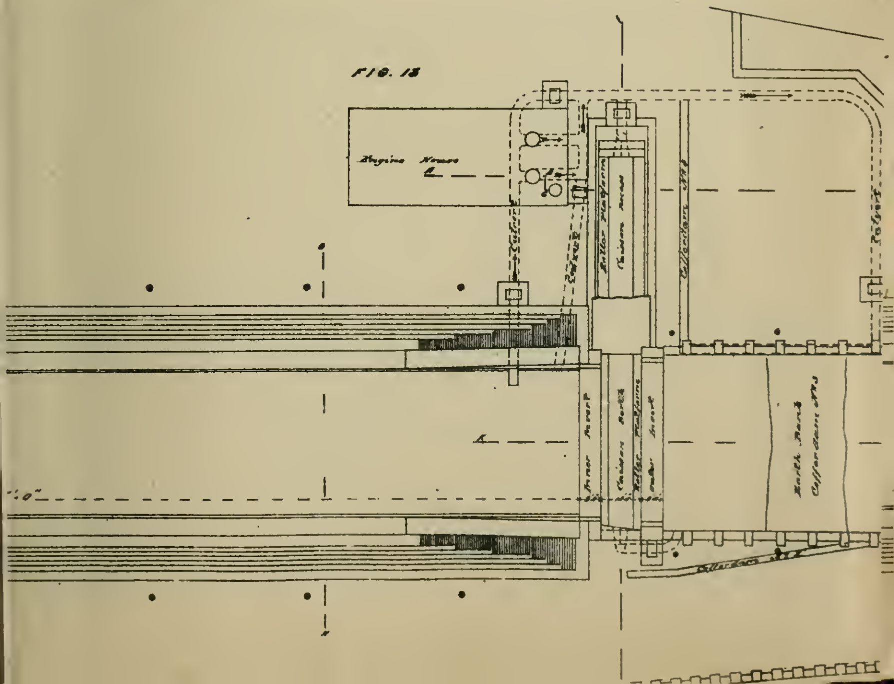
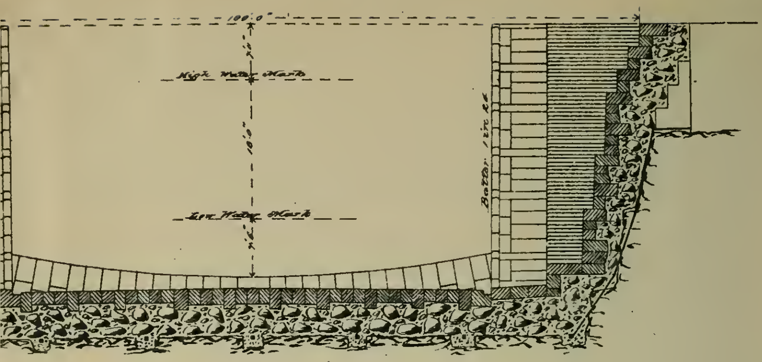
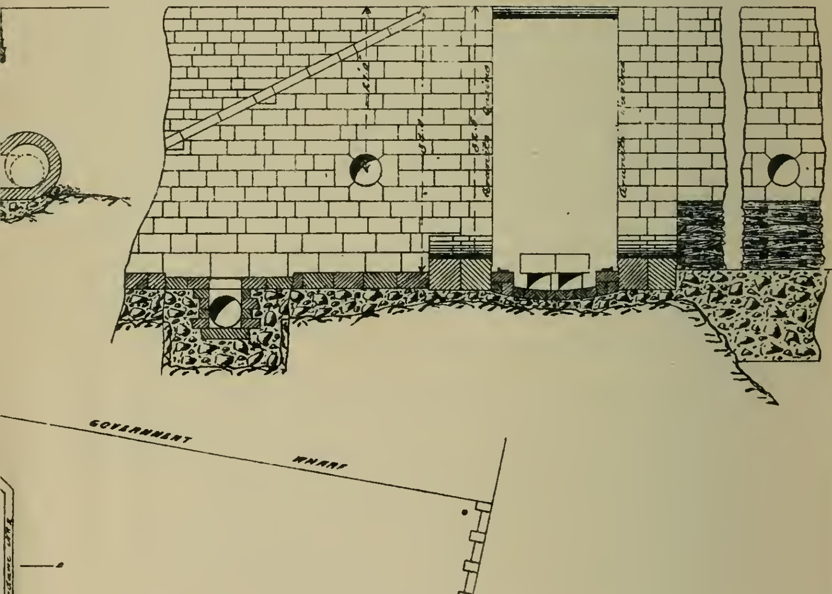


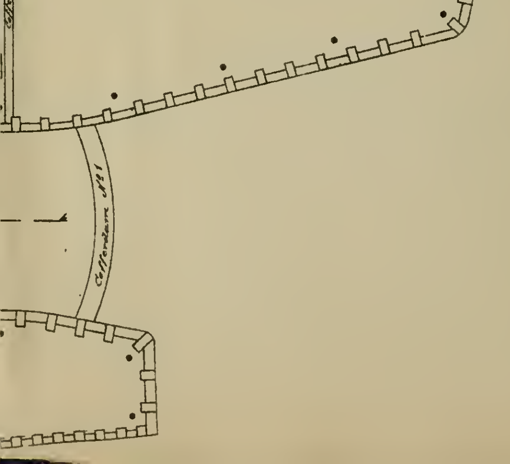
PLATE II.

SECTION ON G.H. FIG. 16



SECTION ON K.L. FIG. 14





SECTION ON ABCD.

FIG.

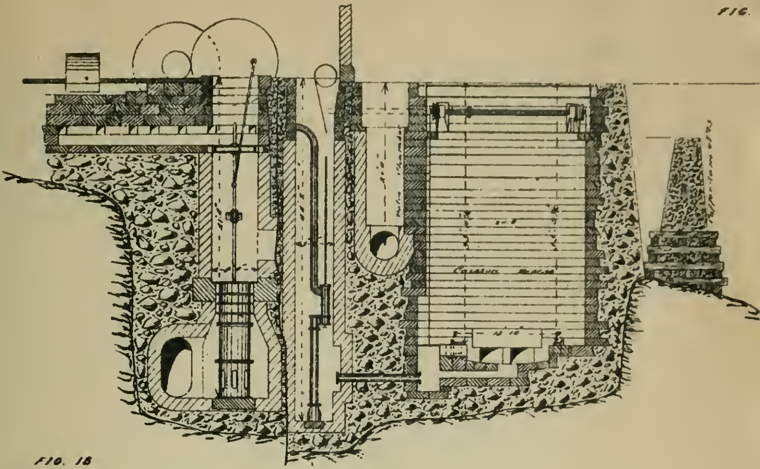
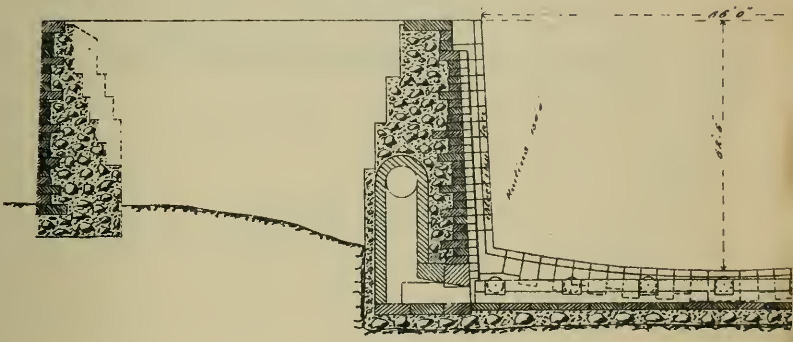
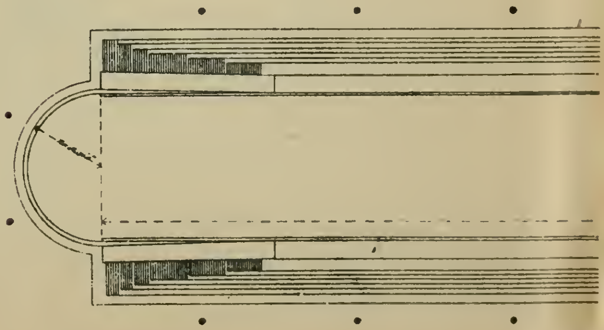


FIG. 18



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

SCALE FOR FIG. NO 13

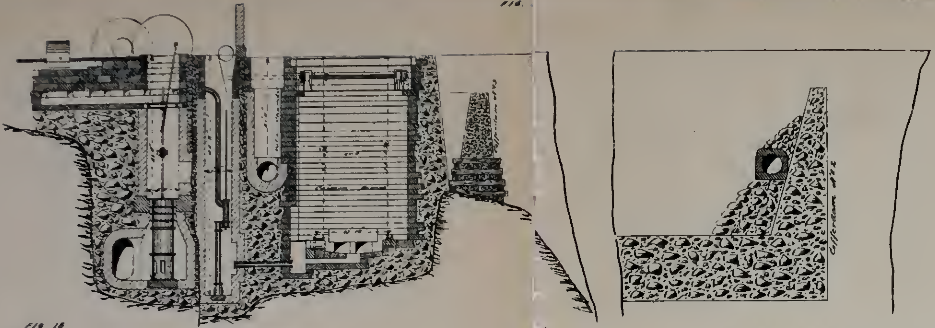


GRAVING DOCK
QUEBEC HARBOUR WORKS

PLATE II.

SECTION ON ABCD

FIG.



SECTION ON G.H.

FIG 16

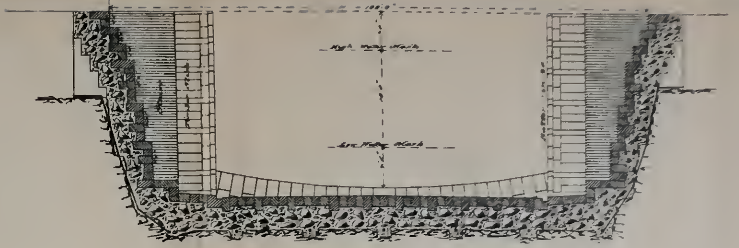
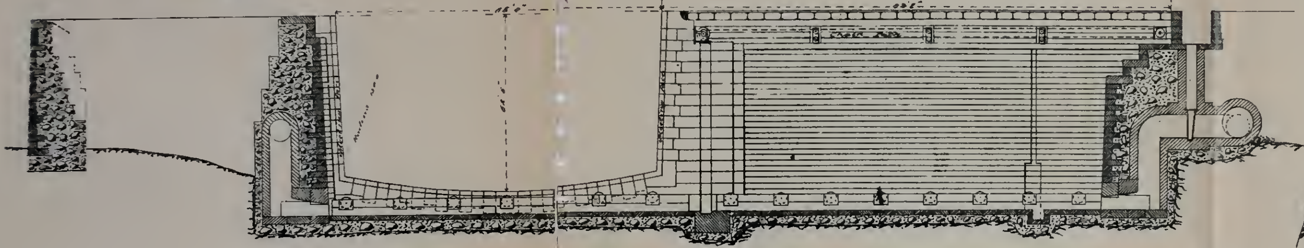


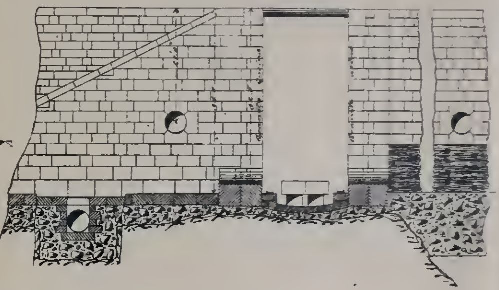
FIG 15

SECTION ON E.F.



SECTION ON K.L.

FIG 14



SCALE FOR FIGS. Nos 14, 15, 16, 17.

SCALE FOR FIG. No 13

FIG. 13

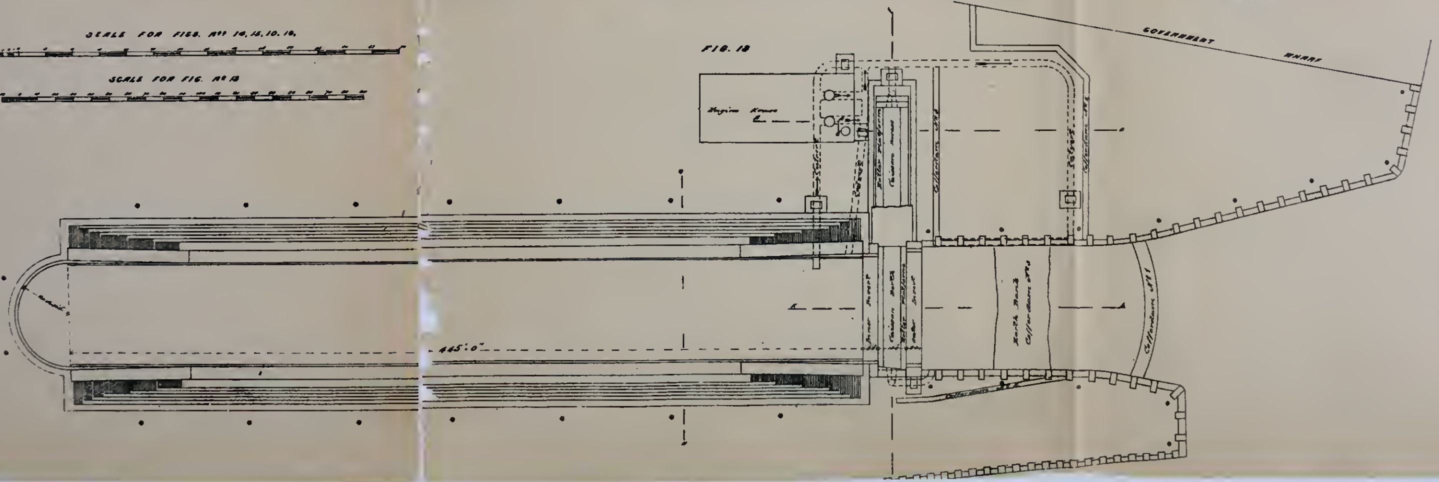
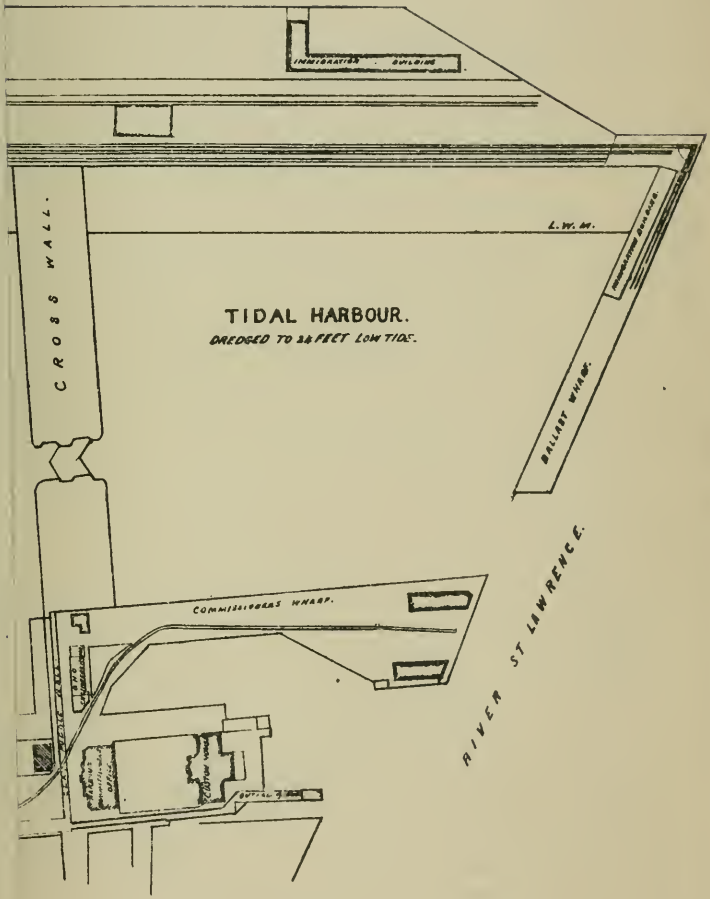
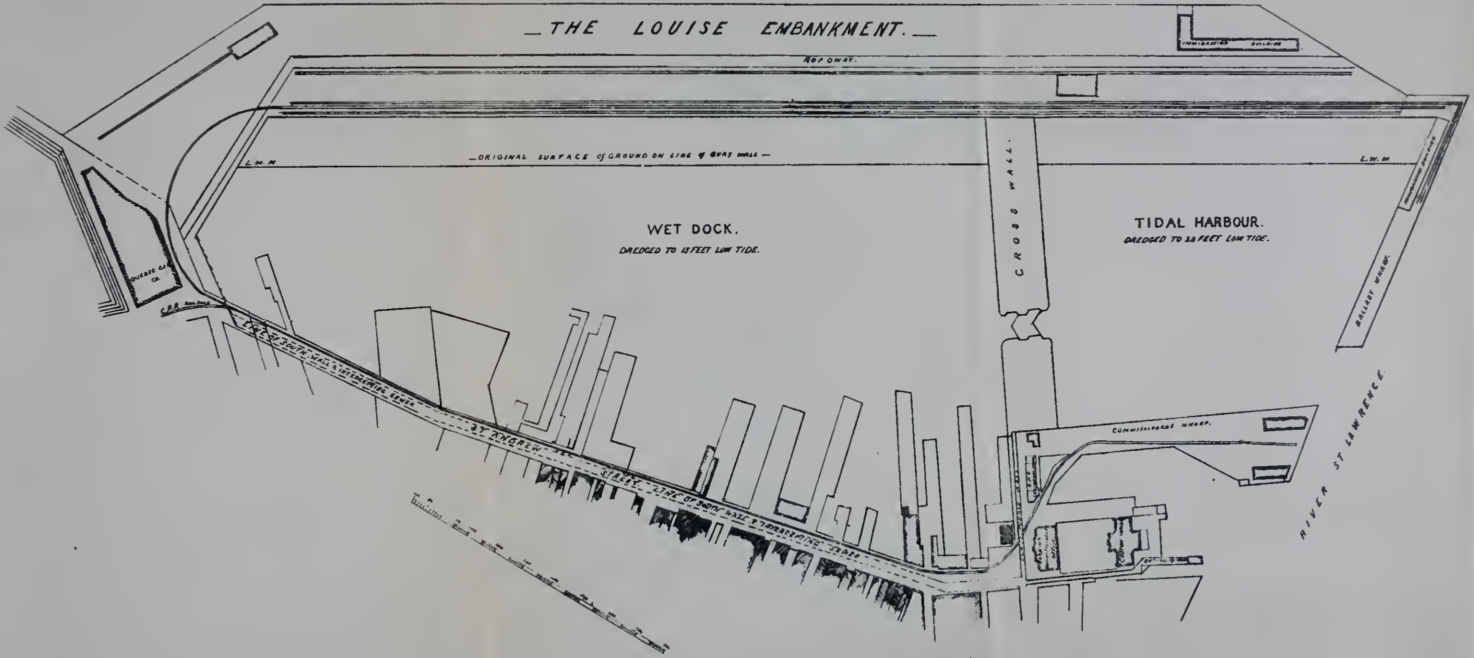
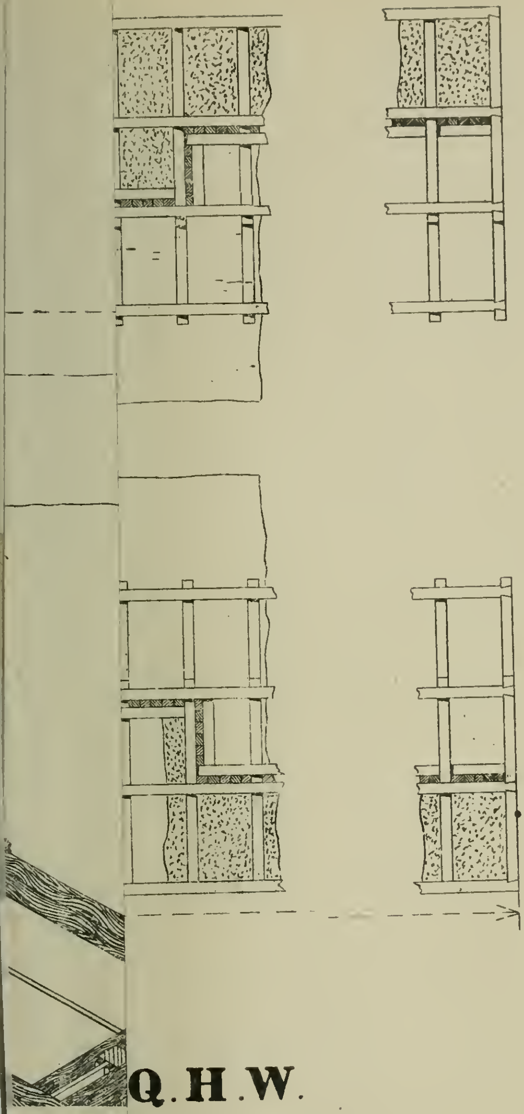


PLATE 12.


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

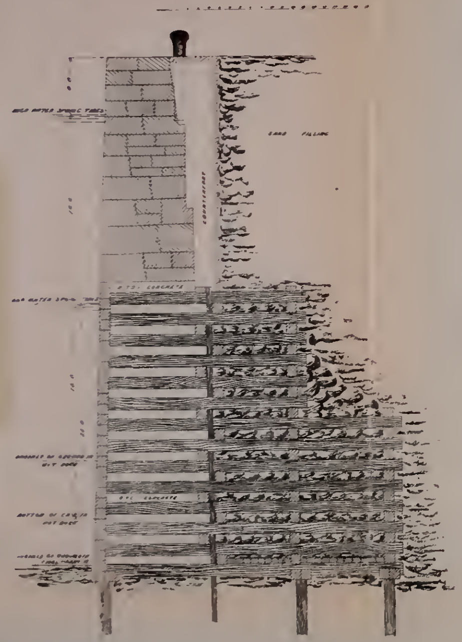
QUEBEC HARBOUR WORKS.



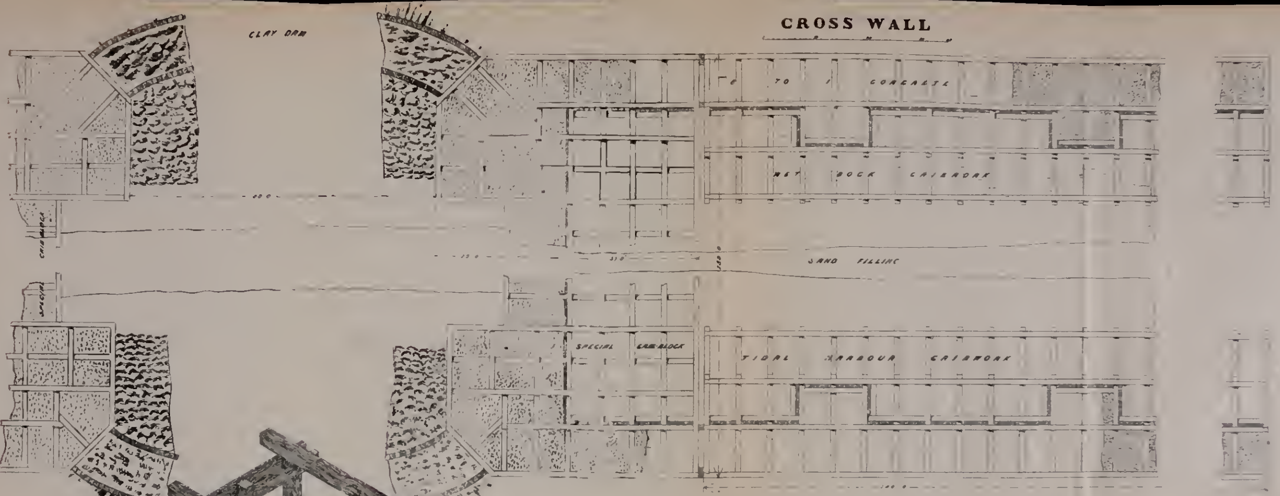

Q.H.W.

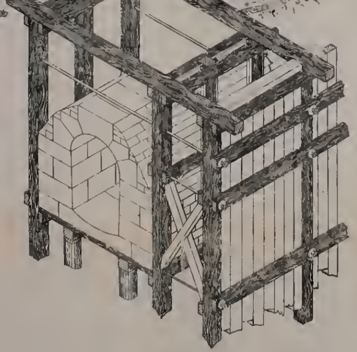
CROSS WALL

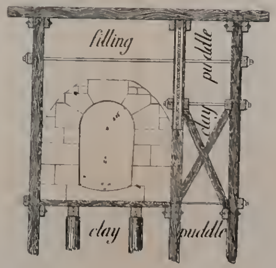
CROSS SECTION OF QUAY WALL



CROSS WALL







Q.H.W.

SOUTH WALL