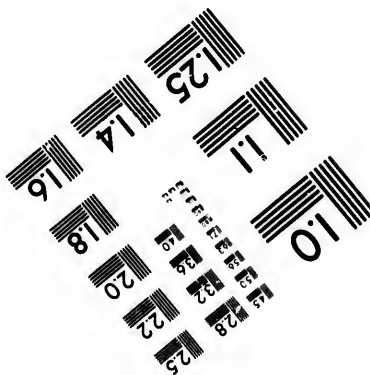
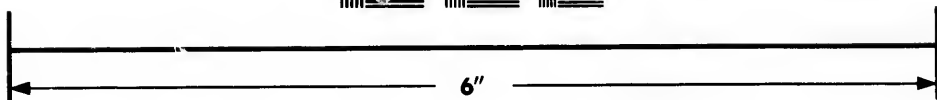
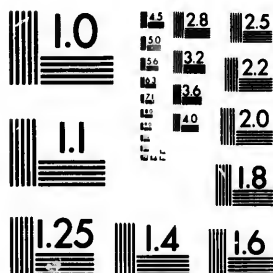


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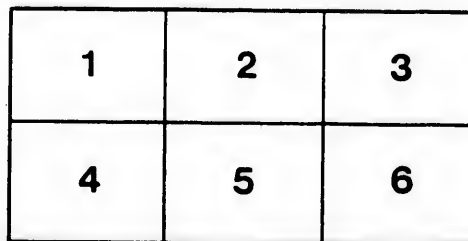
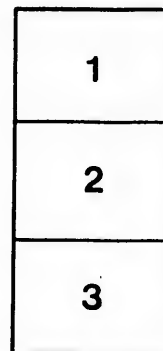
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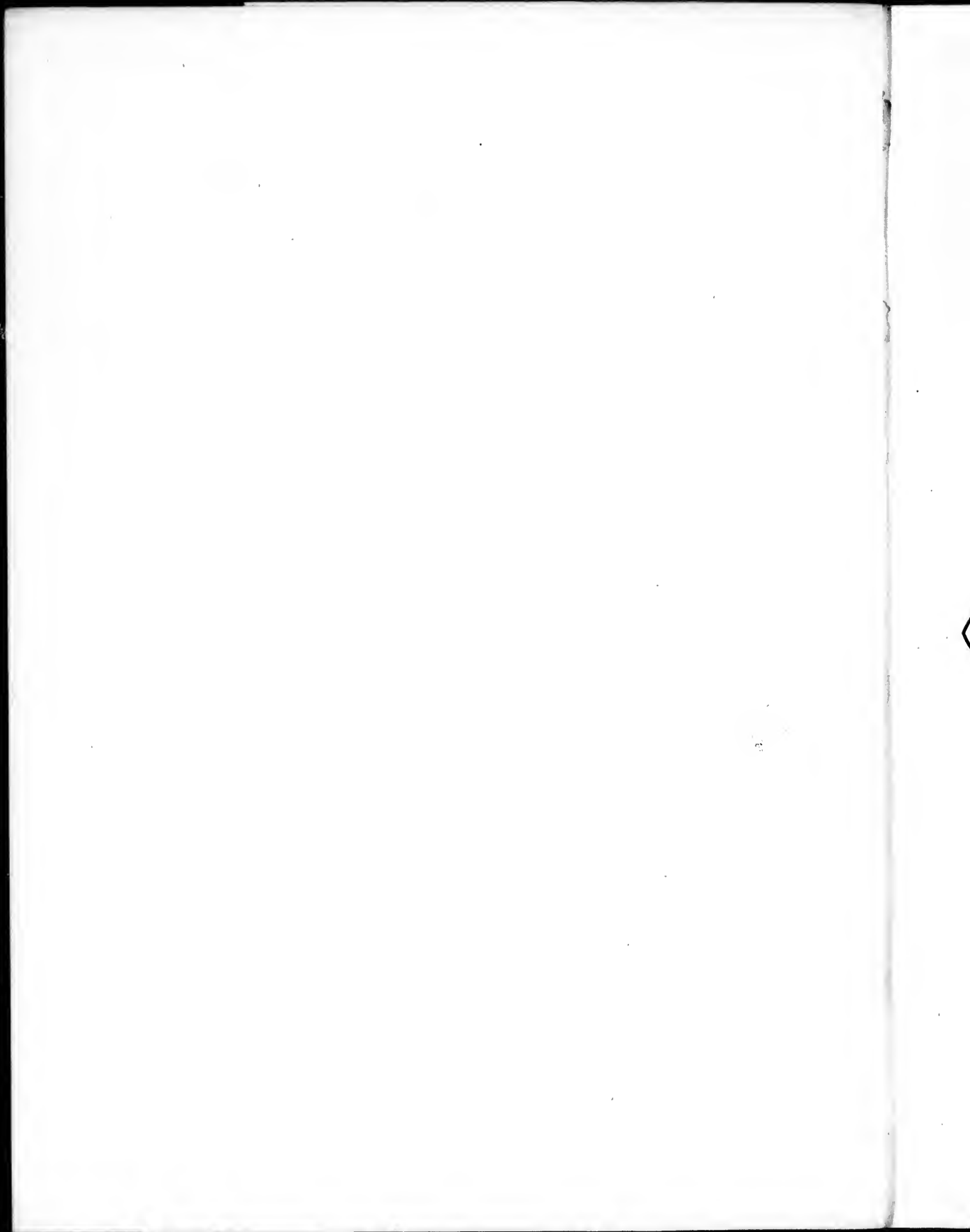
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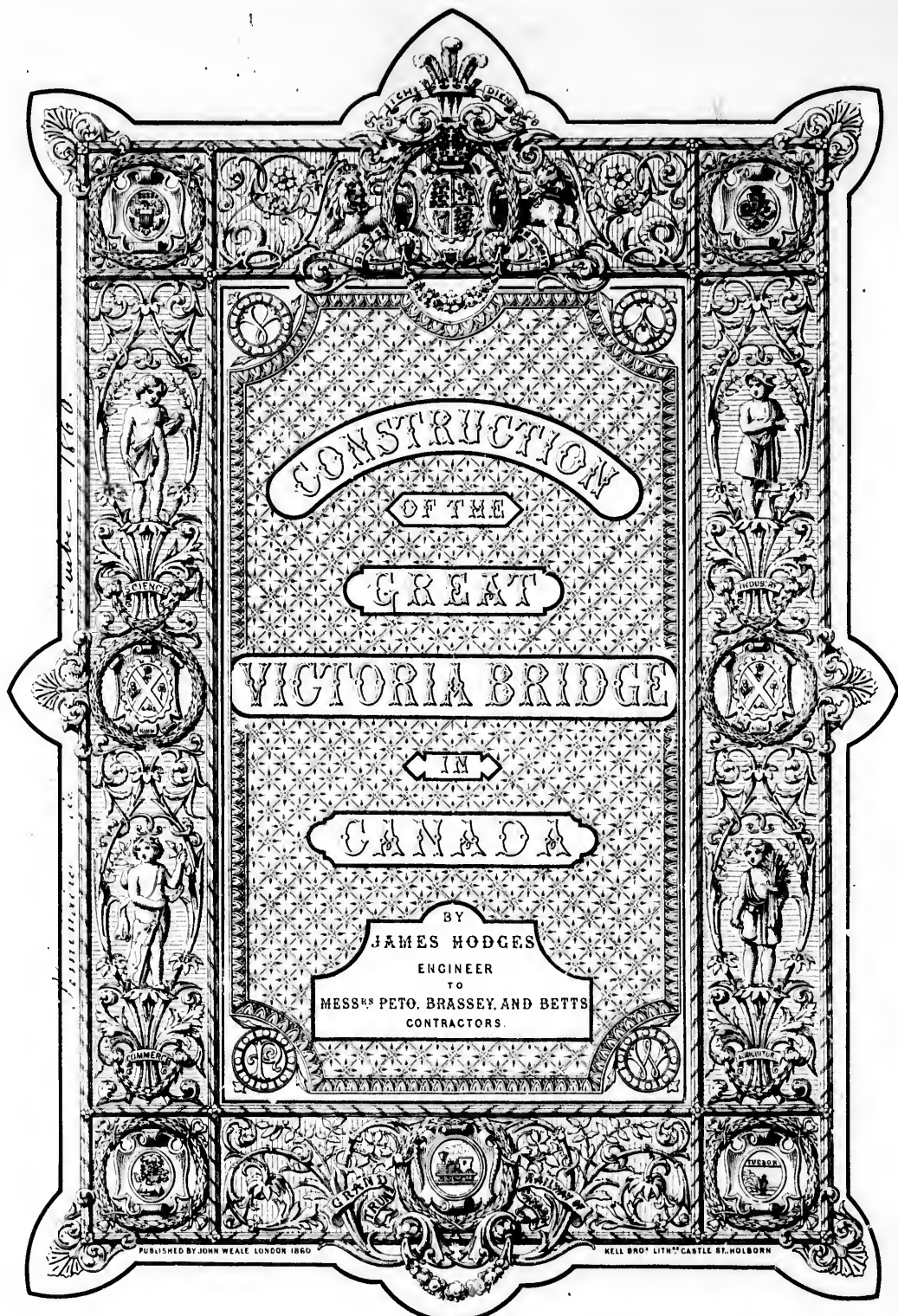
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CONSTRUCTION

OF THE

GREAT

VICTORIA BRIDGE

IN

CANADA

BY
JAMES HODGES
ENGINEER
TO
MESSRS PETO, BRASSEY AND BETTS
CONTRACTORS.

London 1860.

PUBLISHED BY JOHN WEALE LONDON 1860

SELL BRO^S LITH^G CASTLE ST. HOLBORN

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GREAT

VICTORIA BRIDGE

IN

CANADA.



BY

JAMES HODGES.

*Don de
l'auteur
1860.*

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TO

MESSRS. PETO, BRASSEY, AND BETTS,
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Séminaire de Québec 1860



LONDON:

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1860.

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TO

HIS ROYAL HIGHNESS
ALBERT, PRINCE OF WALES, K.G.,

WHO HAS GRACIOUSLY VISITED CANADA TO INAUGURATE THE OPENING

OF

THE VICTORIA BRIDGE,

CONSTRUCTED FOR THE PASSAGE OF THE TRAINS OF THE GRAND TRUNK RAILWAY ACROSS

THE RIVER ST. LAWRENCE,

This Attempt

TO EXPLAIN AND ILLUSTRATE SOME OF THE DIFFICULTIES AND LABOURS ENCOUNTERED BY
HER MAJESTY'S SUBJECTS IN THE ACCOMPLISHMENT OF THIS IMPORTANT WORK,

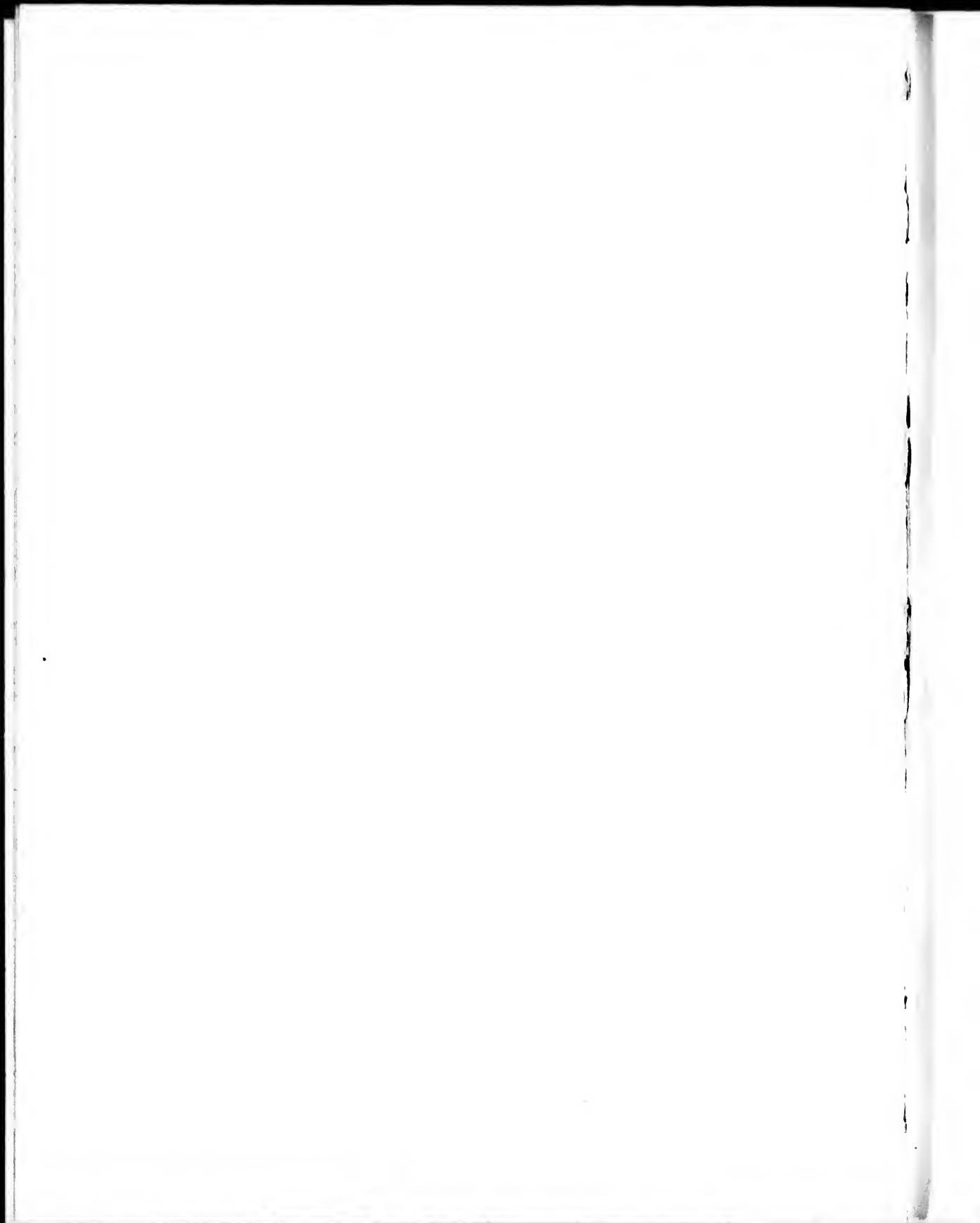
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CONSTRUCTION

OF THE

GREAT VICTORIA BRIDGE.

CHAPTER I.

THE GRAND TRUNK RAILWAY OF CANADA.

The Grand Trunk Railway of Canada traverses British North America from the shores of the Atlantic to the rich prairie country of the Far West. By one unbroken line of railway, passing, under one management, through upwards of 1200 miles of cultivated country, it carries the varied products of the distant western states of America to the sea-board. It opens up for the inhabitants of the wonderful valley through which it passes the means of inter-communication and transport throughout the whole of the year,—an advantage of which the severity of the climate deprived them, previously to its construction, for at least six out of every twelve months. But, besides the commercial and social benefits, the Grand Trunk Railway presents to Canada a great political advantage. It connects and associates together the British dependencies in North America, and, by means of the Great Bridge over the St. Lawrence, it brings them all into direct communication with the United States and the best ports of the Atlantic.

Before the construction of the Grand Trunk Railway, the River St. Lawrence presented to the Canadians the sole available means of inter-communication either for business or for pleasure. To this grand river, and its magnificent chain of inland navigation,—natural and artificial,—Canada is no doubt indebted for her prosperity and growth. But for six months of the year the St. Lawrence was sealed up by frost.

For six long months of the year, therefore, Quebec and the other ports and harbours of the river were unavailable, and trade was virtually suspended. For six long months communication between one province and another was virtually stopped. Not even the power of steam could contend against the inert force of the frost upon those waters. Against the power of the current, sweeping downwards from Niagara, the steam-ship could ply successfully her upward course; but when the waters of that current became congealed in winter, her power necessarily became suspended also.

But the ice was not the only difficulty attending the navigation of the St. Lawrence. Even during the summer, the contracted dimensions of the Welland Canal presented a serious obstacle to the navigation. As far as Lake Ontario, sea-going vessels of 700 or 800 tons burden could with ease accomplish the navigation; but from that point, no vessels of greater burden than 300 tons could reach the upper chain of lakes. At this point, therefore, transshipment became necessary, either for imports or exports. The produce coming from Lakes Erie, Huron, Michigan, and Superior, and from the great prairie cities of the West, such as Buffalo, Chicago, and Detroit, had to be brought down in vessels of a size sufficiently small to navigate the canal, and to be transhipped into larger vessels for the sea-voyage. In the same manner, imports from Europe had to be transhipped into small craft, to effect the same navigation,—thus depriving these growing centres of population and trade, each containing from 90,000 to 200,000 inhabitants, of the main facility of direct inter-communication.

The rapid growth of these cities,—yet in their infancy,—the development of the rich and fertile districts by which they are surrounded, and of which Mr. Cobden declared a year ago that they would “produce grain enough to feed all Europe in addition to their own requirements,” rendered improved communication an urgent necessity. The Grand Trunk Railway of Canada was designed to effect the object. Following the course of the St. Lawrence, and uniting all the principal towns of Canada, it brings the whole country to the best ports on the sea-board by the nearest route, and affords the greatest facilities for communication with Europe by a passage 600 miles shorter than any other that can be made between the continents. It maintains its chain of communication, moreover, without either of the drawbacks attending the river navigation. The whole course of the Grand Trunk Railway can be traversed without change of vehicles, and the line is open for traffic irrespective of seasons.

In its extent, its social, mercantile, and political bearings, and also in the important position which it holds as an enterprise, the Grand Trunk Railway may be, therefore, said to stand unrivalled. Regarding it as a work conceived and entered

upon by a Provincial Government, it may also be said to stand alone as an evidence of the enlightenment and energy of a colonial population, and of their true appreciation of the value of their resources and of the means necessary for their development. It is not the design of this statement to make any particular or special reference to the individuals by whose instrumentality the work has been accomplished; but no account of the railway would be complete without some allusion to the leaders of the movement which resulted in the accomplishment of so great a work. It is to the Hon. Francis Hincks, now Governor of Barbadoes, and to the Hon. John Ross, Speaker of the House of Assembly, that Canada stands mainly indebted for the promotion of this means of communication through their adopted country. Through a series of years, and amid difficulties and depressions of no ordinary character, the first as the head of the Government in Canada, and the second as President of the Corporation, never ceased to lend their active and effective aid to bring the enterprise to that successful termination which they have had the happiness to see accomplished.

CHAPTER II.

THE VICTORIA BRIDGE.

THE Grand Trunk Railway of Canada was, however, of itself, an imperfect work. Confined to the north shore of the River St. Lawrence, it presented itself, within such limits, as a mere provincial line. As such it would have been undoubtedly of immense value to the province; but it could not have commanded its external trade and intercourse. Inasmuch as from the head of Lake Superior to the Atlantic Ocean, a distance of more than 1500 miles, there was no bridge across the St. Lawrence, excepting at the Niagara gorge, it was obvious that the key to the province, even after the construction of the Grand Trunk, would be in other hands, if the railway did not span the river, and afford the connecting link so much required between British North America and the United States.

During the summer of 1852, at the request of the Provincial Government of Canada, the firm of Sir S. Morton Peto, Bart., M.P., Thomas Brassey, and Edward Ladd Betts, made an examination of the country with a view to assisting in the development of a complete system of railways for the colony; and Mr. W. Jackson, M.P.—afterwards associated in the undertaking—accompanied by Mr. A. M. Ross, C.E., proceeded thither for that purpose.

From the information they obtained, the Grand Trunk as a complete system of railways, including the Victoria Bridge, was brought before the public in England under the auspices and with the influence of the agents for the province, Thomas Baring, Esq., M.P., and G. C. Glyn, Esq., M.P.

As early as 1846, the Hon. John Young, of Montreal, suggested the practicability and necessity of a bridge across the St. Lawrence, near Montreal, and succeeded in obtaining surveys and reports upon the subject from several eminent engineers; from Mr. Morton in 1846, Mr. Gay in 1847, Mr. Gzowski in 1849, and Mr. T. C. Keefer in 1851, with which, and the information he obtained on the spot, Mr. Ross on his return to England designed the structure upon the principle on which it is carried out, and upon which the provisional contract was taken, and, as Engineer in Chief of the Grand Trunk Railway, afterwards resided in Canada until the works were completed.

Upon the inauguration of the Company, the great importance of this work, the large expenditure it involved, the various opinions that existed of its practicability, and the great difficulties and risks connected with its construction in such a position, decided the Board of Directors, previous to bringing it before the public, to consult Mr. Stephenson, whose high authority and sanction it was deemed of great importance to obtain; and who, after examining the information and designs laid before him by Mr. Ross, signified his approval of them, and undertook jointly with him the responsibility of engineer to the bridge.

In the summer of 1853, Mr. Stephenson visited Canada to personally examine the site of the bridge; and with the additional information procured during the previous winter under Mr. Ross's instructions, and carefully reviewing the opinions of those best acquainted with the locality, decided conjointly with Mr. Ross upon the structure as it at present exists.

The site of the bridge is at the lower end of a small lake, called the La Prairie Basin, which is situated about one mile above the entrance to the Lachine Canal, at the west end of Montreal Harbour. At this point the River St. Lawrence is, from shore to shore, 8660 feet or a mile and three-quarters, wide. The lake, however, which is full of boulders, is extremely shallow—so much so, that excepting in the main channels it is only navigable for vessels drawing from one foot six inches to two feet of water. And even these have difficulty in approaching the shore, there being no landing-place above the site of the bridge except at the La Prairie village.

At the head of the lake, some eight miles from Montreal, are the Lachine rapids. They form a total fall, in a course of two miles, of about forty-two feet. They are navigable only in one direction, and in that but for rafts and steamboats.

The waters of the St. Lawrence, after passing these rapids, are separated by a cluster of islands, terminating in one of larger dimensions called Nun's Island. This island extends eastward to within a mile of the Victoria Bridge. From thence to a point opposite the city of Montreal, there is a bank called the "Middle Shoals," which divides the river into two channels. Upon this bank lie innumerable boulders, some just showing themselves above the surface of the water, and rendering navigation among them impossible, except in small row-boats or canoes. This condition of the river proved seriously inconvenient in the construction of the bridge, as it was necessary, in order to convey materials from one part of the bridge to another, to pass down one channel for nearly a mile, and then return by a second, stemming a current of some seven to eight miles per hour.

The bed of the river, at the point selected for the construction of the works, consists of a solid rock, called by Sir William Logan, F.R.S., the provincial geologist, "Utica slate." Near the shores, say for some 1900 feet on the north side and 600 feet on the south side, this rock is perfectly free from any deposit excepting large boulders. Towards the centre of the river it is covered with shale, quicksand, clay, and, on the surface, with a kind of hard pan, composed of boulders, gravel, and clay intermixed, almost as hard as the rock itself. The distance from the bed of the river to the solid rock is, in some instances, from twelve to fourteen feet. The boulders which had to be removed varied in weight from one to twenty tons.

The scenery at the point at which the bridge is thus constructed, if not grand, is far from uninteresting. On the one shore lies the City of Montreal, on a sloping site, the towers of its Cathedral and numerous church spires adding continually to the picturesque appearance of its white, well-built houses, which are frequently well placed amid shrubberies and gardens. On the other side of the river a range of blue hills forms a bold and agreeable background to the somewhat low surface of the shores nearer to the river. The whole character of the scenery is agreeable and English; and, reversing the position, and looking at the bridge from the ground over Montreal itself, few scenes can be fairer than the noble river which rushes through the valley, crossed as it now is by the stupendous work which may be described without exaggeration as one of the "Wonders of the World."

CHAPTER III.

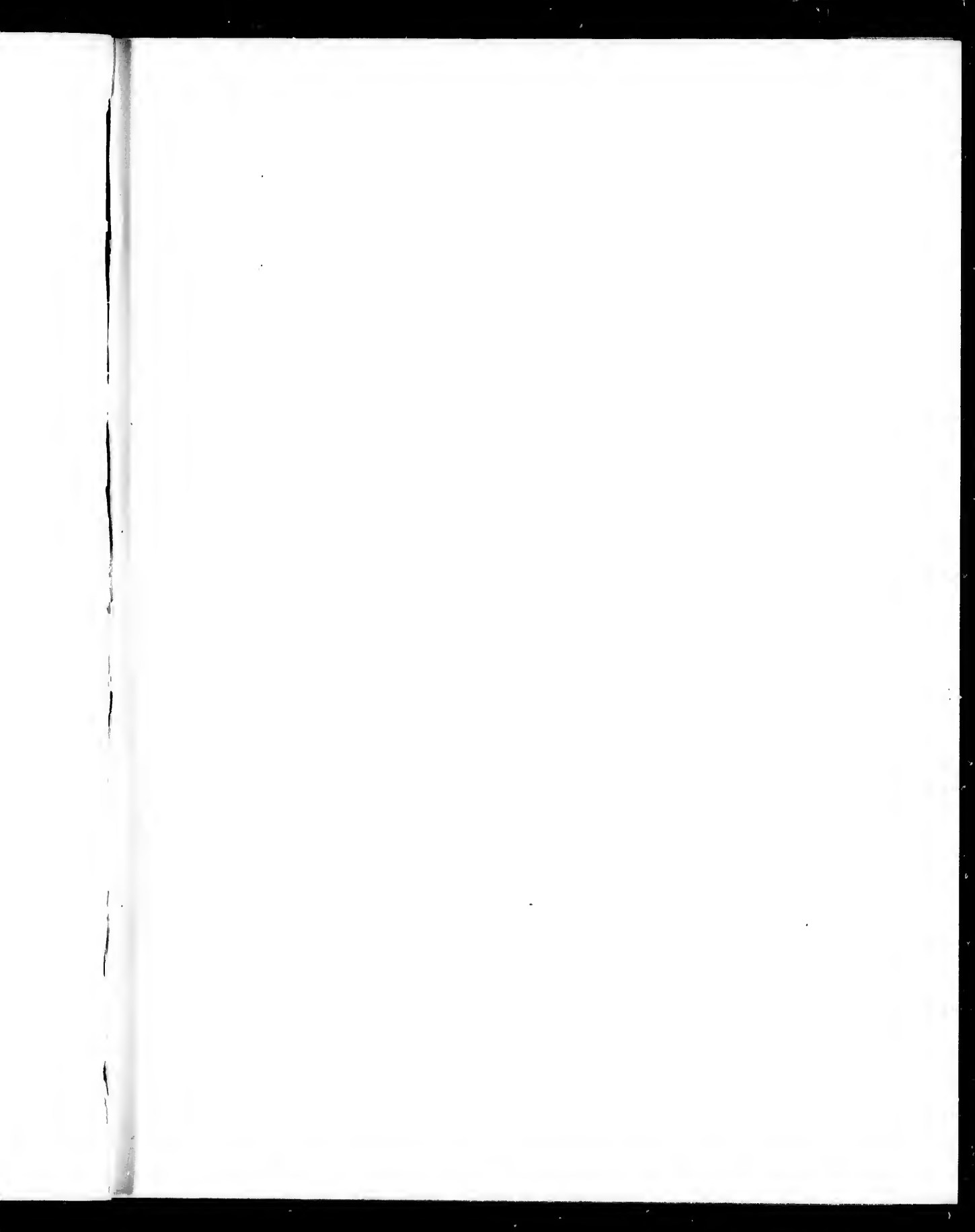
THE ICE.

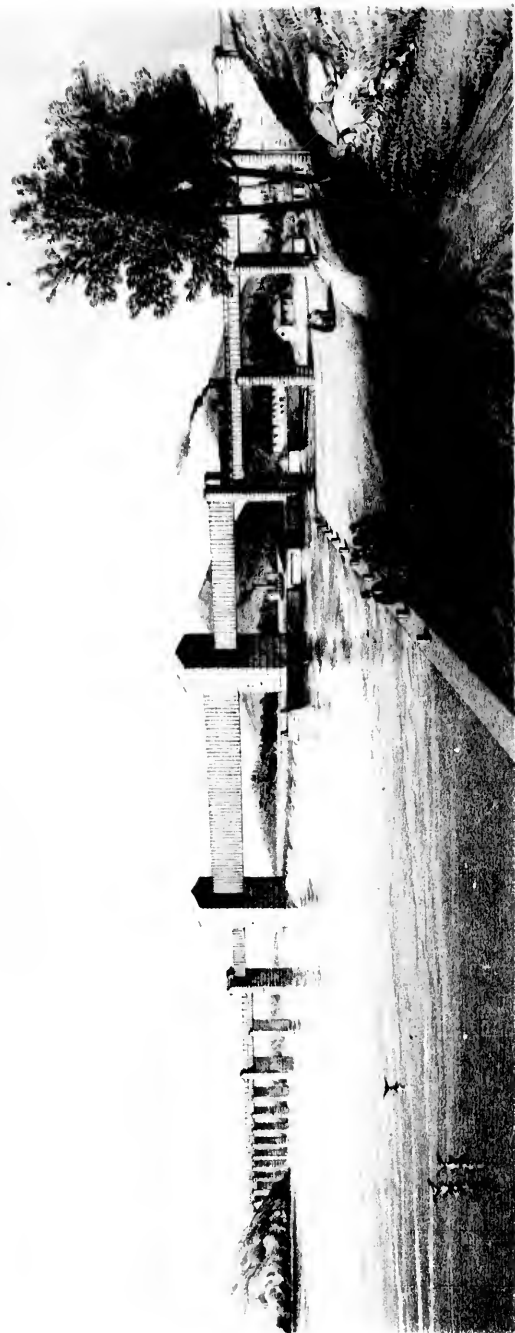
UNDOUBTEDLY, the most serious difficulty to be guarded against, both in the design and in the execution of the Victoria Bridge, was that operation of nature which occurs twice in the year, and which is known in North America as the "Shoving" of the Ice.

Ice begins to form in the St. Lawrence about the beginning of December. Then, along the shores and in the shallow, quiet places, where the current is least strong, a thin ice begins to make its appearance, gradually showing signs of increasing strength and thickness. Soon after, pieces of ice begin to come down from the lakes above; and then, as winter advances, anchor, or ground ice, comes down in vast quantities, thickening the otherwise comparatively clear water of the river.

A word as to the "Anchor Ice." It appears to grow in rapid currents, and attaches itself to the rocks forming the bed of the river, in the shape of a spongy substance, not unlike the spawn of frogs. Immense quantities form in an inconceivably short space of time, accumulating until the mass is several feet in depth. A very slight thaw, even that produced by a bright sunshine at noon, disengages it, when, rising to the surface, it passes down the river with the current.

This description of ice appears to grow only in the vicinity of rapids, or where the water has become aerated by the rapidity of the current. It may be that the particles or globules of cold air are whirled by the eddies till they come in contact with the rocky bed of the river, to which they attach themselves, and being of a temperature sufficient to produce ice, become surrounded with the semi-fluid substance of which anchor ice is formed. "Anchor Ice" sometimes accumulates at the foot of rapids in such quantities as to form a bar across the lake (similar to bars of sand at mouths of rivers) of some miles in extent, lifting the water in its locality several feet above its ordinary level. This frequently happens at the foot of the Cedar Rapids at the head of Lake St. Louis, where a branch of the Ottawa empties itself into the St. Lawrence.





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Upon such occasions the water at this point is dammed up to such a height as to change its course, and run into the Ottawa, at the rate of some four or five miles per hour. From thence it eventually finds its way back into the St. Lawrence by the rapids of St. Anne's (celebrated by Moore in the "Canadian Boat Song"), after performing a circuit of some ten or twelve miles. The accumulation of ice continues, probably for several weeks, till the river is quite full, and so thickened as to make the current sluggish and cause a general swelling of the waters. The pieces, too, become frozen together, and form large masses, which by grounding, and diminishing the sectional area of the river, cause the waters to rise still more (there being always the same quantity of water coming over the rapids). Then the large masses float and move further down the river, where, uniting with accumulations previously grounded, they offer such an obstruction to the semi-fluid waters that the channels become quite choked, and what is called a "jamb" takes place.

The surface ice, arrested in its progress, packs into all sorts of imaginable shapes; and, if the cold is very intense, a crust is soon formed, and the river becomes frozen over till many square miles of surface packed ice is formed. As the water rises, the jamb against which this field rests, if not of sufficient strength to hold it in place, gives way; when the whole river, after it is thus frozen into one immense sheet, moves *en masse* down stream, causing the "shovings" so much dreaded by the people of Montreal. The edges of the huge field moving irresistibly onwards, plough into the banks of the river, in some instances to a depth of several feet, carrying away everything within reach. In places the ice packs to a height of twenty or thirty feet, and goes grinding and crushing onwards till another jamb takes place, which, aided by the grounded masses of packed ice upon the shoals and shores, offers sufficient resistance to arrest in its progress the partially broken up field.

As the winter advances and the cold increases, the field of packed ice becomes stronger, and as the lakes above become frozen over, the ice from thence, which had hitherto tended so much to choke the channel, ceases to come down, and the water in the river gradually subsides, till it assumes its ordinary winter level, some twelve feet above its height in summer. The "Ice Bridge" *i.e.*, the complete and solid condition of the ice in the river, now becomes permanently formed for the winter, and this generally takes place about the first or second week in January. The thickest Virgin Ice seldom exceeds three feet. Upon the clear blue waters of the St. Lawrence it is perfectly transparent.

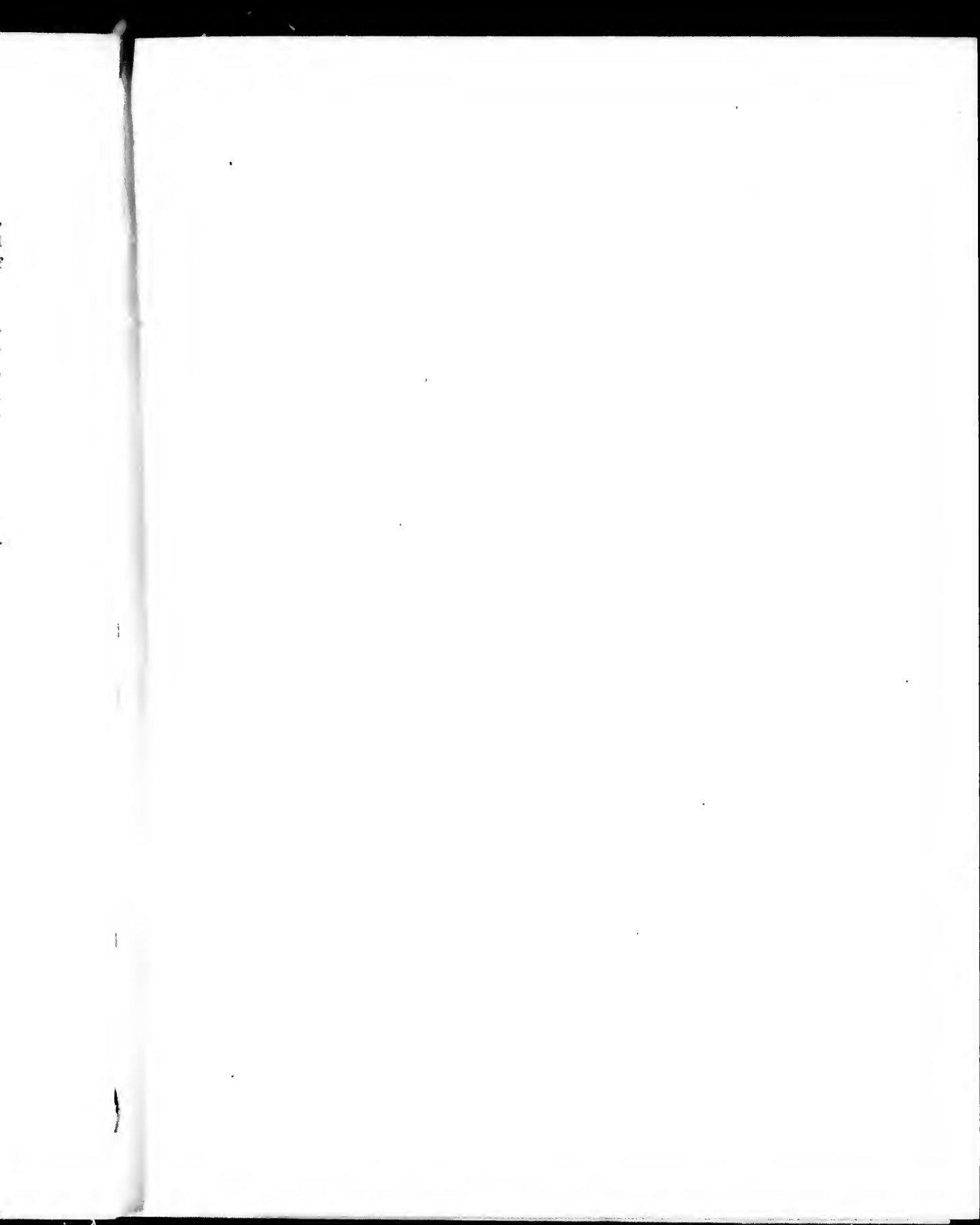
By the middle of March the sun becomes very powerful at mid-day, which, with

the warm heavy rains, so affects the ice as to make it rotten, or, as it is usually called, "honey-combed;" and when it is in this state, a smart blow from any sharp-pointed instrument will cause a block, even though three feet thick, to fall into thousands of pieces, as if it was composed of millions of crystallised reeds placed vertically.

The ice when it becomes thus weakened is easily broken up by the winds, particularly in places where, from the great depth of water in the lakes, they do not entirely freeze over. This ice, coming down over the rapids, thickens the water, and causes a rise of the river, as in early winter. The weakened fields of ice then begin to break up, and in a few days the river becomes free, excepting upon the wharves and some particular parts of the shore, where shovings may have taken place. In these places ice may be seen for many weeks. When the lake ice comes down before that in the river and its lower basins becomes rotten, great "shovings" take place, resulting in jams, and the consequent rise of the water level.

In order to avoid the dangers and difficulties consequent on these operations of nature, it was determined to build the Victoria Bridge with stone piers, placed at wide intervals, each pier being of the most substantial character, and having a large wedge-shaped cut-water of stonework inclined against the current, and presenting an angle to the ice sufficient to separate and fracture it as it rose against the piers. The piers of the bridge were, in fact, designed to answer the double purpose of piers to carry the tubes, and of ice-breakers to encounter the pressure of the ice. In each of these respects they have fully answered the important objects sought to be attained.







FEDERAL BUREAU OF INVESTIGATION

U. S. DEPARTMENT OF JUSTICE

WASHINGTON, D. C. 20535

MEMORANDUM FOR THE DIRECTOR

DATE: 10/15/68

TO: SAC, NEW YORK

FROM: SAC, NEW YORK

SUBJECT: [Illegible]

RE: [Illegible]

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CHAPTER IV.

EARLY PREPARATIONS FOR THE CONSTRUCTION OF THE BRIDGE.

ONE of the first objects prior to entering on the work of construction, was to find a suitable stone for so important a work. This duty devolved on the writer, who had been out to Canada as the agent of Messrs. Peto, Brassey, and Betts, with powers and instructions for the building of the bridge. Prior to making any personal inspection of quarries, he placed himself in communication with Sir William Logan, F.R.S., the provincial geologist, and Mr. Samuel Keefer, Commissioner of Public Works, to both of whom he is much indebted for valuable suggestions and information both as to this and other matters.

After having inspected several quarries, a visit was paid to Caughnawaga, where very fine stone was found. The lands from which it was obtainable were, however, in possession of the Indians, and it became necessary to treat with the chiefs of the tribe who held its possession.

After considerable delay and difficulty, an appointment was made with them for an interview. It was fixed to take place on a Sunday, after church, that being the only time when a number of them could be brought together sufficient for the transaction of such important business.

At the appointed time, accompanied by an interpreter, the writer was ushered into the presence of the assembled chiefs. To the number of twelve or thirteen they were awaiting his arrival in a wooden shanty. After so much form and ceremony as had been expended on preliminaries, he certainly expected to have met chiefs ornamented after the manner of those in Cooper's novels, with paint and feathers, and prepared, before they proceeded to council, to offer him the "calumet of peace." Instead of this, he was introduced to a body of miserably dirty-looking old men, with hank hair, smoking short clay pipes. At first they exhibited great disinclination to treat. The writer endeavoured to discover the obstacle, and found that they considered

his youth a serious disadvantage. Upon assuring them, however, through an interpreter, that he was not less than forty, and by pointing out the grey hairs with which time had adorned him, he managed to persuade them that he was not unworthy the honour of their notice. Preliminaries thus adjusted, the other arrangements were easy, the more so as the terms proposed were liberal. The treaty was adjusted, and, after a shaking of hands all round, the meeting was dissolved—all parties being satisfied.

Half an hour after this interview, the writer found himself, with one of the chiefs, in a canoe, paddling off to a mail packet, in which he was to return to Montreal. This chief, although at the interview exceedingly taciturn, and apparently quite ignorant of English, was now sufficiently garrulous, and evidently a fluent speaker of the language. He was a pilot for the Rapids of Lachine, which the steamer was about to shoot, and of which, as they lay in the direct course between the stone quarries and the Victoria Bridge, the writer was more especially anxious to feel the force.

The river, just above the rapids, is half a mile in width and very deep. It suddenly widens out to several miles of shallow water, tumbling over an uneven rocky bed, the whole river, as far as the eye can reach, being quite white with broken water, amidst which, in numerous places, bare rocks are visible. Through these breakers the steamboat seemed to be rushing on to destruction; an idea which was strengthened when, after getting fairly into the rapids, the steam was shut off, and the ship was left to all appearance to her fate.

It soon, however, became evident that the vessel was passing along a deep hollow in the water, into which a torrent from either side was rushing with great velocity, without any apparent cause.

After passing along this trough for some distance, the bed of the river became quite visible on both sides, within a few feet of the surface. It was now apparent that the navigable channel down which the ship was rushing was a fissure in the rock, into which the waters were pouring. At one point this chasm, only a few hundred feet in width, turned almost at right angles, and the bows of the ship approached within a very few feet of its rocky edge. The rush of waters over the sides of the channel dashed against her bows with extraordinary force; but, at the very moment her destruction seemed inevitable, she was carried round and hurried along in safety, with a wall of waters on either side of her, till the quiet lake was seen, and to our infinite relief we felt that we were safe. There is, indeed, more real danger in

GREAT VICTORIA BRIDGE.



navigating the troubled shallow waters, filled with huge boulders, into which the river afterwards passes, than in going through the gap that looks so fearful to the inexperienced.

It is very commonly supposed that because the steamboats pass through the most crooked part of the channel (a distance of some half mile), with the steam shut off, that all steerage way is lost. Such, however, is not the case. Care is taken that sufficient way is always left upon the ship to admit of her answering her helm. It appears pretty certain, however, that once fairly in the hollow trough formed by the chasm, a craft would pass through in safety, even though floating without way, like a log or raft, the rush of the water pouring into the chasm over its sides being sufficient to keep her in mid-channel.*

Stone quarries, on a scale commensurate with the magnitude of the undertaking, were opened at Point Claire, some sixteen miles west of Montreal. From this point a tramway of about a mile in length was laid to the Lake St. Louis, where wharves were constructed for the shipment of stone. A great deal of it was brought to the bridge down the river; but the line of the Grand Trunk Railway of Canada passes within some half mile of this quarry, so that when that line was subsequently constructed, and in operation, stone was conveyed by this route also.

The stone thus obtained was very hard limestone, perfectly black in fracture, but when tooled, or when exposed to the atmosphere for a number of years, it becomes of a light grey colour.

* The shooting the rapids of the St. Lawrence is described by Mr. Hogan, in his Prize Essay on Canada, in the subjoined graphic language:—

"Before you reach them there is usually hardly a breath of air stirring; everything is calm and quiet, and your steamer glides as noiselessly and gently down the river as she would down an ordinary canal. But suddenly a scene of wild grandeur breaks upon you: waves are lashed into spray and into breakers of a thousand forms by the dark rocks they are dashed against in the headlong impetuosity of the river. Whirlpools—narrow passages beset with rocks—a storm-lashed sea—all mingle their sublime terrors in a single rapid. In an instant you are in the midst of them! Now passing with lightning speed within a few yards of the rocks, which, did but your vessel touch them, would reduce her to an utter wreck before the sound of the crash could die upon the air. Again shooting forward like an arrow towards a rocky island, which your bark avoids by a turn almost as rapid as the movements of a bird. Then, from the crests of great waves rushing down precipices, she is flung upon the crests of others receding, and she trembles to her very keel from the shock, and the spray is thrown far in upon her decks. Now she enters a narrow channel, hemmed in by threatening rocks with white breakers leaping over them; yet she dashes through them in her lightning way, and spurns the countless whirlpools beneath her. Forward is an absolute precipice of waters; on every side of it breakers, like pyramids, are thrown high into the air. Where shall we go? Ere the thought is come and gone, she mounts the wall of wave and foam like a bird, and glorious sublime silence lands you a second afterwards upon the calm unruffled bosom of a gentle river! Such is 'shooting the rapids.' But no words can convey a just idea of the thrilling excitement that is felt during the few moments you take in passing over them. It is one of the sublime experiences which can never be forgotten, though never adequately described."

A model barge was constructed for the conveyance of stone from the quarry to the works of the bridge, the rapidity of the current and shallowness of the water rendering a particular craft necessary for the purpose. The great object was to obtain a barge that, when laden with 100 tons, should only draw 3 ft. 6 in. to 4 ft. water, and have so clear a run as to be navigable when being towed against a current of six to seven miles per hour. The barge ultimately constructed was of the following dimensions :—

Length over all	92 feet.
Beam	22 feet.
Depth of hold	6 feet.
Draught of water, unloaded	1 foot 6 inches.
Ditto ditto, loaded.	4 feet.
Framing apart	1 foot 5 inches.

Material used—For keel, sternpost, gunwale, bilge, and principal beams—White Oak.

“ ” For floor and top timbers, keelsons, and planking—Tamarac.

Twenty-five of these barges were ultimately constructed.

The barges were eventually decked over, and the whole of the cargo carried upon deck, which, as some of the blocks of stone weighed as much as seventeen or eighteen tons, was the means of saving both time and labour, the decks of the barges being about level with the top of the dams and the loading wharves.

Two steam-tugs, the “Beaver” and the “Musk Rat,” were constructed by Messrs. Cantin and Risley, each of sufficient power, draught of water, and beam, to enable them to tow a barge against a stream six or seven miles per hour, to pass over some of the shallows of the river, and also to go through the locks of the Lachine Canal.

Their dimensions were as follows :—

Length on deck	158 feet.
“ of keel	150 feet.
Breadth of beam	26 feet.
“ over paddle-boxes	14 feet 6 inches.
Depth of hold	8 feet.
Draught of water forward	2 feet 6 inches
“ “ astern	3 feet.

They were built of oak, tamarac, and white pine. They were furnished with—

Condensing Engines :—Diameter of cylinder		36 inches.
Stroke		10 feet.
Skeleton walking beam, wrought-iron shaft and cranks.		
Paddle wheels		23' 6" diameter.
Floats, 6' 6" long, 28 inches in breadth, 22 in number.		
Boilers—Two circular tubular boilers :—		
Length	15' 4"	Length of tubes 6 feet.
Diameter	3' 10"	Diameter 3 inches.
Fire-box	6' 3"	Number of ditto 180.
Tested to 75 lbs. per square inch. Working pressure, 45 lbs. per square inch.		

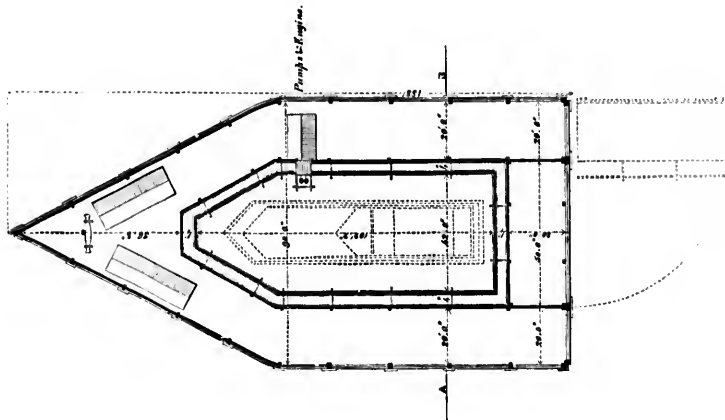
CHAPTER V.

DAMS FOR THE BRIDGE.

THE St. Lawrence, where it is crossed by the Victoria Bridge, was, by the soundings taken previously to the commencement of the work, shown to be of a depth varying from five to fifteen feet at summer water level, and to have a bed of limestone rock, with large boulders upon its surface. This led to the contriving of floating dams or caissons, which might be built during the winter season, and immediately upon the opening of the navigation floated into position and scuttled, so as at once to form a nucleus from which the dam could be constructed. As it was understood that no temporary works could be left in the river during the winter, these floating dams were so devised, that they could be readily pumped out and taken to a place of safety some seven miles below Montreal, to be again used the following spring.

The construction of these dams will be better understood upon reference to Plate. No. 3. They consisted simply of a framework of timber, forming a large caisson of proper shape and dimensions to encircle a pier, with sufficient space for piling, puddle chamber, and for the workmen engaged in the construction of the masonry. These caissons were 188 feet in length, and 90 feet in width over all. The front part, or bows, were made wedged shape to stem the current, and the stern, or hinder part, was made so that it could be removed when the masonry was completed, thus enabling the floating dam to be taken to winter-quarters.

The frame-work, or caissons forming the sides of the dams, were twenty feet broad, and twelve to sixteen feet deep, the width being increased near the bows to give

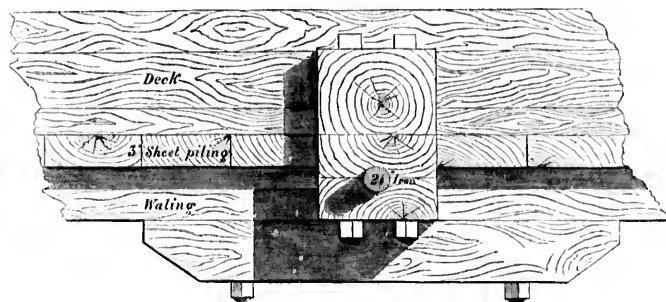


additional strength where the sides unite, and likewise to give more space for workshops, dormitories, &c. The bottom and lower part of the sides were carefully caulked, and when launched they drew some eighteen inches water only. Even with this light draught great difficulty was experienced in navigating the shallow rapid waters with so huge a mass. They were continually getting aground upon boulders, and in one instance, the floating dam having grounded upon a boulder, it was found requisite to cut a hole through the bottom of the caisson, lift the stone inside, and take it away with the floating dam,—a work causing both loss of time and cost.

The bed of the river being of rock, into which piles could not be driven, provision had to be made to prevent the dam when scuttled from being carried away, or at least moved out of its position, by any of the timber rafts which navigate the river during the summer. The bows were therefore made strong; and, at distances of twenty feet, around the whole of the outside of the caisson, strong piles, sliding in grooves, were provided, which, when the dam was moored in position, were lowered till they rested upon the bed of the river, keeping the whole perfectly steady.

Through the centre of some ten or twelve of these piles was placed a two-inch bar of iron, with a properly tempered point of steel, shaped for drilling the rock, which

being drilled some two feet down, rendered it impossible that the toes of these piles could, by any strain, be moved out of position.



The whole being thus far advanced, it was intended that the scuttling valves provided for the purpose should be opened and the mass allowed to sink till some part of the underside rested upon the bed of the river, or, as it generally happened, upon a boulder some two or three feet above the general level of the river-bed. The valves were to be closed till the whole of the dam was adjusted (by means provided for that purpose), and made as level as possible.

The piles were then to be bolted to the sides of the dam, and the scuttles opened to throw the whole weight upon the piles. It was hoped that by these means the dam would obtain sufficient stability, with the assistance of the heavy mooring chains used while the scuttling was going on, to stand against any raft that might strike it.

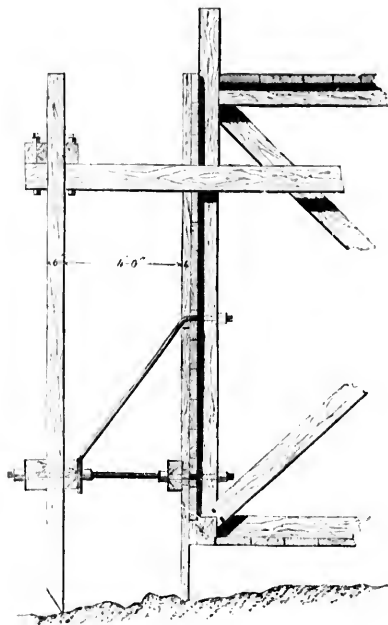
The mooring and scuttling was, in practice, found to occupy some four days, so that generally within a week from the time of getting the dam into position, the men were fairly at work, with every means and appliance at hand for prosecuting the work with dispatch.

The getting the dam into position was always found to be the greatest difficulty, whether from the place where built, or from its winter-quarters; indeed, this was the only drawback to their general usefulness.

In addition to the guide piles on the outside of the caisson, walings were

prepared on the inner side, or that part next the masonry, for the guidance of the sheet-piling necessary to form the puddle chamber. One set of these walings was bracketed from the sides of the caisson by means of iron rods, or bars, as shown.

It may not be amiss to mention, that the iron rods forming the bracketing were, in practice, found to be very objectionable, from the great difficulty there always was in getting the puddle clay rammed sufficiently close to the underside of the bars to prevent the passage of water.



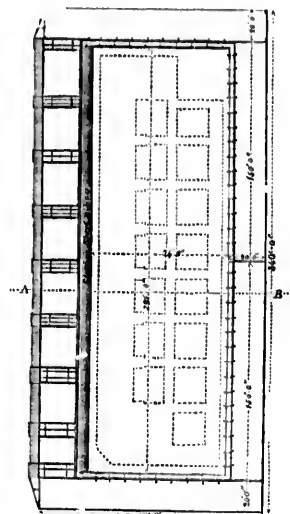
Up to a depth of ten or twelve feet, this plan answered admirably, but with a greater pressure than was given by this head of water it was found advisable to introduce a separate framing of timber into the space to be occupied by the masonry of the pier, the transverse pieces, or struts, being cut away as the masonry progressed. [See Plate, No. 3.]

The floating dams above described were commenced in the winter of 1853, and two of them were completed and launched in May. Upon reference to the diagram

[Plate No. 4], showing the rise of water consequent upon the breaking up of the ice in the spring, when "shoving" usually takes place, and destroys every temporary work within its reach, it will be easily understood that the dams had to be constructed at a sufficient distance from the shore to ensure their safety till the "shoving" was over. This placed the site for building so far from the edge of the river, that to get the requisite inclination for launching, they had to be elevated some ten feet above the level of the ground. These ways were formed of four rows of piling to within the limit prescribed by the ice, after which they were formed in the usual manner. The dotted lines upon plan, Plate No. 2, show the position of building ground, as likewise the intricate channel (if it can be called a channel) through which the huge masses had to be navigated to get them into position.

Preparations and arrangements were also made during the winter for proceeding with the dam for the formation of the north abutment, the dimensions of which required that it should be 340 feet by 150 feet, out to out. It was decided to use caissons of a similar character to those already described, which being provided with walings, sliding piles, scuttling valves, &c., might be readily moored in position. Six caissons, each 150 feet by 20 feet broad, were constructed upon the banks of the Lachine Canal, and were ready for work early in May.

The building of floating-dams, two steam-boats, and twenty-five barges equal to a tonnage of nearly 7200 tons, added to the unusual activity in the ship-building business during the winter of 1853,* greatly increased the rate of wages and material, the cost of building being at least sixty per cent. above ordinary prices.



CHAPTER VI.

EARLY WORKS. [1854.]

THE ice bridge having formed, and the river having assumed its ordinary winter level, the staff of the contractors commenced their operations by setting out and marking the position of the piers, taking soundings in the immediate locality of the works to be executed, and marking and buoying out the most navigable channels for their steamboats and barges.

Being without any experience of such a rigorous climate they suffered severely; many of the men had their noses, ears, or feet, frost-bitten, and some had to be sent to

* In the year 1853, forty-eight ships, with a tonnage of 48,000 tons, were built at Quebec, valued at £500,000, being an increase in one year of twenty-two ships, and of value £340,000.—*J. S. Hogan's "Prize Essay on Canada."*

the hospital from partial blindness, produced by the glare of the sun upon the snow. During strong winds their eyes were filled with fine drifting snow, at the same time that the sun was shining brightly over head,—very different to the scorching heat which a few months afterwards struck them down with *coup-de-soleil*.

The first operation was to make a level road over the roughly-packed ice, in the exact line of the bridge. This was performed by men with axes and shovels, in the same way a road is formed on land, some of the excavations being eight or ten feet deep.

The sites of the various piers were then marked out upon this level track, admeasurements being carefully taken by means of wooden staves, tested by a standard from

FIG. 6.—PIER No. 13.

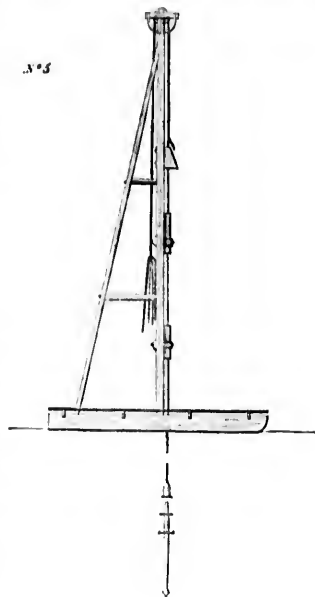
18.1	18.10	16.10	15.6	17.0	17.0	15.3	14.9	11.7	15.1	13.7
19.1	17.10	16.3	15.3	15.0	17.0	14.6	11.9	14.10	13.10	13.7
18.1	15.7	15.6	15.3	13.3	15.3	11.0	11.9	11.1	13.10	11.1
16.4	16.4	15.0	15.9	13.6	13.9	13.9	15.3	12.4	12.4	12.4
16.7	16.4	15.3	15.0	15.6	13.9	11.0	15.3	13.1	13.7	12.10
16.7	16.4	16.3	15.9	15.3		11.6	15.0	11.1	13.4	12.4
15.4	16.1	16.0	15.9	13.9	13.0	11.6	11.3	13.16	11.4	9.10
16.1	17.1	16.0	14.3	13.3	11.6	11.3	14.9	13.10	11.10	11.4
16.4	17.1	16.3	15.0	13.0	12.0	12.0	13.3	13.1	13.1	12.4
17.1	18.1	17.0	14.9	13.6	13.6	12.6	12.3	12.7	13.6	11.1
18.7	18.7	16.6	14.9	11.3	13.3	12.0	12.6	14.10	14.10	12.4
18.1	17.1	16.0	14.3	13.6	13.6	13.0	12.9	13.4	13.1	11.4
17.1	16.10	15.3	13.9	13.0	13.6	13.6	13.9	13.7	13.4	11.10

the Canada Works at Birkenhead, and by which the lengths of the tubes were subsequently measured. Holes were then cut in the ice around the site of each pier, as shown at Fig. 6, and soundings were taken as accurately as possible; though it happened, from the rapidity of the current and the accumulation of anchor ice, that some of the soundings taken were found to be very erroneous. The centre of each pier was also carefully marked out, and an iron drill, or pin, was bored into, and left in,

the bed of the river, to mark the exact position of the pier when the dams should be pumped out. These pins or drills were 5 feet long, 4 inches diameter, bored into the bed of the river about 3 feet 6 inches to 4 feet, or till the cross-bar, to which was attached buoys, touched. In drilling these in, a small ringing-engine was used, and the drill being attached to the long rod by a square socket, was lowered till it rested upon the ground. When the current was very rapid, a guy-chain was used, which, passing through a chase cut in the ice on the up-stream side, held the drill in position till the point was fairly entered. A small ram was then worked upon the top of the rod, and at every stroke the drill was made to revolve a certain distance by means of a ratchet-lever attached to the machine. No augur was used to test the material bored into, because the hard conereted mass forming the bed of the river was in some instances even harder than the rock itself, and it was therefore taken for granted that it was rock, the same as seen in the shallow water near the river banks,

and covered only with a few inches of gravel, interstrewn with large boulders. Hence it was that nothing was known of the existence of live sand and clay between the bed of the river and the rock upon which the piers had to be founded. During the winter, crib-work moorings were framed upon the ice, filled with stone, and sunk in position above the piers, for the purpose of ensuring anchorage during construction. These cribs were formed of such height, that when sunk they should be about a foot above summer water level, by which means the ice would pass over without injuring them.

Despite all this care and arrangement, the spring of 1854 burst upon the country before the barges, steamboats, and dams were ready for work. It was not until the 24th of May that the first caisson was towed up the stream from the Lachine Canal, and moored as near as possible to the site of the north abutment. This may, therefore, be fairly considered the commencement of the season's operations, and indeed of the commencement of the bridge itself, as up to that time all had been but preparation.



The caisson towed up was 150 feet by 20 feet. It was intended that six of these caissons should be scuttled, to form the four sides of the dam to the north abutment. It was, however, soon found that to moor and sink such a mass, broadside on, in a current of five miles per hour (such being its velocity at the site of the abutment), would be a very difficult operation. The two end scows were therefore moored and scuttled, after which small skeleton cribs were framed and sunk 25 feet apart, in the line of the up-stream side of the dam. Upon a longitudinal timber laid on these, sloping planking was placed at about an angle of 45° , the lower end resting upon the bed of the river.

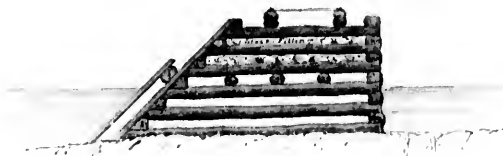
By this means quiet water was obtained across the whole of the space to be occupied by the abutment, and the caissons forming the lower part of the dam were very easily sunk in position (see Fig., page 17). The sheet piling was now proceeded with immediately, great care being taken that the toes of the piles fitted the rock,

which at that particular point was perfectly free from any deposit whatever. The puddle chamber was so contrived that at its juncture with the sloping planking forming the upper side of the dam, the puddle-clay should be continuous and unbroken, the very small portion laid at the foot of the sloping planking being pressed so firmly down upon the rock, by the weight of water, as to render this by far the tightest part of the dam. Planking laid in this manner, with the joints a little open upon the upper side, and with a small quantity of fine gravel sprinkled upon it, makes the staunchest dam that can be formed, providing the ground upon which the lower end rests is sufficiently strong to prevent underwash.

Pumping was commenced 24th August; and, after some little difficulty in stopping leakages where the toes of the piles did not fit into crevices of the rock, or where they came upon boulders, the dam was made perfectly tight; and men were seen with brooms sweeping the almost perfectly level rock clean of the deposit caused by the washing in of the puddle clay during the stoppage of leakage.

The dam thus formed was some 1200 feet from shore, and as the water in the river lowered, was almost inaccessible, excepting on one side only, and even on that side, in consequence of the immense number of boulders and the rapidity of the current, it was scarcely safe for the navigation of heavily laden barges.

A tramway was therefore constructed from the shore (in the manner shown). Piers of skeleton cribwork were placed at intervals of some twenty feet, which were kept in position by loose stone laid upon a flooring provided for the purpose, and upon the top of the cribs, longitudinals were placed to carry the roadway, at the same level as the shore and top of dam.



Sloping planking was laid along the whole length of the tramway, in the same manner as that used for the upper side of the dam, leaving perfectly quiet water, in which the embanked approach was formed during the summer, the crib-piers and sloping planking being buried in the embankment.

It may not be out of place to say something here concerning "Cribwork," which, although quite unknown in England, is so universally used both in Canada and the United States. The whole of the Canadian habitans use the axe with far greater facility and skill than an ordinary carpenter does in England; and, as the timber of which such work is usually constructed, flatted pine, hewn on two sides only,



is very plentiful, it is constructed at little cost, and with great rapidity. Piling is comparatively little used in America, the wharves, and even the foundations for bridges in deep water being almost entirely of this "cribwork." It is formed simply by laying timber along the whole of the outer edge of the work, and at intervals of from five to ten feet, parallel therewith throughout the whole of the breadth, connected by means of transverse timbers firmly trenailed and notched into them. The transverse timbers for rough work are not notched down flush with the longitudinals, but are left some four or five inches up. As soon as one course of work is thus formed, another is laid upon the top of it, and the two are firmly trenailed together. An axe and an auger are the only tools used. The flatted pine (which is usually floated in a raft to the site of the work), and a piece of freely splitting hard wood for trenails, are, with the stone required for sinking, the only materials employed. After some two or three courses are formed, it is usual to place the transverse timbers close enough together to form a flooring, upon which stone is placed to sink the crib as the work progresses. By this means the timber has never to be lifted any height till the work is above water. As soon as the underside of the crib touches the bottom it is filled with loose stone to the water level; and as in all probability the ground upon which it rests is not perfectly level, the upper course of timber work is made to correspond with the surface of the water. Above this all the courses are made perfectly fair, and to fit closely upon each other, and they are neatly chopped on the outside so as to present a smooth face, the ends of the transverse timbers being neatly dovetailed and showing upon the front of the work. Another flooring is frequently put on at the water level, upon which the backing, if for a wharf, or the stone filling, if for a pier, rests. The timber work below the water line, not being subject to worms, never decays; and as in the Canadian lakes and rivers the rise of the water is not great, the major part of such work is imperishable, and a stranger cannot fail to be astonished at the rapidity with which work of this description is executed, and with its stability when finished.

The piers of a bridge constructed in this manner are built to the water level in a few weeks. Sometimes holes are cut in the ice during winter, and the cribs built to water level and left till the summer low water, by which time the scour of the spring

flood has caused the whole of the crib to subside. The timber work is then levelled to lowest water, and is carefully filled with loose stone, upon which substantial masonry is erected. If the bottom, upon which the work rests, is likely to be subject to further scour, loose stones are thrown around the outsides of the cribs, till they form a slope from low water mark outwards all round. In these cases, if ordinary care is taken, further subsidence seldom or never takes place, and the work remains as substantial as if of ashlar to the bed of the river. Some of the most important bridges in the United States are thus constructed. The piers of a bridge over a branch of the Ottawa, at Vaudreuil, were built in this way; and although the current, in time of floods, equals six miles per hour, not the slightest subsidence has occurred.

Having mentioned the Vaudreuil Bridge, it may not be out of place to mention a circumstance connected with its construction, which may show, in some slight degree, the difficulties to which contractors are subject, when executing works in a climate and in a country of which they have comparatively little local knowledge.

At the Vaudreuil Bridge, some six of the piers were upon an island, flooded only occasionally in the spring, and, as it was partially covered with brushwood, no danger was apprehended from ice, and the piers were erected without ice-breakers. In the spring of 1855, before the breaking up of the ice in the Lake of Two Mountains (which immediately adjoins the arm of the Ottawa spanned by the Vaudreuil Bridge), its waters, from some unknown cause, rose to an unprecedented height. This, together with a storm of wind, set in motion the smooth level sheet of ice covering the lake, which was about two feet thick. The ice, thus set free, was carried over the now submerged island. It soon began to press against the piers of the bridge; and ultimately, even though moving very slowly, it forced the whole of them some 2 ft. to 2 ft. 6 in. down the stream, without disturbing a joint of the masonry above the line of the moving ice, and leaving all below uninjured! The masonry in each of the piers weighed over 150 tons, and was composed of large stones, many of them running quite through the work. The piers had to be rebuilt, with ice-breakers in front. In that amended form they will not probably again be moved.

CHAPTER VII.

WORKS. [1854.]

THE masonry of the north abutment of the Victoria Bridge was commenced on the 28th August, 1854, the stone being brought by barges through the Lachine Canal as far as the canal basin. There it was transferred to trucks, and conveyed immediately to the work. As the various travellers intersected the track at right angles, great facility for setting the masonry was afforded, and 85,428 cubic feet of stone were laid during this summer, raising the work to some six feet above the summer water level.

The embanked approach was raised to some five feet above ordinary winter level; but in consequence of difficulties arising from a scarcity of labour, from strikes amongst the workmen, and from sickness, the embankment was not carried so high as could have been desired. Neither was it complete at its junction with the masonry when the winter made its appearance, and all work ceased. The pumps used this season were of very rude construction, being only square trunks, formed of deal and bound with iron. They threw a large quantity of water, and answered well with a lift not exceeding fourteen feet. The pumps ordered from England not having arrived, necessity compelled the use of such as our limited means enabled us to make for ourselves. The floating dam, or caisson, of No. 1 pier, was got into position, scuttled, and the piling fairly in hand by the 19th June. The rapidity of the current, together with the numberless boulders lying in all directions, caused more delay and trouble than was anticipated. This, in addition to the difficulty of getting men competent to handle such unwieldy things in so rapid a current, raised great doubts as to the economy, either of time or money, resulting from this mode of proceeding.

The dam once in place, the piling and puddling proceeded rapidly. By the 15th July, pumping was commenced, and in a few hours the rock forming the bed of the St. Lawrence was dry, and the toe of every pile distinctly visible.

It was a curious sight to stand upon the deck of the dam, and to watch the waters

of the St. Lawrence rush frantically past, while, inside the dam, the bare rock was visible, with the piles simply resting upon it. In the first instance, not a little alarm was entertained lest something should come down the stream and displace the whole. So strong was this sensation at first, that when a steamboat or a barge came against the dam more heavily than usual, every one would be looking anxiously around, with the apprehension that some leakage might be produced by the concussion, and that those upon the dam might be compelled to seek safety in a precipitous retreat.

The dam, however, stood well. By the 22nd July, the first stone was laid, and on the 14th of August the masonry was above water level.

From various causes beyond control, the pier was not finished till late in November, too late by a few days, as it happened, to allow of the dam being removed to the shore, as was intended. For details of masonry of piers, see Plate 21.

The floating dam for No. 2 pier was launched and moored in position by the beginning of July. During a storm, however, which occurred soon after, a large raft was driven out of its course, and tore away the moorings of this dam, carrying it with it a considerable distance, until, becoming disentangled from the raft, the dam was brought up with the anchors provided on board for such a contingency. Three tugs were required to get the dam back into position; and this task was not accomplished, and the work fairly progressing, till July 20th.

Various other delays occurring, the second dam was not ready for pumping until the 18th September. When the water was nearly pumped out, one of the pumps failed entirely, while its fellow, which threw only some 700 gallons per minute, proved insufficient to clear the dam. It soon became evident that there was considerable leakage somewhere, although the water remained perfectly clear, without any of the cloudiness generally produced by leakage through the puddle chamber. Another engine and pumps were therefore put up as speedily as possible. By the 28th a further attempt at pumping was made, and in a few hours the bed of the river was visible. It was then found that the rock in this immediate locality was of a very uneven character, a trap dyke some three yards in width crossing the dam almost diagonally, through a fissure in which a clear spring of water issued, discharging about 800 gallons per minute. As all attempts to stop this were useless, the pumps had to be kept continually going until the masonry reached water level early in November. On the 11th November the pier was some four feet above summer water level, and as the season was far advanced, no further attempt at progress was made.

In consequence of the extreme difficulty experienced in navigating floating dams, and the almost absolute impossibility of procuring sufficient skilled labour to manage them, it was determined that Nos. 5 and 6 dams should be constructed of cribwork in the manner usually adopted in Canada.

Messrs. Brown and Watson, two of the most experienced contractors in the province, who had succeeded in constructing a dam across a branch of the St. Lawrence at the head of the Co'leau Rapids (where the current was so strong that large boulders, weighing upwards of a ton, were frequently rolled along by its force), were engaged for this work, and commenced operations in June.

The commencement of a dam in the middle of a river nearly two miles in width, full of shoals covered with boulders, and with a current never less than five miles an hour, proved, however, a very different matter to the commencement of a dam from the shore. Still, these sub-contractors, to their great credit, struggled against every difficulty, and eventually succeeded in accomplishing their task. (For plans of cribs, see Plate 5.) Their first operation was to form portions of cribwork, some forty feet long, for the sides of the dam in the quiet water near the entrance to the Lachine Canal. These were then to be towed into position and sunk. Two steamboats were employed for the purpose, and after repeated attempts, the towing of them against such a current was found to be impracticable. The cribs in some of the attempts were literally torn to pieces.

The material, therefore, was loaded into barges and conveyed to Lake St. Louis, where the cribs were again formed, and brought down the rapids by Indians. A steamboat was in waiting for each piece as it came into the La Prairie Basin above the Bridge, and towed it to moorings placed immediately above the site of the pier for which it was intended.

To arrest the progress of the crib in such a current was found to be as impracticable as to tow it against the stream, and this method of proceeding had also to be abandoned. The timber for the cribs had therefore again to be collected and re-loaded into barges. These were taken to the site of the dam, and the framing of the first crib was commenced in the rapid waters immediately behind the moorings. After great difficulty, this crib was framed and sunk, and well weighted with stone. The men now having something stable to work upon, the remaining cribs were much more readily put together and got into position; and although the whole of the season was spent in constructing the cribwork of this one dam, and the process seemed

exceedingly slow and costly, yet the experience gained was of great service throughout the whole progress of the work.

The first working season at the Victoria Bridge was a period of disaster, difficulty, and trouble. We had opposed to us, first, our inexperience of the climate and of the country; second, numerous strikes of our workmen; and, above all, the dreadful ravages of the cholera. To these were superadded difficulties which arose from jealousies on the part of many inhabitants of Montreal, who predicted that although we might succeed in erecting the piers, the first winter's ice would sweep all away. In writing home the agent did indeed muster sufficient courage, at almost the very worst period, to express a hope that he "should live to see the bridge finished;" but he must now candidly confess that at the time he scarcely saw good reason for such a hope, except in his dependence on the beneficence of a higher power. Nevertheless, despite all discouragements, it is right to record that every assistant and sub-contractor engaged upon the work struggled on manfully to the end, and never failed in duty or in zeal.

The amount of work in progress at this period, not only in Canada, but throughout the whole of America, particularly in the Western states, was so great, and the demand for labour in consequence so pressing, that it was no uncommon thing for an agent from some other works to come amongst our workmen, and by an offer of almost fabulous wages induce perhaps more than half of them to leave. The effect of this upon those left behind was to render them discontented and ready to strike, unless their demand for an increased rate of wages was immediately complied with. The workmen brought from England were also exceedingly troublesome this year. In one instance, a number of mechanics, brought out at a cost of upwards of £3000, became so unmanageable, that in a fortnight from the time they got to work they were all disorganised, and struck. These men, during this year, never worked more than four days in the week; and although bound by an agreement made in England, it was found better to forego the amounts advanced to them and let them leave, than to endeavour to restrain them by force of law against their inclinations.

Besides strikes occasioned by these causes, it is almost a custom in Canada for mechanics and labourers to strike twice a year, let the rate of wages be what it may. The first period of general strike is in the spring, when increased activity in every business is occasioned by the arrival of the spring fleet. The second is at the commencement of harvest, when there is abundant demand for labour. These strikes, though lasting a short time only at each period, produced disorganisation in the

work, and the loss of many of our best workmen ; and this, in so short a working season as six months, and with scarcity of labour at all times, proved a much more serious evil than can be readily understood by those who have not been exposed to similar dilemmas.

Early in July, the cholera made its appearance, making sad havoc amongst our men. In one case, out of a gang of 200 men, 60 were sick at one time, many of whom died. On the 31st July, in writing home, the agent stated, "we are struggling against the cholera, but it is a hopeless task, for all who are not attacked, and who can do so, leave this part of the country : nearly the whole of our best men have gone westward." Again, on the 14th August : "The harvest is now taking the few men the cholera left us, and some gangs are dispersed entirely. The cholera has been a fearful scourge, and at Vaudreuil is now followed by typhus. A few weeks may bring cooler weather, and we may yet get a great deal of work done before winter sets in. It is annoying, however, to be in want of labourers just as we are ready to make a push, and with the winter so near."

During the month of August the weather was fearfully hot. The country became so parched that fires in the woods spread to an almost unprecedented extent, and hundreds of square miles of forest were burned. These fires were not in the immediate neighbourhood of Montreal, nor indeed within many miles of it, yet the smoke for several days was so dense that our steamers and barges were unable to cross the Lake St. Louis, and the works suffered considerable delay in consequence. During these periods the air was laden with particles of ashes, and the sun became partially obscured, and of a lurid reddish colour. The heat was insufferable.

After harvest, about the end of September, the cholera having disappeared, labour became more plentiful, and the work went on more satisfactorily. On the 16th of October the first snow-storm gave warning that winter was approaching, and great efforts were made to press the work. It was, however, too late to place it in such a state as it should have been before the winter set in.

During November the frosts were very severe, the thermometer registering Zero : yet, as the days were fine, some little work was done, although towards the end of the month we were able to do little more than endeavour to protect what had already been done against the ice, which now began to make its appearance in the river.

The first week in December was so cold that all work on the river had to be

abandoned, and at the close of this, our first season, it was apparent that, although the most strenuous exertions had been made, regardless of cost or trouble, very little progress had been the result. Even the work that had been done was left in an unsatisfactory and unsafe state.

The progress diagram (Plate 1) will show the state of the work at this period.

No. 2 pier will be seen carried up to four feet above summer water level, with the floating dam, that should have been removed, still encircling it. This was protected in a temporary manner by timbers sloping from the bows to the bed of the river, and with some 300 tons of stone placed upon the deck, and upon timbers laid across the dam over the masonry. The whole of the staging remained up, there being time only for the removal of the machinery.

No. 1 pier was finished, and the floating dam within one day of removal, when the ice set it fast, and, beyond removing the staging, nothing more could be done than to weight it with stone as described for No. 2.

The north abutment was left some six feet above summer water level, with the scows that formed the dam still in position, weighted with large quantities of backing placed upon the deck. The most exposed angles of the dam were also protected by large cribs filled with stones, and sunk on the up-stream side of the work.

The embanked approach was made up to winter level.

No. 5 dam, being of cribwork filled with stones and planked over, was considered perfectly safe, and caused no uneasiness.

There are, as already stated, two channels crossed by the bridge, which are partially separated by a bank called the Middle Shoals. The inner or north channel takes the water passing between Nun's Island and the Island of Montreal, and in this channel No. 2 pier is situate, No. 5 dam being upon the Shoals.

Upon the first setting in of winter, the whole of the water north of the middle shoal became frozen over and covered with smooth ice, which was held in position and strengthened by the works of the bridge. This continued unbroken till the river had become frozen over, and vehicles had crossed several times. There had been a great deal of "shoving" below the bridge, and likewise upon the south side of the river

above, yet up to this time the part held up by the bridge remained uninjured, and great hopes were entertained that the temporary works might stand through the winter.

A rapid thaw, however, set in, accompanied by heavy rain, destroying the ice-bridge, and setting the river again in motion. For a long time the smooth field of ice remained unmoved, although upon its outer edge, along the line of the Middle Shoals, a great deal of shoving and packing took place. This packing continued till it blocked and completely choked the whole of the channel south of No. 1 pier, and till the grounded ice upon the Middle Shoals, upwards towards Nun's Island, quite separated the waters of the two channels. The water coming down the inner channel being thus pent up, had to find its way between the abutment and No. 1 pier, which, being likewise partially choked, the rise of water and the pressure became so great as to carry away three of the scows from the abutment dam, together with about thirty yards of the embanked approach, the whole of which was swept away *en masse*, and deposited some distance below. In this position all remained quiet for some time, the packed ice on the ridge or shoals effectually separating the waters of the two channels; but the rush of water over the masonry of the abutment, and through No. 1 opening, was most alarming.

The scows and portion of the embanked approach removed, became frozen, and formed a portion (though a very small portion) of the immense mass of packed ice by which they were surrounded. As the water rose, the scows were floated away down the stream till the waters subsided, when they grounded again and remained stationary.

The river continued to rise, and the ice to pack and shove, until the 4th of January. On that day, the water having risen sufficiently to float the packed ice on the shoals, and the jamb below having given way, a general movement took place. Nos. 1 and 2 dams were carried away in the same manner as the abutment scows. This movement of the ice took place at noon on the 4th January, and presented a sight never to be forgotten. The whole of the river and La Prairie Basin was one mass of packed ice, which, being held up by the jamb below, had been accumulating and rising for four days. At last some slight symptoms of motion were visible. The universal stillness which prevailed was interrupted by an occasional creaking, and every one breathlessly awaited the result, straining every nerve to ascertain if the movement was general. The uncertainty lasted but a short period, for in a few minutes the uproar arising from the rushing waters, the cracking, grinding, and shoving of the

fields of ice, burst on our ears. The sight of twenty square miles (over 124,000,000 tons) of packed ice (which but a few minutes before seemed as a lake of solid rock) all in motion, presented a scene grand beyond description.

The traveller-frames and No. 2 dam glided for a distance of some hundred yards without having a joint of their framework broken. But as the movement of the ice became more rapid, and the fearful noises increased, these tall frameworks appeared to become animate, and, after performing some three or four evolutions like huge giants in a waltz, they were swallowed up, and reduced to a shapeless mass of crushed fragments.

After gazing at this marvellous scene in silence, till it was evident that the heaviest of the shoving was over, all those in the transit tower from which it had been witnessed, began to inquire how the solitary pier, No. 1, which had been battling alone amid this chaos, had escaped? Although some affected to entertain no fear, the author confesses, for his own part, to have felt infinitely relieved when, upon looking through the transit instrument, he discovered that the pier had not been disturbed.

The ice bridge formed on the 5th of January, after which there was no further movement till the spring.

CHAPTER VIII.

WORKS. [1855.]

DURING the winter of 1854 and 1855, very little preparation was made for proceeding with the work, beyond providing timber and quarrying stone. Neither was the third floating dam finished. The financial state of the Company, and the rise in the value of money caused by the Russian war, prevented any work being proceeded with, or any preparations made, that were not absolutely needed to keep the best men together, so that in case of brighter prospects the season might not entirely be lost.

On the 20th of April the ice began to show signs of movement. On the 21st it shoved over the embankment, and some clear water displayed itself in the La Prairie Basin. But it was not till the 28th that the river was clear enough to allow the steamers to leave their winter quarters for the harbour of Montreal.

On the 5th of May the ice bridge at Quebec broke up, the crossing to within a few days of that date having been safe.

Upon an inspection of the works, the masonry both of the piers and the abutment was found to have remained sound and uninjured. The damage and loss sustained had been limited to temporary works only, viz., floating dams Nos. 1 and 2, the scows forming the abutment dam, and the material washed away from the embanked approach. The making good of the last gave more trouble and difficulty than was experienced in its original construction. The quantity washed away amounted to some 9000 cubic yards.

The season commenced, as usual, with strikes of the workmen. Upon the bridge-work the men were content and satisfied; yet they were compelled, by the disaffected from other works, to remain idle till the strike was over.

The programme of this year's work was not decided upon till the season was far advanced. Ultimately it was arranged—

To finish No. 2 pier.

To build crib-dams and put in foundations to summer water level, for Nos. 3 and 4 piers.

To complete dams Nos. 5 and 6, and put in foundations to summer water level.

To build dam for south abutment, and carry up the work to the summer water level.

For No. 2 pier the masonry was commenced August 7th, and the pier completed October 20th, the staging being erected upon two scows built for the north abutment coffer-dam in the previous year; one scow being placed on each side of the pier, supported upon legs or piles, as the floating dams were. The whole of the floating dams built to this and to No. 1 pier had been cleared away by the ice, leaving the masonry perfectly clear.

The dam for the south abutment was commenced as soon as the ice cleared away, about the middle of May, and was proceeded with very vigorously.

The water on the south side of the river being shallow, and with a current not exceeding two miles per hour, the cribwork of which this dam was constructed gave very little trouble. The materials were conveyed to the works by means of a

tramway laid upon cribs, constructed in the same manner as that used for the north abutment.

This dam was commenced immediately upon the breaking up of the ice, say by the middle of May. It was completed and pumped out by the 26th July. Some eight feet of excavation was required, the site of the abutment being in a hollow of the rock. The ground, however, was sound and hard. It gave very little trouble, and masonry was commenced on 27th August. At the close of the season the masonry was two feet six inches above summer water level, at which it was left. For details of masonry, see Plates.

The stone for this abutment, and likewise for several of the piers on the south side of the river, was obtained from an island, called *La Motte*, in Lake Champlain, where it was found in great abundance. It was conveyed from the quarry by barges to St. John's, a distance of some forty miles; and from thence immediately to the work, nineteen miles, by the Champlain Railway.

This stone differed but very little from that obtained at Point Claire; it was much more easily quarried and wrought, the beds being more even. Excepting that the transverse fracture showed a cleaner and more even surface, the stone from the two quarries could scarcely be distinguished the one from the other. In the work it was only perceptible by the smooth fracture of the Champlain stone producing a less bold rock face to the masonry than the stone from Point Claire.

At the junction of the Champlain Railway with the temporary track for the bridge works, was erected the celebrated steam-traveller, constructed by Mr. Chaffey, which handled the whole of the stone for the work on the south side of the river. (Plate No. 6). This traveller was sixty feet span, moving upon gawntrees, 1300 feet in length and twenty feet in height. Between these the stone was sorted and stacked ready for work. The engine and hoisting apparatus formed one machine, moving transversely upon the traveller, which was likewise moved longitudinally with the greatest facility by the steam power. The machine unloaded the waggons, and stacked the largest blocks of stone, some of which weighed ten tons, with the greatest ease. In addition to all this, it performed the work of a locomotive; for, after the train was once placed between the gawntrees, it did all the shunting required. Over 70,000 tons of stone were moved twice by this machine; and, although it was most rudely constructed, and frequently handled as roughly, it remained, at the close of the work, an efficient machine in good working order. One man only was required upon the traveller, with one other to lewis and

stack the stone. These men, with the assistance of a labourer to pump water, were all that were required to manage the unloading, sorting, stacking, and shunting.

And here it may not be amiss to observe, concerning the emigrant mechanic (who so often has to perform work without either proper material or appliance, and who likewise is so often driven to contrive simple labour-saving machinery), how superior he is to the man he was when he first left home. Why is it that a plodding man of this description, shut out (as he is usually considered to be, by those who pay him a transitory visit in the colonies) from all means of gaining information or knowledge, should, in a short space of time, become self-reliant, competent, and able? He has scarcely any means or appliance at his disposal to accomplish that which a few years before, when at home, with everything at hand, he would after repeated attempts have abandoned as impracticable. Before leaving England, the writer made a sketch and description of a steam-traveller, such as the one described. One of the most eminent firms in England was consulted and employed to accomplish what he required, and, after some two years of experiment and an expenditure of some thousands of pounds, a machine was sent out which could never be made to do very much more than move itself about; and which, after various fruitless attempts to make it available, was thrown on one side and never used afterwards. In the meantime, the same drawings and description were shown to Mr. Chaffey, one of the sub-contractors, himself an Englishman, but who had been in Canada a sufficient length of time to free his genius from the shackles riveted to him in early life, and during the winter of 1854 and 1855, the rough, ugly, but invaluable machine referred to, was constructed, and in the spring was put to work. This is only one illustration which could be given of acquired skill and ready application, out of many exhibited by members of the staff, men who, when they left home, gave little evidence of being above the ordinary mark, but who, in Canada, proved themselves full of enterprise and resource.

During the winter of 1854 and 1855, a portion of the cribwork, forming the head of No. 6 dam, was framed upon the ice, and sunk in position. The greatest care was taken to remove all ground ice before sinking it, and likewise to leave the top at summer water level, so that the ice at its breaking up might pass over it. Nevertheless, upon inspection in the spring, it appeared that it had been shoved down stream by the ice a considerable distance, rendering the removal of some portion of it absolutely necessary before the puddle chamber could be made perfect. In consequence of this, the whole season was spent in constructing this dam. Small mooring cribs were afterwards sunk; but, till the winter of 1858, no more cribwork intended to form portions of a dam was sunk through the ice.

The dam No. 5 was completed this summer, and after great difficulty from leakage, the masonry was commenced on the 10th of October, and left at 2 feet 2 inches above summer water level on the 24th of November. The dam for No. 3 pier, built this year, was not, from financial pressure, commenced till the end of June. Cribwork was used for this dam, which was framed *in situ* and sunk in the same way as No. 5 dam, proper mooring cribs having been sunk through the ice during winter to facilitate operations. The bed of the river at this part was exceedingly uneven, the water on one side of the dam being some ten feet deeper than on the other. To frame the cribwork to fit this uneven surface took much time, and it was not until the 26th of October that the water was pumped out.

On the night of the 28th of October, the engine-house covering the pumping machinery took fire, destroying the whole of the apparatus; and it being too late in the season to commence the erection of others, the dam was planked over and made secure till next year.

Dam No. 4 was built of cribwork this year, but being upon the centre of the Middle Shoals, with a tolerably even bottom, very little difficulty was experienced in its construction.

The floating dam, commenced in 1854, was also completed ready for launching, it being intended for No. 7 pier.

A *resumé* of the season's operations shows—

The north abutment carried up to winter level, with the embanked approach made good to it.

Nos. 1 and 2 piers finished.

Nos. 3, 4, and 6 dams complete.

No. 5 pier two feet two inches above summer water level.

South abutment two feet six inches above summer water level.

The cost of the work this year was much increased by the financial depression which had caused the loss of the best portion of the season. As it appeared probable that this would continue during another year, the writer strongly advised the abandonment of the contract, if such a thing could be accomplished. Abundance of plant and material, able assistants and foremen, competent contractors and workmen, all sharpened and experienced by their former mishaps, were ready for the prosecution of the work, and to lose these by delays, and eventually to have to replace them by inexperienced men,

was a contingency so much to be dreaded that any sacrifice appeared to be better than the continuance of the work in such a state of uncertainty. Different views upon these matters prevailed, however, in other quarters, and it remained to the contractors who had undertaken this great enterprise, to continue their prosecution and to complete the works they had commenced.

CHAPTER IX.

WORKS. [1856.]

The snow storms of the winter of 1855-6 were far more formidable than any before remembered in Canada. When strong winds and intense frosts occur simultaneously (a very rare occurrence), the minute particles of which snow-drift is composed pack so closely that they become almost as hard as a well-beaten road. The writer has driven over a newly formed snow-drift of this kind fifteen feet deep without leaving more than a faint impression of the horse's feet, and no track whatever of the runners of the sleigh upon its delicate surface.

Our first operations this year were to frame and sink mooring cribs from the ice for piers Nos. 7, 8, 9, and 10. Those for 8, 9, and 10 were in pairs, twenty feet apart, but so arranged that by dropping an apron, hinged by a timber laid across, upon the down-stream end of the cribs, it would effectually stop the current, and form an eddy in which the cribwork of the dam could be constructed. The cribs were sunk some 100 feet above the site of bridge.

The ice bridge which was formed on the 10th of January broke up on the 10th of April.

The river became clear, and the first steamboat was in harbour on the 24th of April.

This season's operations were in all respects similar to those described for last year.

No. 3 dam was pumped out by the 2nd of June. At the bows of this dam, where the excavation was twelve feet deep, a vein of clear blue clay was found, while

along the north side and across the stern, where the water was deeper by some ten feet, there was nothing but boulders intermixed with gravel and sand. When the water was pumped out of the dam considerable leakage was discovered along the whole of this space, the water appearing to percolate through the stratum. To stop this, another row of sheet piling was driven, breaking joints with the first, but to no purpose; for as the finer particles were washed out from between the large stones, the leakage increased. A third row of piles were then driven, many of which penetrated the loose stratum some eighteen inches or two feet, twisting till they were probably at right angles to the line in which they were first pitched. Eventually, after nearly filling the puddle chamber with piles, and after the water had burst in many times, bringing large boulders from under the puddle chamber with it, the dam was made tolerably staunch. The masonry, which was commenced on the 9th of July, was completed on the 31st of October.

No. 4 pier presented no difficulties, the water being shallow, and the ground excavated solid, without any clay or running sand: depth to rock, 12 feet. No craft, excepting canoes or row-boats, could approach this dam in consequence of the numberless boulders surrounding it. A temporary bridge upon scows was erected across the opening between piers Nos. 3 and 4, over which the material was conveyed.



In excavating for this foundation, a very large boulder was discovered occupying the north-east corner of the dam, in such a position that, to make room for the masonry, it was necessary to cut through some eight feet in depth of it, an operation both tedious and annoying. During the whole time this work was in progress, fear was entertained lest the water might find its way around the stone into the dam; as the boulder, to all

appearance, extended under and far beyond the outside of the puddle trench. Fortunately, it was so firmly imbedded in the stratum by which it was surrounded, that not the slightest leakage occurred, and the masonry was commenced on the 24th of July.

No. 5 pier was completed on the 3rd of October.

No. 6 dam.—In consequence of the partial displacement by the ice of one of the cribs forming the head of this dam, great difficulty was experienced in making it staunch. The object was not accomplished till the 21st of July, although pumping commenced on the 19th of May. No excavation was required at this pier, the rock being quite bare. The masonry was finished on the 29th of October.

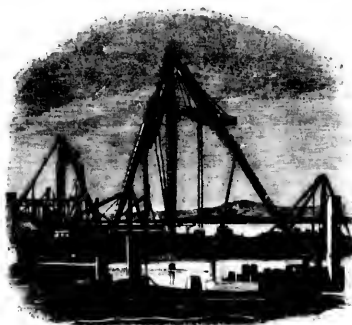
No. 7 pier.—The floating dam was launched on the 1st of June. On the 23rd of June it was in place, and scuttled. On the 12th of August, pumping commenced. On the 18th of August the masonry was commenced; and on the 31st of October the masonry was completed.

This dam was upon the bare rock, and when pumped out was found to be perfectly free from any deposit, and nearly level, the toe of every pile being visible. Depth of water, 13 feet; velocity of current, five miles per hour. This was the staunchest dam yet constructed, giving no trouble from leakage whatever. After the completion of the masonry, and removal of staging, the caisson was pumped out, and floated to winter-quarters, five miles down the river, about the end of November.

Dams 23 and 24, framed of cribwork, were put in this year with very little trouble, being in comparatively quiet water, and approached by a tramway upon cribwork piers, erected as those of the previous year.

No. 23 pier was commenced on the 1st of October, and completed on the 15th of November—under seven weeks.

In the erection of these piers, the steam derrick, constructed expressly for the purpose by Mr. Challey, was used. (See Plate No. 7.) By this machine both the hoisting and setting were performed with the greatest facility, it being a most perfect derrick.



The south abutment was this year carried up to the tube level. The material for this abutment was conveyed to the work by the tramway upon cribs put down last year, and now extended to Nos. 24 and 23 piers. In the rear of the abutment, upon the cribwork of the old dam, which was still in place, sidings were laid, into which the trucks carrying the stone for the work were shunted.

Gawntrees, at right angles to the line of the bridge, carrying a series of travellers covering the whole length of the work, were extended over these sidings, and by this arrangement the stone was taken immediately from the trucks to any part of the work. Common travellers were used both for hoisting and setting; a shaft running the whole length of the abutment, worked by a belt from a small engine fixed below, had gearings attached to it (in each of the traveller spans) driving sockets, into which the spindles of the hoisting-jenny fitted.

The men working the traveller had merely to lift the stone till it cleared the truck, then to move the jenny, and place the spindle into the socket, turn on the power, and when the stone was hoisted sufficiently high, remove the traveller to the place where it was required.

All the hoisting was done by this simple contrivance, and as manual labour for setting the stone was generally preferred, this arrangement was used throughout the work, and in all instances where hoisting by travellers was required.

This year the north abutment was carried to thirty-two feet above summer water level. The stone for this abutment was brought along the embanked approach, now some twenty feet above summer water level, to a staging erected for that purpose, in the rear of the abutment, and upon which a tramway was laid. A series of travellers crossed the track at right angles, and extended over this track. They took the stone immediately from the trucks to the work, so that no hoisting was required.

In the month of September, 8000 cubic yards = 216,000 cubic feet, of masonry was set, being at the rate of 13 cubic feet per working minute during the whole of that period.

There being no service ground at any of the piers for the stacking or sorting of masonry, every course of stone had to be prepared, sorted, and shipped upon the deck of barges, exactly in the order and at the time required. A course, or even a stone, wrongly sent, the slipping of any one of the quoins or ice-breaker stones, while being

hoisted, so as to break it, caused delay and disorganisation throughout the whole of the work. Occasionally a barge, with a course or portion of a course, would get aground, when immediately the whole of the force employed on the pier to which the stone belonged would be thrown idle; and, although there might be several laden barges at the pier, yet all must wait, and the pumps must be kept going night and day, till the barge was got off, and the stone required was put in place. In some few instances, the whole force employed upon a pier has been kept idle for several days, simply from the breaking of a chain while one of the shoulder stones were being hoisted. These stones were very large. They weighed from ten to fifteen tons; were of peculiar shape, and required a very large block of stone to make them, so that the breakage of one was a very serious matter. The quarrying, working, shipping, towing across the lake, through the canal, and eventually against a current of seven miles per hour to its destination, occupying sometimes more than a week. The cost, loss of time, and vexation caused by such an accident, can only be understood by those who know and have experienced the shortness of a Canadian working season. That season is, at the outside, six months. The earlier portion of it was taken up in preparing for the setting of masonry. It was, indeed, seldom that the setting of stone was fairly commenced before the middle of August; and it was quite certain that all work must cease by the end of November. *Sixteen weeks*, therefore, constituted the whole of the working season for the pier masonry.

The amount of material used in the work this season, was

Masonry	579,120 cubic feet.
Puddle clay	13,223 cubic yards.
Timber	344,450 feet.
Stone, for weighing crib	11,793 tons.

Daily consumption :—

Masonry	9,157 cubic feet.
Puddle clay	183 cubic yards.
Timber	2,865 feet.
Loose stone	123 tons.

CHAPTER X.

WORKS. [1857.]

The ice bridge across the St. Lawrence formed in 1857 during the first week of January. It broke up on the 12th of April. The first steamboat came into Montreal harbour on the 18th of April.

Great delay was caused, during the earlier portion of this season, by the uncertainty which prevailed as to whether the Company would be able to provide the means for proceeding with the work. It was not until the end of June that definite instructions were received, and the amount of work to be put in hand determined. The most valuable part of the year was therefore lost, and work that might have been done to advantage with great ease at the proper season, had to be performed in November, amidst cold and snow, at increased cost and inconvenience.

No. 18 pier was commenced early in the season, it being determined that the floating dam used at No. 7 pier should be used this year at No. 18. This dam was accordingly cleared of ice, pumped out, towed up the stream and moored to a crib (sunk during the winter for that purpose), on the 10th of June.

On the 26th of June, scuttled and commenced the inner frame-work to form puddle chamber.

August 18.—Pumped out water and commenced excavation. Rock was found at nine feet below bed of river. On the 25th of August commenced masonry. The pier was completed by the 6th of November, and the caisson was again floated and taken to its winter-quarters, at Boucherville, by the end of November.

Nos. 19, 20, 21, and 22 dams were constructed of cribwork, in precisely the same manner as Nos. 23 and 24, the materials being conveyed to them by means of a temporary track laid down as last year. The excavation of foundation for No. 20 pier gave a great amount of trouble, from the continual breaking in of the ground under the piles.

The whole of these piers were completed this season, No. 19 being the last that could be approached from the shore by temporary tramway.

Dams Nos. 8 and 9 were built this season. The mooring cribs for these dams were sunk from the ice in the winter of 1855-6, it being intended that this work should have been proceeded with during the previous year. The second winter's shoving destroyed or removed a portion of these cribs, and deposited them upon site of dams, causing great delay in the commencement of the work till the cribs were replaced, and subsequently great loss of time in the removal of the débris of the cribs before the dam could be commenced.

No. 8 was commenced about the middle of July. The pumps were tried on the 6th of October, when a strong leakage was discovered under the front puddle chamber. This leak could not be stopped, nor the water lowered, by three sets of pumps, four of 18-inch diameter and four of 12-inch, driven by three 10-horse engines, although they threw some 5000 gallons per minute. Ultimately the dam was secured and left till another year.

No. 9 was commenced, and the first crib sunk, on the 7th of July. Dam complete for pumping on the 11th of September. A heavy leakage showed itself under the front puddle chamber. Another set of pumps were put up, by which the water was lowered sufficiently to show that the leakage proceeded from the remains of the mooring crib in the puddle chamber, which had not been effectually removed by the divers. An inner puddle chamber was immediately formed, and the leakage was so much reduced by the 2nd of November, that the rock was reached at twelve feet below the bed of the river. By the 3rd of December, the masonry was 18 ft. 4 in. above summer water level, but at that time the weather became so severe that it had to be abandoned.

The shortness of the season for setting masonry, induced at this time a consideration of the advisability of using felt to bed the ashlar in, as at St. Anne's Bridge over the river Ottawa, where several of the piers were so constructed, and made good sound work. Strips of asphalted felt, about three inches in width, were laid along the whole of the front edge of the masonry, at such a distance in, that the work might be effectually pointed. On each of the cross joints similar strips were laid, as likewise at the back of the ashlar. As soon as one course of ashlar was laid, it was dressed perfectly fair on the bed to a straight edge for the reception of another course, which was laid on in a similar manner, the backing being laid dry and packed as closely as possible. Open spaces or flues were left, about one foot square, throughout the whole height of the pier. The work was completed in this manner during the winter; and, as soon as the weather permitted and the frost was fairly out of the stone, the piers

were carefully pointed, and the whole of the interior well grouted from the flues. The whole thus became one solid mass; the clear water which filtered through the pointing showing very accurately the progress of the grouting.

I now come to describe a portion of our operations wholly different from the operations of any preceding period. Our works had previously been limited to the erection of the piers to carry the tubes, but this year we were in a position to commence the tubes themselves. No. 1 tube was placed together in the course of this season. The staging which we erected for this tube is shown in Plate No. 8. This staging was constructed with scows, 60 feet by 20 feet, which were moored in position, scuttled, and kept in place by piles sliding in grooves in the manner described for caissons, or floating dams. These piles, when fairly fitted to the rock, were bolted to the sides of the scows, and the tops levelled to receive the sills upon which the framing carrying the truss and platform was erected. Upon the lower chords of the truss (constructed upon the Howe principle) were laid timbers, forming a platform 24 feet in width, closely planked with 3-inch deals. The upper chords, with some slight framing to adjust the height, carried rails, upon which were moved the travellers used for erecting the tubes. The iron was brought directly from the workshops to the platform upon a truck, and with these facilities no difficulty was experienced in putting the tube together.

The platform was kept about 3 feet to 3 feet 6 inches below the under side of tube level. Three lines of longitudinal timbers were laid the whole length of the opening, upon which were placed transverse pieces of timber, 12 feet by 8, at intervals corresponding with the keelsons of tube—say seven feet apart. These transverse pieces were upon packings, each being adjusted by means of oak wedges. The transverse timbers being all laid down and roughly adjusted as to level, ranging lines were carefully strained on each side of the tube, to which the iron plates forming the bottom of the tube were accurately laid.

By means of screw-bolts, held firmly together till the whole of the bottom was plated, the rivet-holes in the various thicknesses of plates were brought together as accurately as possible. Every hole in which there was not a bolt was rimmed by a tool (see Plate 9) to exactly the size of the rivets by which the work was to be fastened together. As the rimming proceeded the riveting followed; and when it was so far advanced that the bolts holding the plates together were no longer required, they were removed, the holes rimmed, and rivets put in. This was continued till the whole of the bottom was completed, and the keelson bars, &c., in place.

Experience proved that when the bottom was composed of five or six thicknesses

of plates, as was frequently the case, it was impossible, with all the care that could be bestowed in the punching, and even by the use of the Jacquard machine itself, to make the holes come perfectly fair, so that rivets of the proper size would go into them. The workmen, if left to themselves, prefer by means of steel pins driven into the holes with heavy hammers, to make them large enough to admit the rivets; and generally, if the plates are not very thick, they succeed in doing so. It will be apparent, however, to any practical man, that the natural tenacity of the iron forming some of the plates would be completely destroyed by this process; indeed, when the hole is near the outside or edge of a plate, and the tendency of the drift is in that direction, the piece will be broken out altogether. In a climate in which the thermometer stands at 30° below zero, or 62° below freezing point, the iron is so brittle that very little rough usage destroys it entirely. The use of the drift-pin for the purpose of enlarging the rivet-holes, was therefore prohibited.

It is probable that an error may have been committed in this prohibition, but, as strength of the tube depends so entirely upon the care bestowed in the manipulation of its bottom, it appeared to be quite necessary to take every precaution. I dwell, however, the more especially on this point, because, in conversation with a very eminent engineer, I found that in his opinion the rimering was altogether wrong. He contended that, although the bottom was composed of seven thicknesses of iron, it was quite practicable that every hole should be punched to its proper size, and should be so mathematically correct as to spacing, that neither drifting nor rimering should be necessary. Of course, if this could be done it would be very desirable; but in practice, even with the best work, I must candidly say that I have never seen anything approaching such perfection. According to my view, therefore, rimering is the least of two evils, and I should advise its adoption wherever it is found, in a large work, that the holes cannot be punched mathematically true. In such cases the holes should be punched rather smaller than the rivet to be used, and, when the work is well plated, every hole should be rimered to the exact size of the rivets, and the use of the steel drift should be avoided, except in taking the plates to their respective places.

The bottom being riveted complete, and adjusted to level and cambré by means of the oak wedges before mentioned, the erection of the sides was proceeded with. We commenced at the centre, and as the side work progressed in either direction, closely followed it up by the plating of the top.

In putting the sides together, it was found in practice that if the plates in the vertical joints, at their junction between the T bars, were allowed to touch each other, the plates that were in contact invariably buckled as the riveting progressed. It was

consequently often requisite to cut out the rivets, take off the bars, and by chipping the edge of the plates, allow sufficient space between them to prevent the buckling taking place. The side plates were therefore kept as close as possible, though never allowed to touch each other. The writer would not dwell on this, but that he has heard men of science insist that these vertical joints should be planed and made perfectly close, and therefore he thinks it right to give the results of his own experience on the subject. For details of tubes, see Plates 23 and 23a.

Level marks were given upon the stagings at twenty feet distances. These were tested by the engineer in charge of the work every morning, and formed a datum from which the workmen kept the cambre true. The top was always the last part of the tube that was completed, and, as before observed, it followed the progress of the sides as closely as possible; and as the whole of the joints of the top were planed mathematically square and true, if ordinary care was taken at the commencement in the centre of the span, no trouble was afterwards experienced—with such care and accuracy were the plates prepared at the factory at Birkenhead.

The tubes of the bridge, although erected separately, as if for independent beams, were afterwards united in pairs, and were firmly bolted to the masonry of the piers over which they were so united, so that no movement could possibly take place. This pier was always called the "resting pier." The other ends of the tube were placed on rollers so arranged upon the adjoining piers that they might expand or contract from the resting piers as the temperature varied; a space sufficient for this purpose being left between each pair of tubes.

In the early part of the work (as will be seen by reference to Table, page 84) the first tube of each pair erected was completed and allowed to take its bearing as if for an independent tube. The second tube, when completed, was joined to its fellow over the resting pier, so as to make a continuous tube of the two, before the wedges of the second tube were struck. This, however, threw too great a tensile strain upon the top of the tubes when connected over the resting piers, and likewise partially threw the bottom into compression for some distance either way from the same points. It was therefore decided by the engineers that the tubes should be built separately, as if for independent tubes, and that after the wedges had been struck, and the tubes had taken their bearing for some ten days, they should be connected over the bearing piers at day-break, before the heat of the sun caused any difference of temperature between the bottom and top.

For cambres, subsidence during construction, deflection, &c., see the Tables at p. 84.

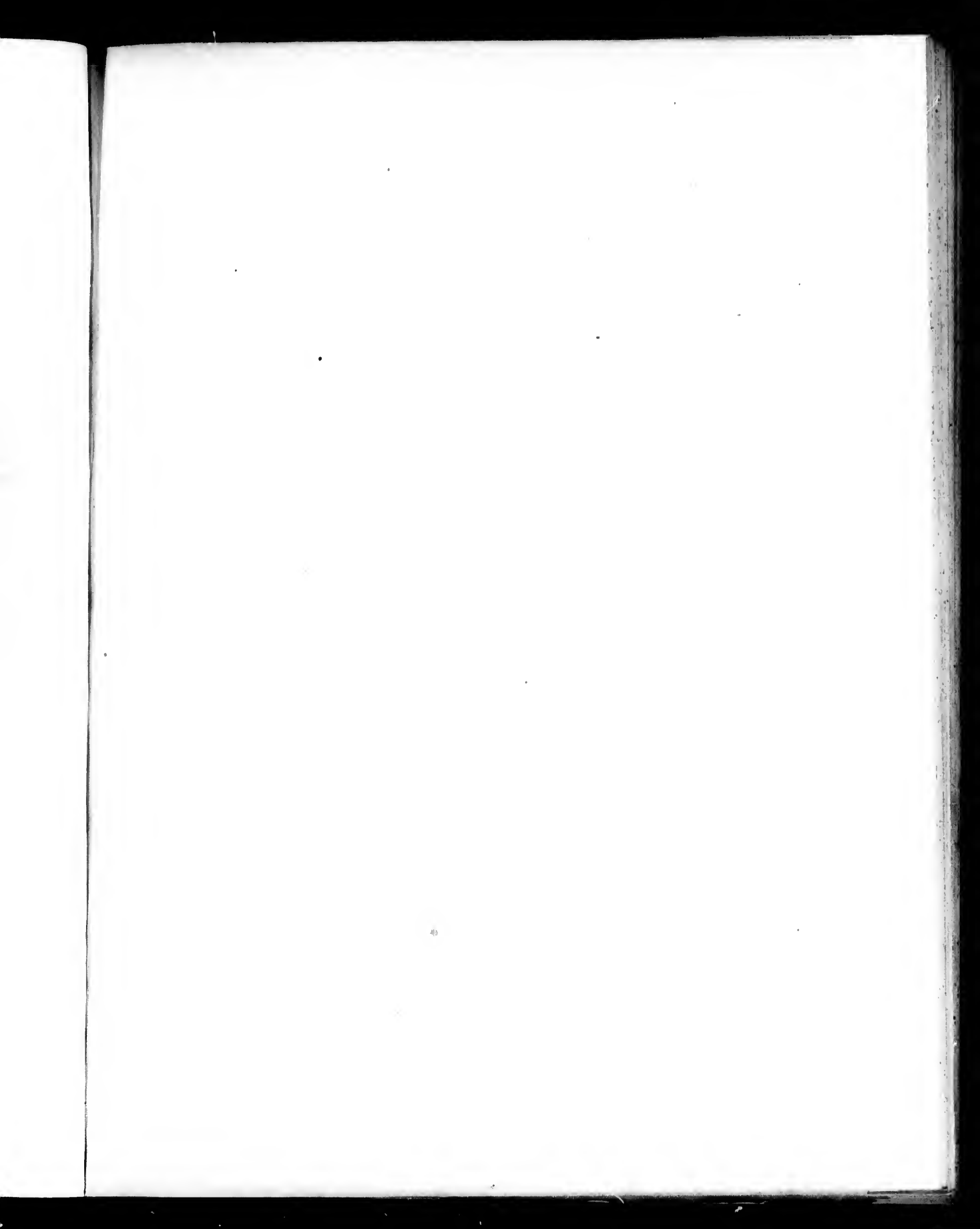
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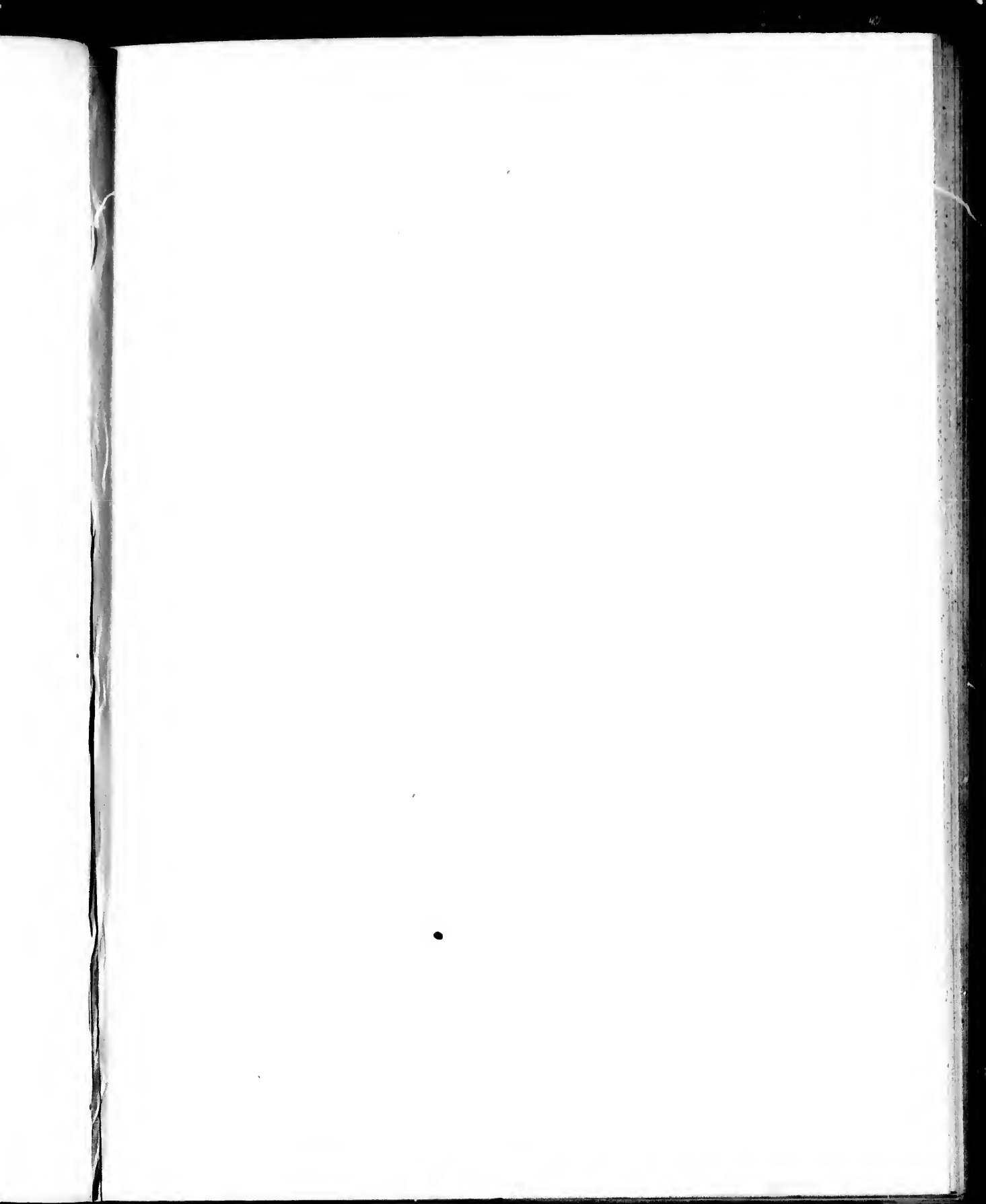
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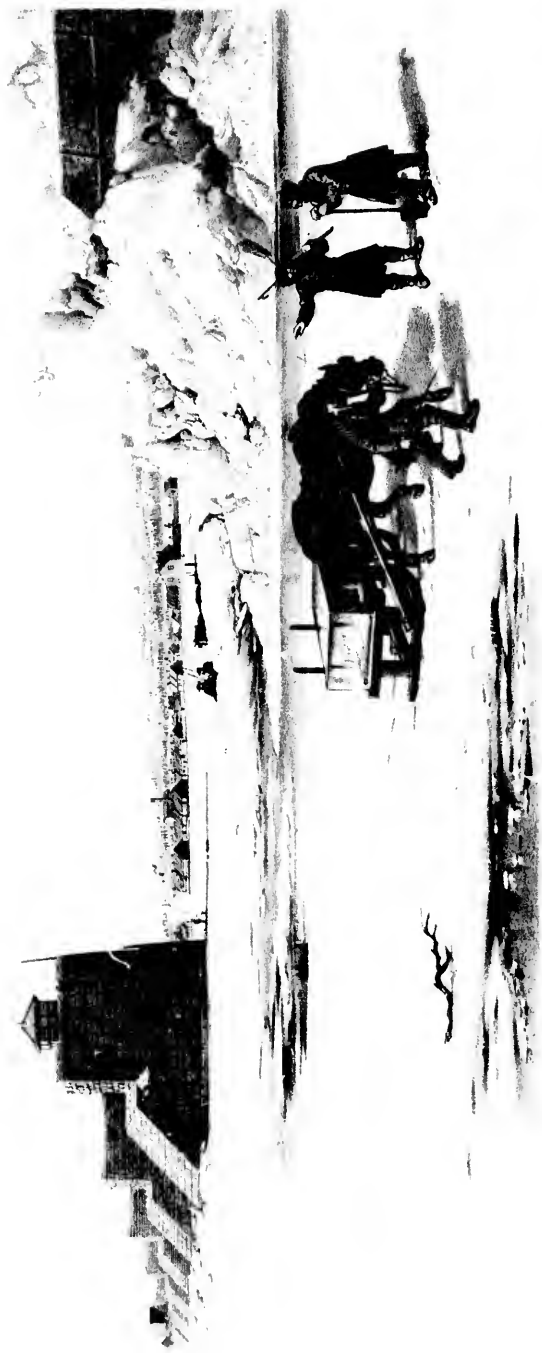
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It may probably be thought by many that the stagings used in this work were unnecessarily heavy and costly. Under ordinary circumstances they would be so; but it must be borne in mind that any failure or subsidence during the progress of construction would have caused so much delay, as to have rendered the loss of some of the tubes by the approach of winter almost inevitable. Moreover, it was felt that with thin plates, without celis to either top or bottom, unless the staging were made perfectly rigid, the tubes could not be riveted together and finished with any degree of accuracy.

This was pointed out to the writer by the late Mr. Robert Stephenson before the work commenced. That lamented gentleman more than once impressed upon him the importance of this precaution, and experience amply established the wisdom of his observations.

The staging for No. 25 tube was proceeded with this summer, and, as an experiment, a temporary pier of cribwork was constructed in the centre of the span. It was of a form and strength sufficient, as was thought, to ensure its standing against the shoving of the ice during winter. The truss forming the platform upon which the tube was to be erected was completed before the winter set in, but no ironwork was commenced.

As soon as the ice bridge fairly formed, the tube was to be commenced, and it was intended to be completed before it broke up in the spring. If, therefore, this pier stood well, the risk of attempting a similar mode of putting the centre tube together was to be considered.

CHAPTER XI.

WORKS. [1858.]

THE ice bridge formed this year about the 16th of January. In arranging for this season's operations, it became necessary that provision for the navigation of the river should be considered, and it was determined that No. 11 pier should be left out for that purpose till the large opening was complete. Nos. 12 and 13 piers were, if possible, to be completed during the season, and provision was also to be made for putting up the centre tube during the following winter. To accomplish the completion of these piers in one season required extraordinary exertion; but, with a view to ensure their completion, it was determined that although upon former occasions cribwork put

in during the winter had been moved by the spring shoving, another attempt should be made this year, upon a larger scale, and with greater care and precaution.

The plan for Nos. 12 and 13 dams will be readily understood upon reference to Plate No. 10. The dam head was to be formed by sinking three cribs, 80 feet long, 24 feet broad. They were to be of a depth corresponding with the water, so that the ice during the spring shovings might pass over them. The cribs were to be kept exactly in position by means of guide piles passing through sockets framed in the cribs, it being considered that as these piles could be driven some eighteen inches into the hard bed of the river, they would help very much in preventing the cribs from being shoved out of position by the ice.

The cribs were likewise to be close planked, in order that the ice might the more readily glide past them, in case the river did not rise sufficiently high to carry it clean over.

The whole dam head extended to a distance of 112 feet, leaving two openings of 32 feet each, which were to be filled up in the spring by means of aprons sloping against the stream. These were framed in a horizontal position, just above the water level, and were hinged to the cribs between which they were to fit by means of a heavy piece of timber at the down-stream end, so that immediately the up-stream end was released, they would swing to the bottom of the river and stop the current. It was felt that an eddy thus formed would give great facilities for building the dam in comparatively still water.

Similar operations had been carried out at No. 8 pier, where an eddy was formed by an apron, framed, hinged, and sunk between the mooring piers placed for that purpose. These, however, were some 100 feet above the dam head, and served only as a turnwater to form an eddy, in which the dam was constructed; whereas, at Nos. 12 and 13, the dam head itself was to be formed by the cribs and aprons.

The sides of these two dams were to be formed of two scows, 180 feet long, 20 feet broad, with guide piles, walings for sheet piling, &c., same as used for floating dams. Four of these were constructed and ready for work upon the opening of the navigation. The cribs were framed upon the ice, filled with stone, and sunk exactly in position with the greatest care and in the most substantial manner possible, as above described.

Nos. 14, 15, and 16 dams were to be of cribwork, and, the state of the ice being favourable, and the facilities for prosecuting the work inviting, it was determined to

put in the heads of these dams in one piece, thus forming a turnwater, behind which the sides of the dam could be proceeded with immediately the river was clear of ice. To carry out this project, holes were cut in the ice 100 feet by 40 feet. All surface ice was removed; and, by means of hooks and tools made for the purpose, the anchor ice was also cleared away. Cribs of the exact size of the dam head were then framed in the water, and kept in position by chains from moorings fixed in the ice above, and by piles driven into the bed of the river behind the cribs. The piles which were held in place at top by the ice were taken away after the cribs were sunk.

The framing and sinking of these cribs proved to be an easier work than was expected; and so sanguine of success were all engaged in the work, that it was regretted Nos. 12 and 13 heads had not been done in the same way. It appeared, moreover, as though great sums might have been saved if similar means upon a large scale had been adopted earlier. The cribs were complete by March the 19th.

The sheet or field of ice above the bridge, before any movement took place, was unusually free from ice grounded upon the shoals, so that the weight of the whole of the area of ice in the La Prairie Basin was thrown upon the abutments and piers on either side of the bridge, which held it in place. The ice below the bridge became very rotten and partially broken up in the centre of the river, so that the ice above received little or no support whatever from that below the bridge, and there was also a large space of open water between them for some time previous to the shoving taking place.

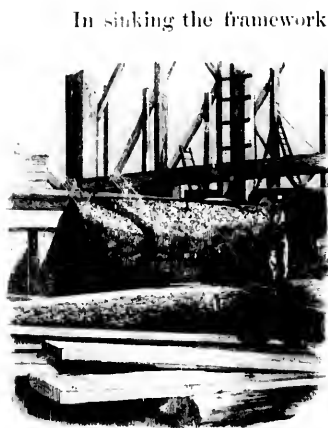
The first movement made its appearance on the south side of the river, where the ice shoved upon the shore and over the embanked approach to the bridge. A large sheet in mid-channel then became detached and moved down stream, shoving upon the north side of the bridge, till it received support from the grounded ice below and from Mollatt's Island, upon which also it shoved, and where it became stationary. This movement left a large open space of water, extending upwards for a quarter of a mile, for nearly the whole width of the bridge between the abutments.

On the 1st of April the ice covering the La Prairie Basin broke up, and, contrary to all previous experience, without any rise of water. All our hopes of success were thus frustrated, depending as they did upon such a rising of the water that the sheet of ice covering the La Prairie Basin might float, and pass over the tops of the sunken cribs. Still it was some days before the amount of damage done could be ascertained, but when the water subsided the whole of the cribs at Nos. 14, 15, and 16, and three of those at 12 and 13 were found to have been displaced. Thus not only was the whole

of our winter's work entirely lost at 14, 15, and 16, but before a commencement of the summer's work could be made, all that had been done had to be removed. At Nos. 12 and 13 matters were not quite so bad, as the cribs remained in position. Immediate steps were therefore taken to repair the damage without delay.

At No. 13, during the time that the repairs to the cribs were being proceeded with, and the dam head made perfect, the scows forming sides of dams were got into position and scuttled:—the cribwork of the end, and that forming the inner side of the puddle-chamber, was also proceeded with.

The sheet-pilings used for the outside row were sawn die square 12 feet by 12 inches, shod with cast shoes 16lbs. weight, driven with a 16 cwt. ram. 12 feet fall, until they would not move, or until they twisted so as to prove they were between boulders, and that further driving was useless. It frequently happened that when the concreted mass forming the bed of the river was very hard, or when the toe of a pile came directly upon a boulder firmly imbedded, it would turn aside completely at right angles, and when the dam was pumped out some four or five feet would be found lying along the bed of the river inside the dam; for this reason it was always requisite that a whole row of piles should be pitched and planted firmly upon the ground before any of them were driven, or they could not be kept close and fair after receiving two or three blows of the ram. On the north side of No. 13 dam the piles drove very easily for a length of some 50 feet, some going as deep as three feet.



In sinking the framework to carry the inner row of piles, a large boulder was discovered occupying the whole breadth of the puddle-chamber. Its removal was necessary before the dam could be proceeded with. This operation caused a loss of time equal to six days. Several attempts were made to split it by blasting, which failed, but it was eventually removed *en masse* on the 7th of July. It weighed over twenty tons.

The outer piling being all driven, and the inside framework sunk and secured in place, divers were employed to remove all boulders and stones from the puddle-chamber, after which it was carefully dredged by means of a machine worked by steam power, and constructed expressly for that purpose. (See Plate II.) All loose material was by this



View of the bridge from the north side.

MEMORANDUM

TO: THE PRESIDENT

FROM: THE SECRETARY

SUBJECT: [Illegible]

1. [Illegible text]

2. [Illegible text]

3. [Illegible text]

4. [Illegible text]

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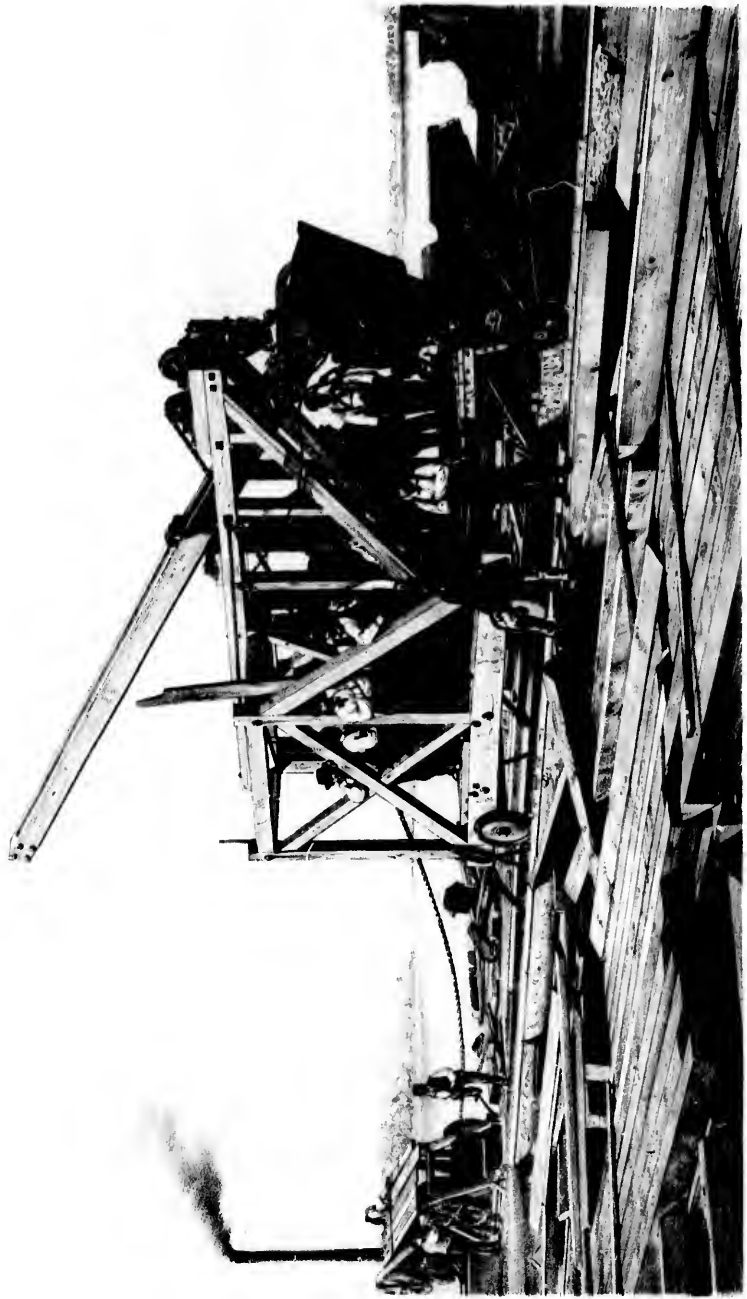


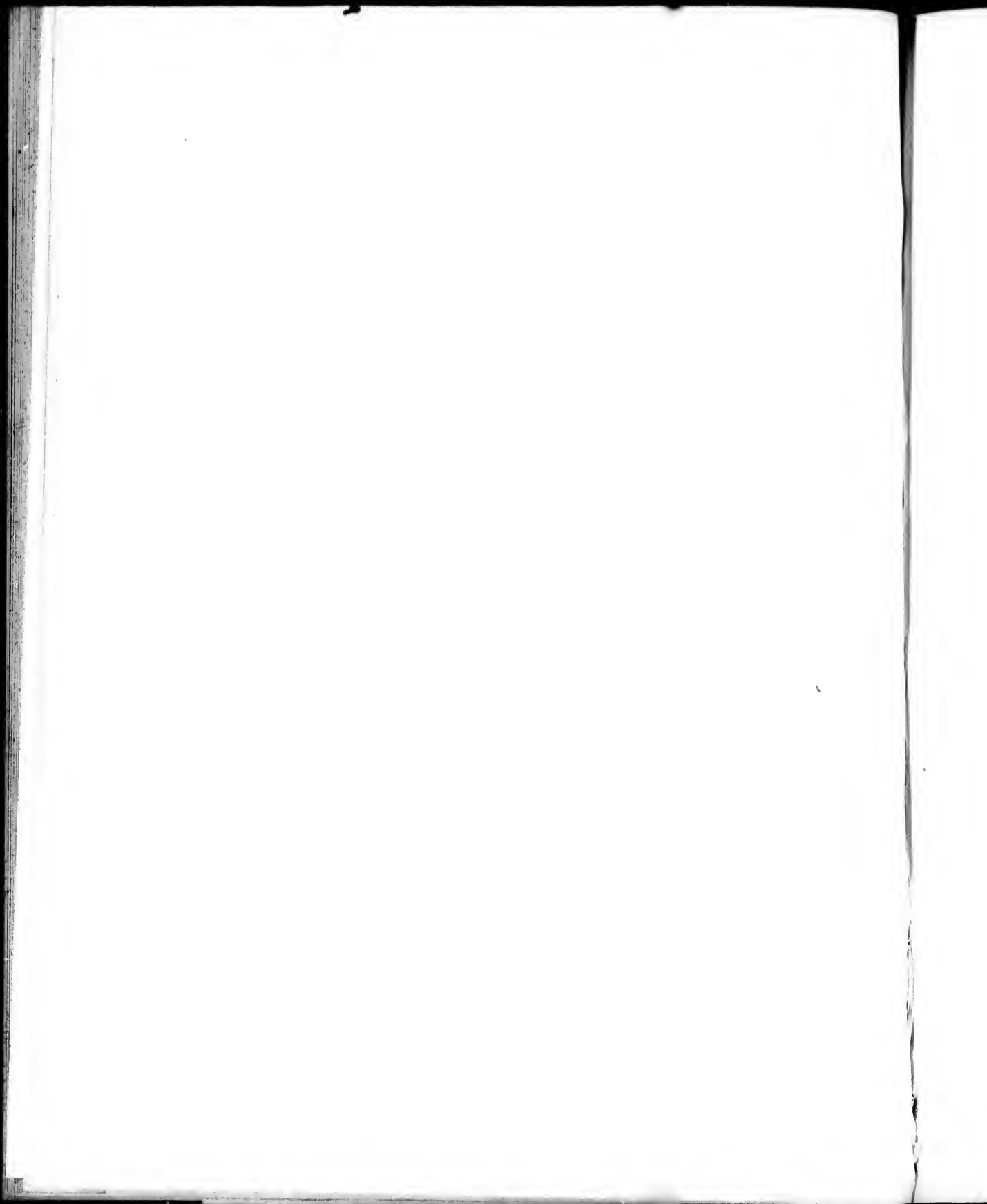
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means removed, till the hard impenetrable concreted pan was reached, upon which the dredging spoon had no effect. Upon the north side of the dam, where the piles drove so easily, a clear hard blue clay was reached, the removal of which by dredging was not attempted. After the dredging was done, the puddle-chamber was again inspected by the divers, who made it as clear as possible. The inner piles, 12 feet by 8 inches, were then pitched and the puddle trench filled, after which the piles were driven in the same manner as those on the outside.

On the 26th July the dam was pumped out, and found to be very staunch. The boulders covering the bed of the river were removed, and the excavation commenced, when a blow of the pick, within a few feet of the centre of the dam, tapped a spring of thick black water, which at first produced a fountain about as large as a man's finger. This attracted the notice of the workmen, who crowded round to see "a spring of ink" (as they called it) issuing from the bed of the river, but they found it increase in volume so rapidly, that in a few minutes they had to run for their lives, and in a quarter of an hour the dam was full. This leakage caused great consternation, and as no subsidence of the puddle immediately followed, it was difficult to discover where the water had found its way under the puddle chamber and piles.

The pile engines were immediately put to work, and every pile tried, till it was found that along the north side, for a length of about ten feet, the piles could be driven further. These being driven till they would not move, caused the puddle to subside in that locality, and the chamber was again filled up. To strengthen this side of the dam, an inner puddle chamber was formed (see Plate 10), provision for which had been made to facilitate the putting in of the piling and planking requisite where any great depth had to be excavated below the foot of piles. This having been formed and puddled, the pumps were again set to work, the dam unwatered and found to be staunch, till the excavation being proceeded with, the water broke in again as before. This second leakage was discovered to have taken place at a spot immediately contiguous to the former leak, extending some ten or twelve feet further in. It was again stopped, but again broke out; and this state of things continued till the whole of the length where clay had been discovered in the puddle chamber had been repaired. Eventually it was discovered that under the clay there was a bed of boulders and live sand, and that until this was washed from under the piles, the leakage could not be stopped. On the south side of the dam no leakage occurred, and on that side none of the piles could be driven a greater distance than twelve inches.

On the 29th August masonry was commenced, and on the 26th November the pier was finished.

No. 12 pier was constructed in precisely the same way as No. 13. Considerable delay was occasioned by having to remove the centre crib sunk during the winter, and which was shoved by the ice into the site of dam. Some difficulty was also experienced with the inner crib framing, from one side of the dam being some eight feet deeper than the other, but there was no leakage after the dam was pumped out on the 2nd of September.

Masonry was commenced on the 15th September, and on the 3rd December this pier was completed. During the latter part of the time the progress was exceedingly slow and unsatisfactory, in consequence of the severity of the cold; but it was imperative that the work should be done, and therefore the greatest exertion was made.

At No. 17 the floating dam was again pumped out, towed up the stream, and moored in position on 7th May. The moveable part of the dam was not used this year, but a framing of cribwork was sunk in place of it. (See Plate No. 3.) On the 16th it was scuttled and made ready for the outer piling, which was driven at the time the inner framework was being proceeded with. All loose stones and boulders were removed by divers, and the puddle chamber carefully dredged. After this the divers again inspected the puddle trench, the inner piles were pitched, the puddle clay put in, and the piles driven: the inner piles were also again tried, to be certain that no under current had bared their toes.

The pumps were put to work and the dam unwatered on the 14th July, just two months from the time of scuttling the caisson.

This dam was perfectly tight, there being no leakage whatever, excepting from springs through the gravel forming the bed of the river, and this was kept under by the pumps working one half hour in the twelve.

The excavation was proceeded with in the usual way by sinking a sumpt hole for the pumps to the level of the rock, or rather some eighteen inches or two feet into it; and as the dip of the rock was invariably against the stream, this was generally made at the bows of the dam. As soon as the sumpt hole was down, the pumps were put in, and a gullet was cut upon the rock to the end of the masonry at the stern of the dam. The gullet was made of sufficient width to admit of the passage of a truck, carrying a bucket or skip, holding about a yard cube, to raise which, the steam-engine attached to the traveller was used, or a small steam crane was erected at the bows of the dam. As soon as the temporary track was laid in the gullet, the lower end was opened out till it was of sufficient width to admit the masonry, which was put in as fast as the excava-

tion proceeded. When the depth to the rock exceeded four or five feet, it was always necessary that every inch should be piled and planked; and as soon as space was excavated to admit of a stone being put in, it was set close home, so as to prevent any chance of a break occurring under the toes of the piles.

By the time the excavation was finished, and the nose-stone in place, the masonry, which had been progressing simultaneously with the excavation, was fairly in hand. After this it was very seldom that any difficulty presented itself, except that of getting a sufficient supply of stone, which was in itself always a troublesome task, particularly in the height of the season, when six or seven piers were in hand at the same time. The first stone of this pier was laid on the 23rd of July, and on the 3rd of September the masonry was completed—just six weeks elapsing from the commencement to the conclusion of the work. The old dam was then dismantled and pulled to pieces, there being no further use for it.

Nos. 14, 15, and 16 dams, the head cribs of which were removed out of position by the ice during the spring-sboving, were much decayed, as nothing could be fairly proceeded with till the old cribs were removed. To accomplish this, turnwaters of planks and timber were formed in front of the old cribs, to prevent the rush of water from passing over the work. Men were then placed as closely as possible, who, by working in the water with tongs and hooks made for the purpose, cleared away the loose stone from the cribs to a considerable depth. After this divers were employed, who removed a further quantity, thus lightening the cribs, till, by means of levers, purchases, and barges, they could be gradually raised and taken to pieces. The sides of No. 16 dam were commenced on the 29th of May, but it was not till the 4th of September that the dam was pumped out. After some little difficulty in stopping leakage, masonry was commenced on the 13th, and the pier completed on the 23rd of November.



In the early part of the work, where the piers were upon the bare rock, the piles were very carefully fitted to the shape of the bed of the river. To accomplish this, the foot of each pile was made chisel-pointed, and after receiving two or three blows from a light ram, was drawn up and examined, the battered point showing very plainly where any alteration was required. At a later period, where there was a deposit upon

the rock and excavation became requisite, greater breadth of puddle chamber was given, and the piles were driven till they would go no further. Experience seemed to show that this driving loosened the ground and did more harm than good. It was then thought advisable to increase the breadth of the puddle ditch still more, and not to drive the piles so hard. Still leakage occurred, and the ground below the toes of piles would occasionally blow in as the excavation proceeded. It was then decided to increase the thickness of the piling, to use heavy shoes, and drive as long as the piles would go. This, with the dredging and removal of all boulders and loose stone, would, it was thought, ensure success, although the result showed that even this was not sufficient.

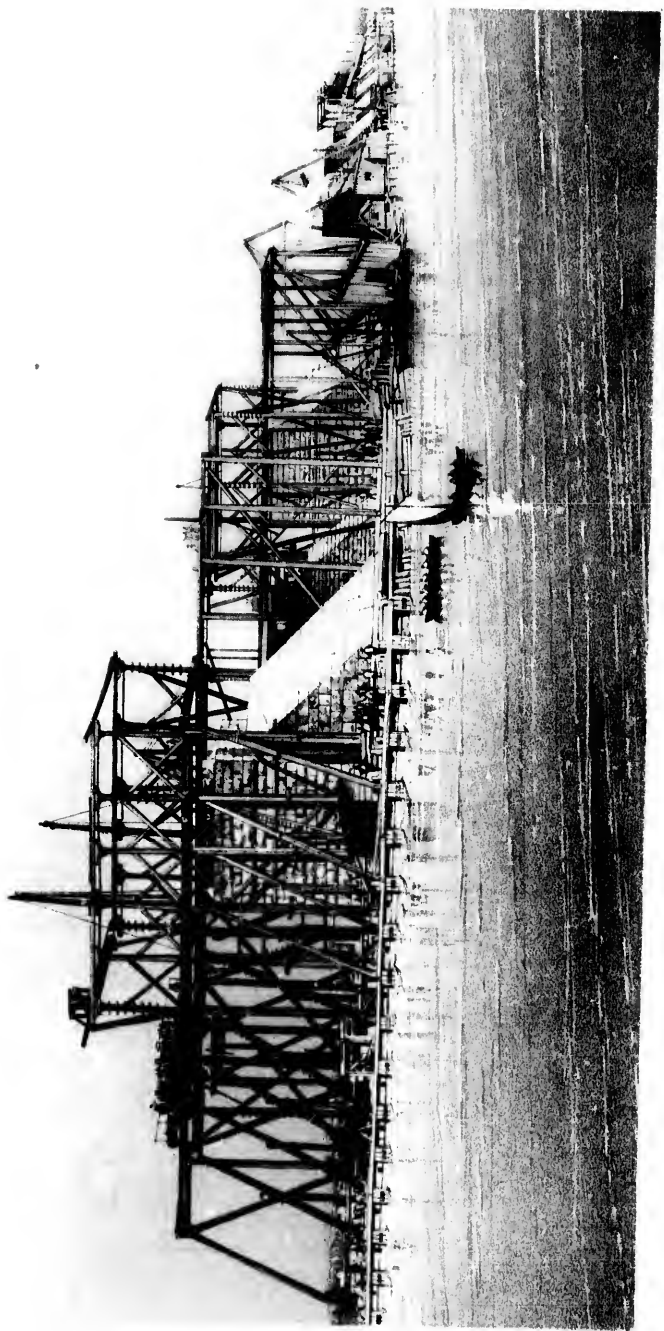
At Nos. 14, 15, and 16, a steam dredger was used, with which the whole site of the dam within the cribwork was dredged, all loose material being scooped up till the hard pan was reached, upon which the dredger of course was useless. After this was done, divers were employed to ascertain that no loose stones lay in the way of the piling, and when this was driven and completed, they were again sent to examine and remove anything that had before escaped notice. In addition to this the piles were grooved, and every possible care taken to ensure success; yet, with all this precaution and care, at No. 16 the water burst in under the piles several times, and it was not till the pot-holes or veins of live sand and boulders running under and across the puddle chamber were washed clear, and the piles driven to the sound ground below, that the dam could be made staunch.

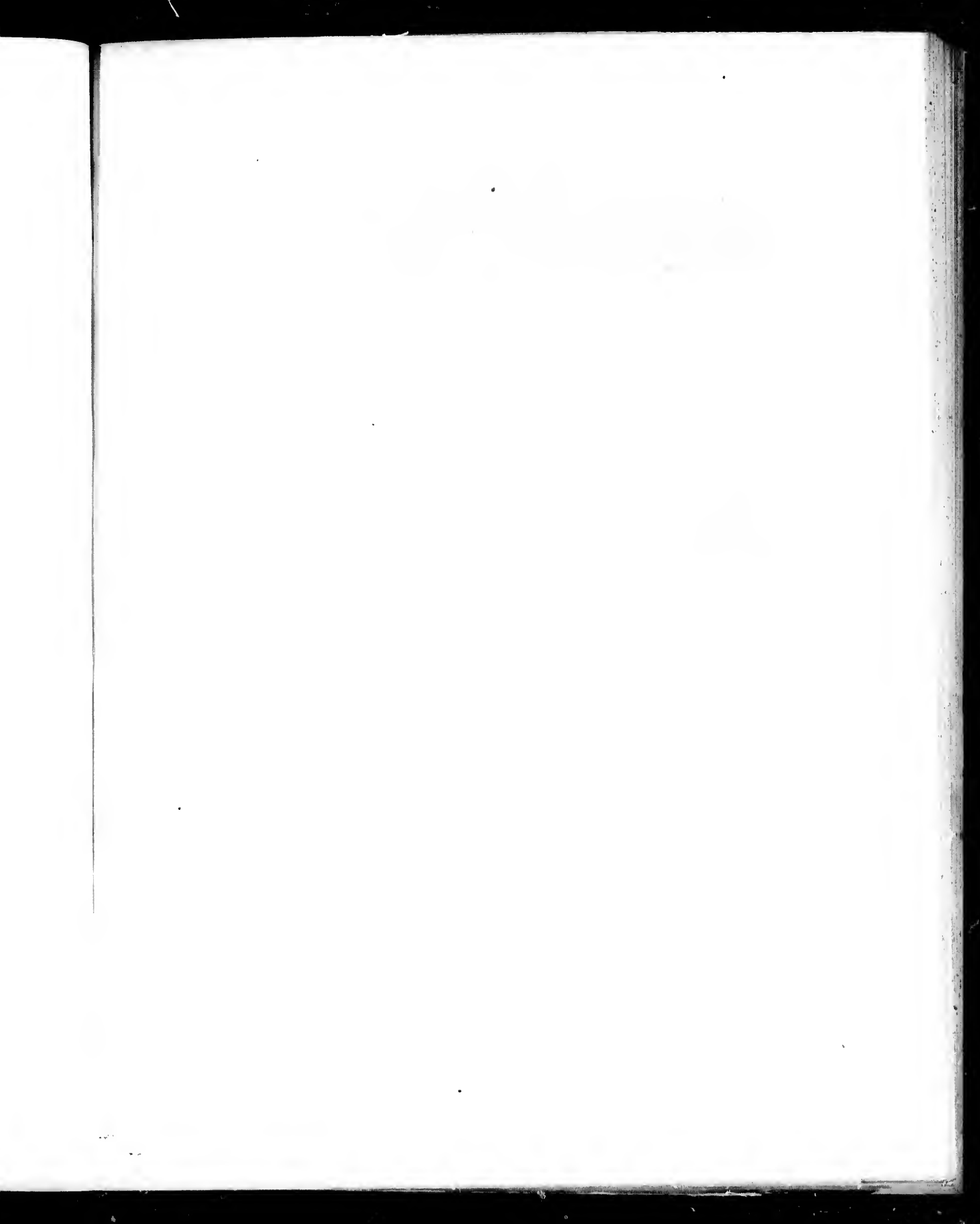
There were different times during the progress of the work when the writer thought each plan, in its turn, certain to succeed. In their turn, however, they all failed, and with all the experience he has acquired he is even now at a loss to decide which plan is the best. Upon the whole, he is perhaps inclined to think that success depended more upon the accident of hitting upon a sound bottom, than upon any extraordinary precaution that was taken with the work.

Failures, such as those described, in a climate where temporary works could remain through the winter, would be comparatively of little importance, and would probably pass unnoticed. But, in a climate like that of Canada, when, by the time the work was far enough advanced for testing, winter was probably but a few weeks distant, the excitement produced by only a trifling leakage or failure was by no means such as would be ordinarily caused by so trifling an occurrence.

In the month of June of this year, anxious deliberations took place as to the possibility of getting the bridge finished and ready for opening by the end of 1859.

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" Could it be accomplished ? " was the question anxiously propounded by the Vice-President of the Company, Mr. T. E. Blackwell. Upon mature consideration an affirmative answer was given by the contractors ; and it was decided that the attempt should be made. From that day the greatest activity prevailed, and every one seemed animated with the desire to accomplish the work.

In consequence of this new arrangement, No. 10 dam was commenced on the 28th of June. It was completed on the 24th of September. The masonry, which commenced on the 7th of October, was completed on the 30th of November following. With this pier very little difficulty was experienced. Every precaution that experience pointed out was taken to ensure success, and fortunately everything turned out right. But when it is considered that in five months 70,000 feet of timber had to be framed into cribs, and sunk in a current running six miles per hour, for which 4870 tons of loose stone were required, 29,620 feet of piles were driven, 2500 yards of puddle clay put in, 88,830 cubic feet of masonry set (equal, from the time it was commenced to completion, to 1890 cubic feet for every working day), in addition to which machinery had to be put up for pumping, hoisting, excavating, pile-driving, &c., it will be evident that much must have depended upon good fortune, and likewise that the work could not have been done with anything like ordinary exertion.

No. 8 dam was abandoned last year in consequence of leakage under the piles at the head of the dam. The puddle was now dredged out, and piles drawn across the head and down some fifty feet of each side of the puddle chamber. Divers were then employed, and it was found that a bed of large boulders extended quite across the puddle chamber. Between these the water found its way, and as the sand in which they were embedded washed out so the leakage increased. The removal of these stones was a very tedious work : but after they were taken away, and the piling and puddling replaced, no further difficulty from leakage occurred. The masonry was commenced on the 31st of August, and completed on the 21st of October.

The embanked approach on the south side of the river was commenced this year, and carried up to winter level.

At the close of this season there was only No. 11 pier to be founded, Nos. 14 and 15 to be carried up from summer water level, and the abutment walls to finish.

The great exertions which were made throughout this year much increased the probability of the Company being able to open the bridge by the end of 1859. The only points of great uncertainty arose, indeed, from the magnitude of the task to be accom-

plished in putting the centre tube together during winter; and also in completion of No. 11 pier in time to receive the tubes Nos. 11 and 12, so that they should be completed before the winter.

During this season eleven tubes were erected, the first being No. 25, the scaffold for which was supported in the middle upon a temporary pier of cribwork, built sufficiently strong to stand against the ice shoves.

This staging standing well, the erection of the tube was commenced on the 13th of January. It was completed on the 31st of March, the wedges being struck before the ice shovings took place.

The erection of tubes upon good substantial scaffoldings where no subsidence can take place, is so simple a work that any other description than that given for No. 1 is unnecessary. The whole of those erected this season were done in precisely the same way.

Upon reference to the tables of cambres it will be found that three inches were given to No. 1, which, coming down a little below the straight, was considered to be insufficient, and accordingly six inches were given to No. 25. This, however, remaining with some two inches of cambre after the wedges were struck, it was decided for the future that four and a-half inches should be given, and the whole of the tubes subsequently erected this season were as nearly as possible laid down to that cambre, the results of which are given in the Table.

The stagings upon which the tubes were erected this season were of very simple construction. (See Plate No. 8.) In deep water, scows were moored and scuttled as last year for No. 1, from which piles were driven to carry the transverse timbers upon which the superstructure was erected. In shallow water, skeleton cribs were used instead of scows, with spaces left in them for piles, upon which the superstructure was erected. The stones for weighting these cribs were all placed above water, to facilitate removal, the weight requisite being that only which was sufficient to withstand the shock of any stray raft that might be driven out of its course against them. As an additional protection against rafts, sloping timbers were laid from the ends or bows of the scow or crib to the bed of river. The spans were divided into four spaces, so that no truss was required upon the vertical framing, a strong longitudinal timber being sufficient, upon which were laid the transverse timbers forming the platform. Wellington cranes were used instead of travellers for moving the iron of the tubes.

The whole of the iron-work for the tubes was prepared at the Canada Works.

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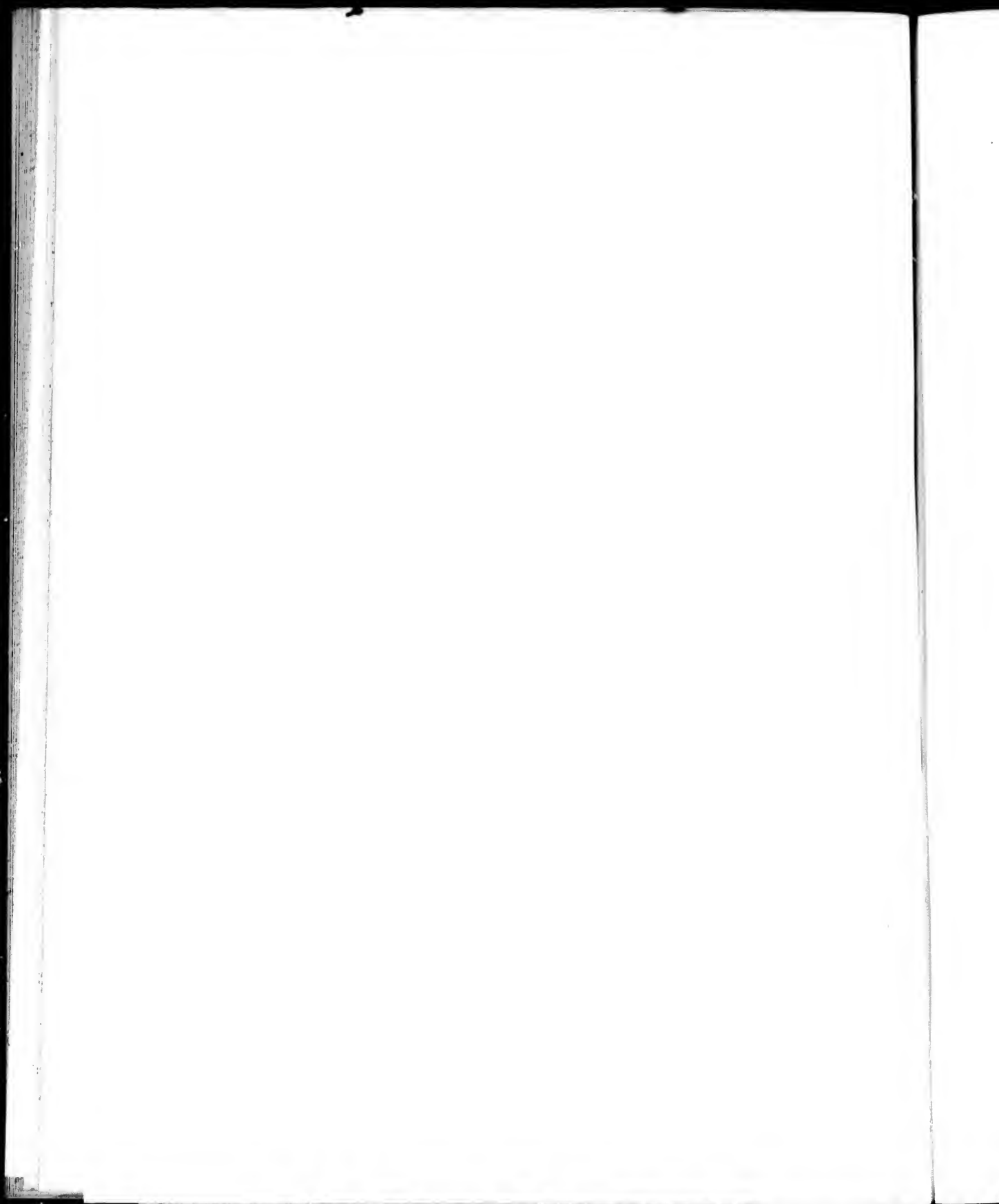
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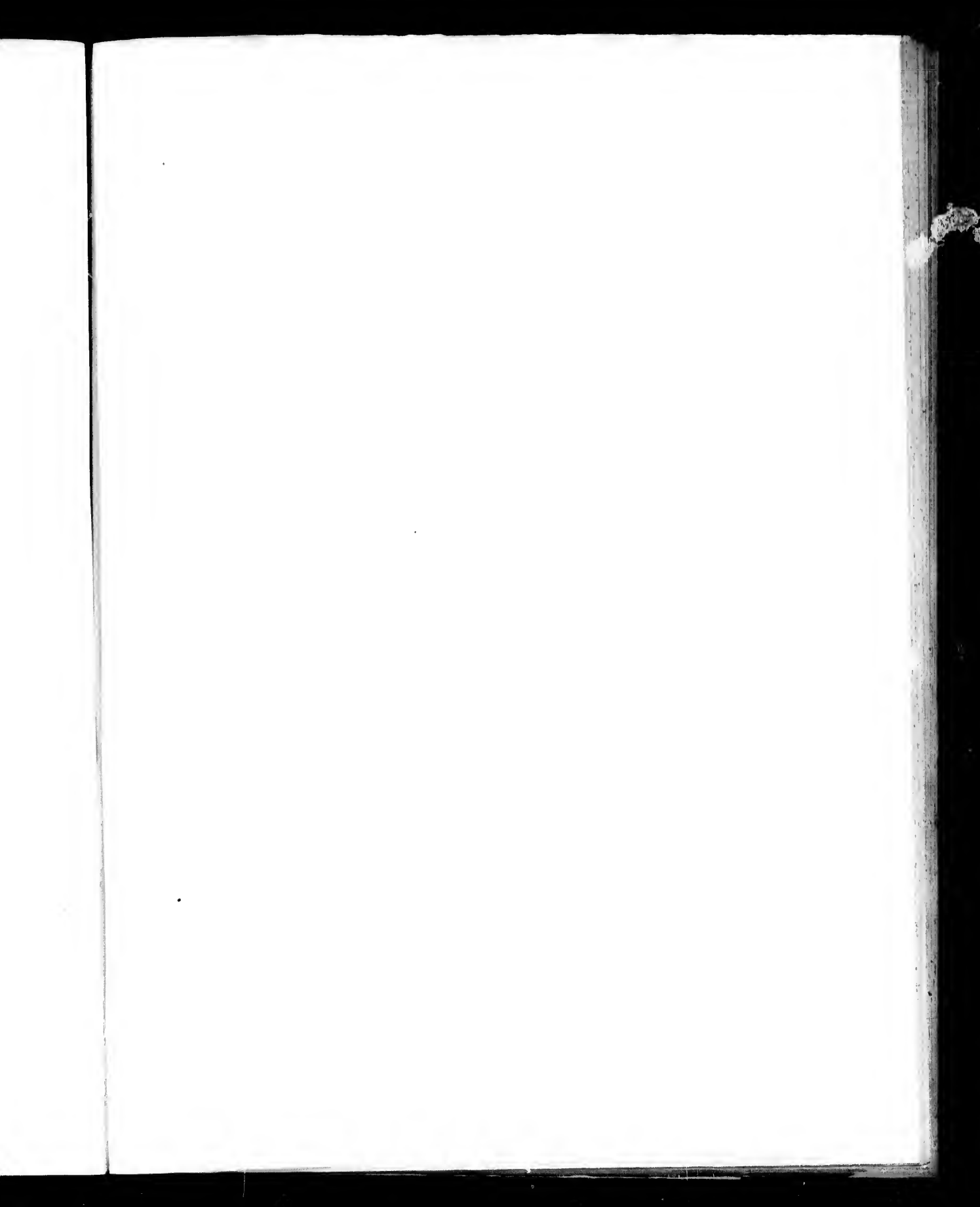
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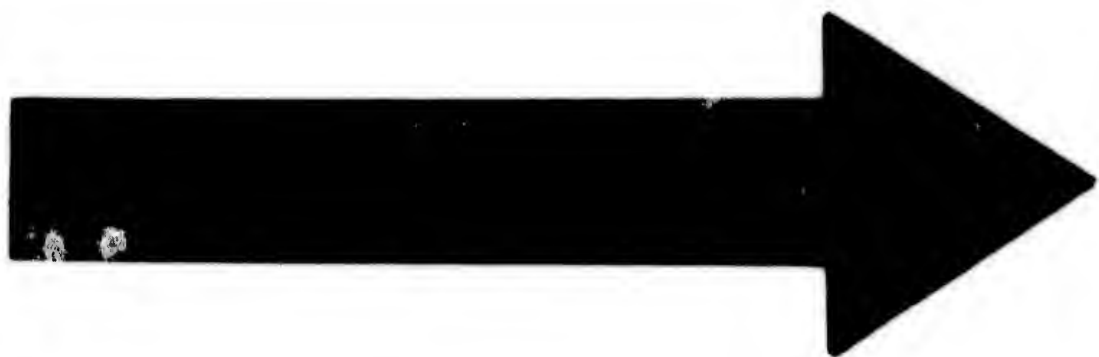


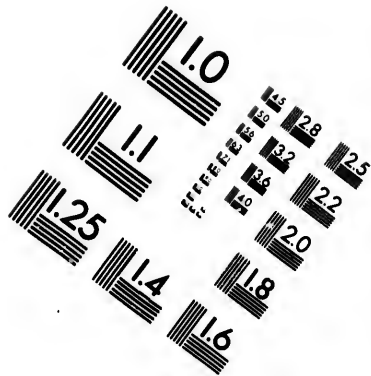
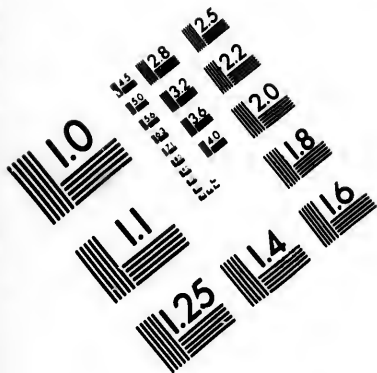
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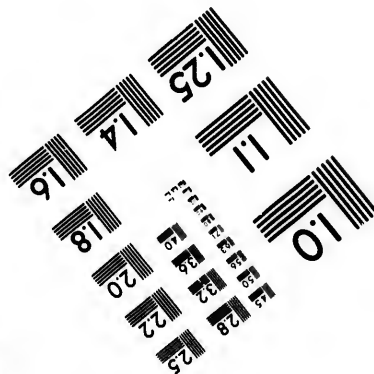
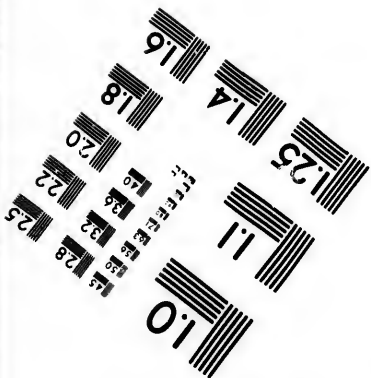
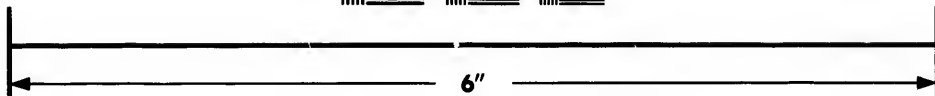
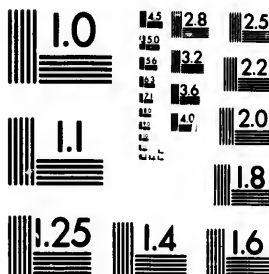








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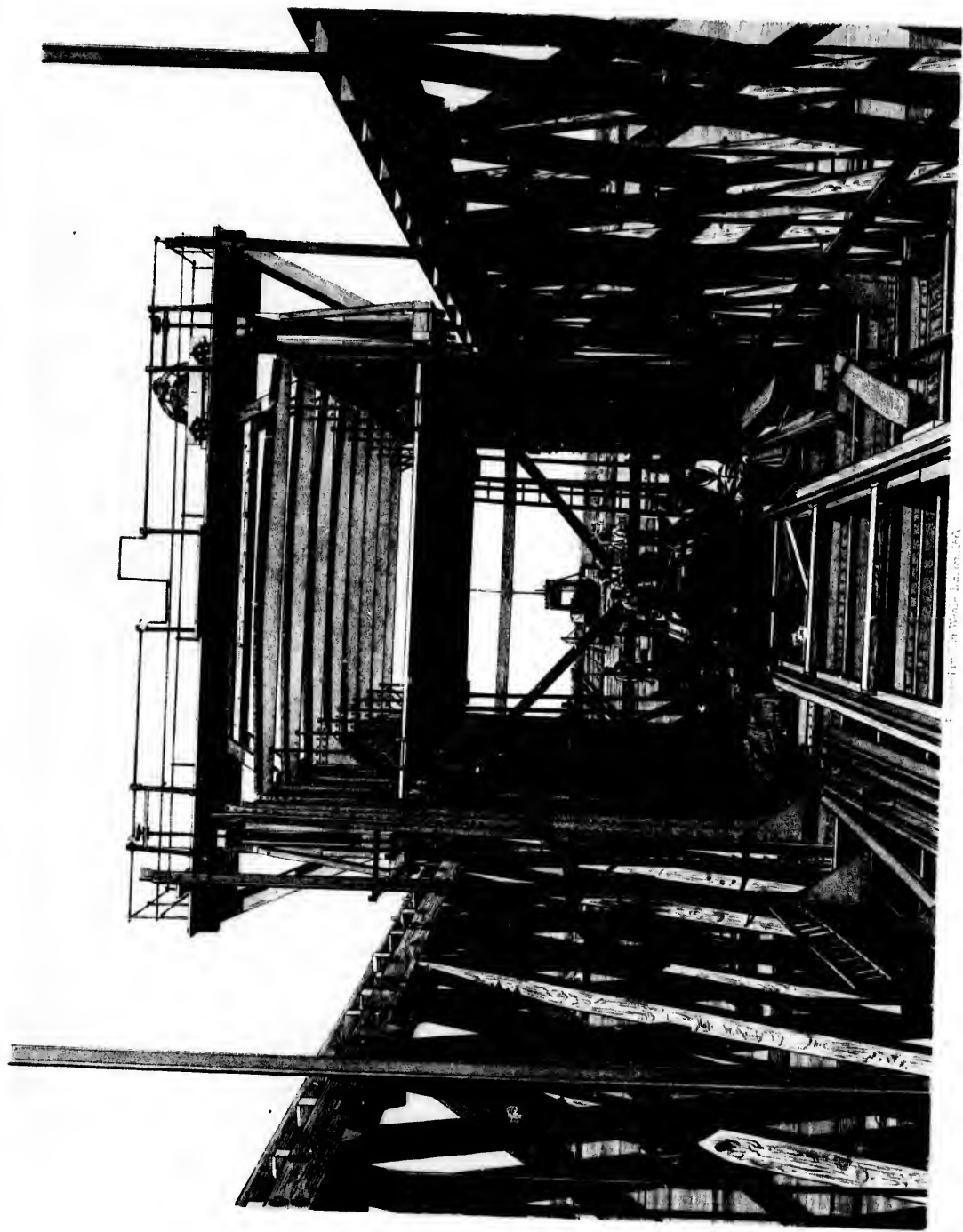


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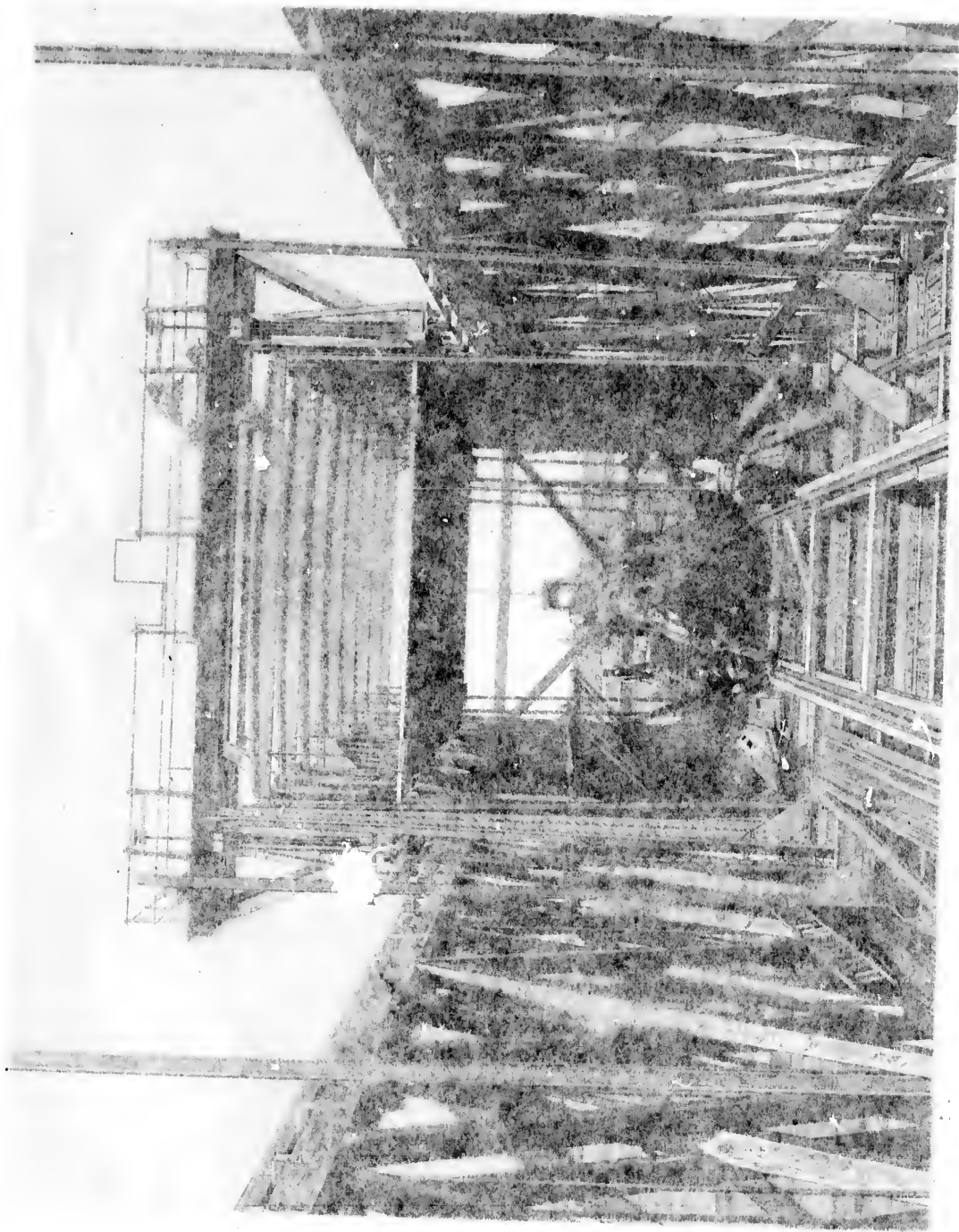


GREAT VICTORIA BRIDGE

... and when a plan or map of each tube was made, upon which was shown every T bar, angle iron, keelson, and cover plate in the tube, the position of each being shown and marked upon it by a distinctive figure, letter, or character. As the work progressed at Birkenhead, every piece of iron, as it was punched and fitted for shipment, was stamped with the identical mark corresponding to that of the plan, so that when being erected in Canada, although each tube was ... a pile, the workmen, being provided with a plan of the ... each piece by piece with ... the ... together of a ... and in making the plans in preparation for shipping the ... it arrived in Canada (where the steel for each tube was ... separately for use, the workmen being provided with the plan work throughout and never put a piece in the wrong place nor have ... work plate. It was not uninteresting to watch the gradual dismantling of the ... on the platform as the work progressed, and eventually to see the last piece ... into some out-of-the-way hole ... to find for certain that the tube ... completed.

At 8 o'clock ... and it would ... in the ... till they were ... on the ...

At 10 o'clock ... work ... impossible to hold ... The plan pursued in this instance was ... the same side of No. 12 tie beam which set ... the ... and then to strut ... as possible. Of course heavy ... the stream, and chains were ... 12 ... delays and failures ...



Birkenhead, where a plan or map of each tube was made, upon which was shown every plate, T bar, angle iron, keelson, and cover plate, in the tube, the position of each being stamped and marked upon it by a distinctive figure, letter, or character. As the work progressed at Birkenhead, every piece of iron, as it was punched and finished for shipment, was stamped with the identical mark corresponding with that on the plan; so that, when being erected in Canada, although each tube was composed of 4926 pieces, or 9852 for a pair, the workmen, being provided with a plan of the work, were enabled to lay down piece by piece with unerring certainty till the tube was complete. To an uninitiated spectator this proceeding would appear as complicated and hopeless a task as the putting together of a Chinese puzzle; but to such perfection did they arrive at Birkenhead in making the plans, in preparing and punching the iron, and in shipping it, that when it arrived in Canada (where the iron for each tube was, as it arrived, sorted and stacked separately for use), the workman being provided with the plan would proceed with his work throughout, and never put a piece in the wrong place, nor have to alter a single plate. It was not uninteresting to watch the gradual diminution of the pile of iron on the platform as the work progressed, and eventually to see the last piece taken to fill up some out-of-the-way hole or corner, and then to hear for certain that the tube was completed.

As soon as it became evident that the centre piers, 12 and 13, would be finished in time to receive the centre tube if erected during winter, two temporary piers were commenced in the centre opening, the intention being to carry up these erections in cribwork till they were high enough to support a continuous Howe-truss extending across the opening, the ends of which were to rest upon large stone corbels left for that purpose on the face of the piers.

At this period the sectional area of the river was so much diminished by the temporary works now in the deep water, that the current was increased greatly, and it was almost impossible to hold a crib of any dimensions in such a current till it was sunk in position. The plan pursued in this instance was to build the crib in the eddy on the south side of No. 12 (the stream which set partially across the piers being favourable to such an operation), and then to strut it off into the current from the dam, and sink it as speedily as possible. Of course heavy moorings were laid out ahead to hold the crib in place against the stream, and chains were likewise made fast to the bow of No. 12. After numerous delays and failures, the first crib was sunk and secured very near its intended position. The second was then proceeded with in a similar manner, but not with the same success; for, when near grounding, the moorings slipped some forty feet, and there was no alternative but either to cut all away and begin again, or to sink the crib where it was and commence another immediately above. The latter

plan was adopted, and the pier built, but not in position to divide the span into three equal openings as desired, the southern span being very much larger than the others.

Every exertion was made to press on this work, and in spite of the severity of the weather the cribs were finished, and two-thirds of the truss were in place by December. (See progress diagram, Plate 1, and also plate for plan of temporary piers of cribwork.) As it at this time became evident that in a few days every craft must leave the river, attention was turned to the hoisting and stacking of the timber requisite for the completion of the work upon the portion already done, so that as soon as the ice bridge formed, the work might be resumed. Fortunately, nearly the whole was hoisted, although the work was eventually stopped by the sinking of the hoisting scow, or steam-derrick, which was cut through by the ice.

The construction of the temporary piers will be readily understood upon reference to the drawings. (Plate 12.) They were of the usual kind of cribwork, with a flooring over all at summer water level to carry the stone piling above. The interior of the crib below summer water level was divided into chambers, which, being sheet piled, were filled with puddle clay; sheet piling was likewise driven around the outsides of the cribs to prevent any subsidence taking place; the interior of the whole of the part above water was packed full of loose stones. The puddle clay also, which was used for weighting the crib, was used in preference to stone, from the facility it afforded in the removal of the crib pier in the ensuing spring, when, by simply drawing a few of the sheet piles, the strength of the current would speedily wash away the whole of the clay, rendering recourse to diving unnecessary.

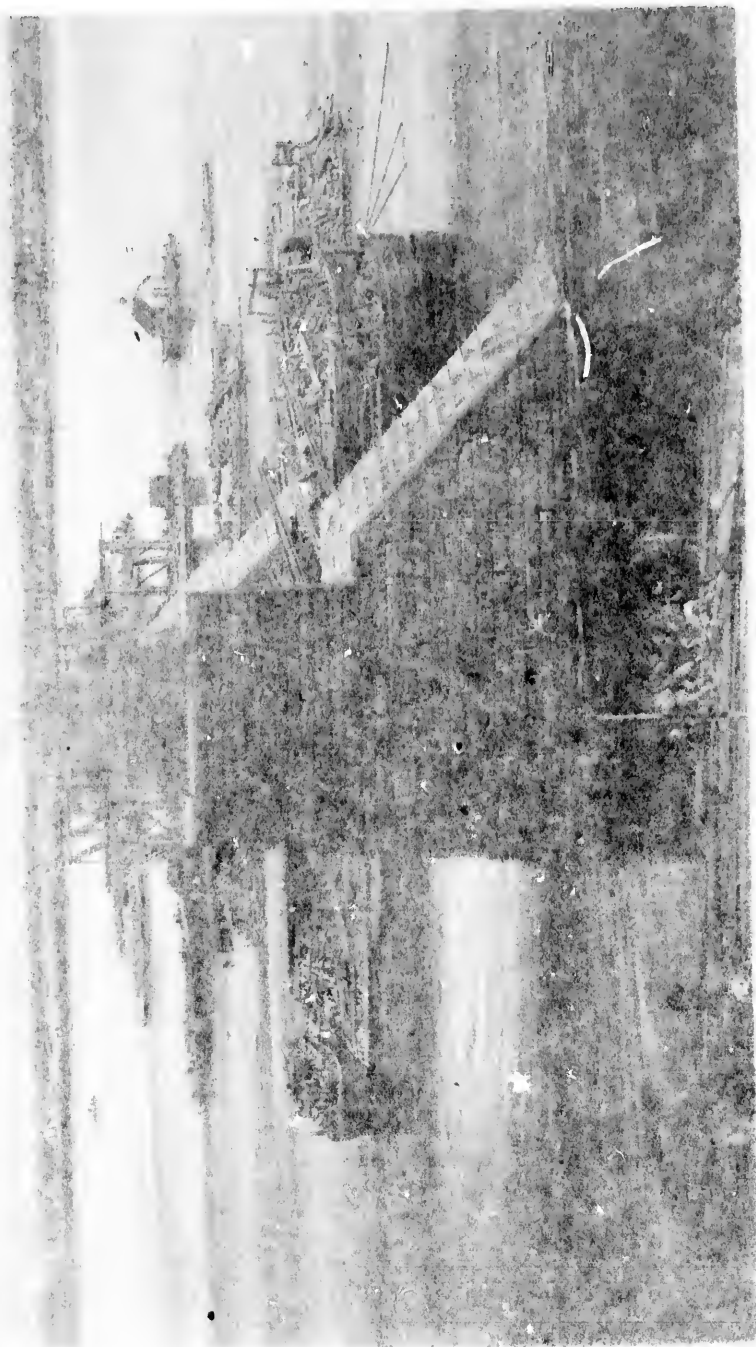
The second crib could not be finished in this way, owing to its being out of position; and as the additional strength gained by its greater length would be considerable, the puddle clay and sheet piling were dispensed with, and such piles only were driven as were required to carry the trusses, and render these independent of any subsidence that might take place from scour under the cribs during winter. The weight of stone in the cribs was 6512 tons; the sides were close planked to winter level; and the sloping face up-stream was covered with planking of hard wood. Great hopes were entertained that they would withstand the shoving in the early winter. Before the spring shoving occurred, it was intended that the tube should be independent of support, so that no damage to the permanent work might result from any scouring of the river.

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CONSTRUCTION OF THE BRIDGE AT THE GREAT FALLS

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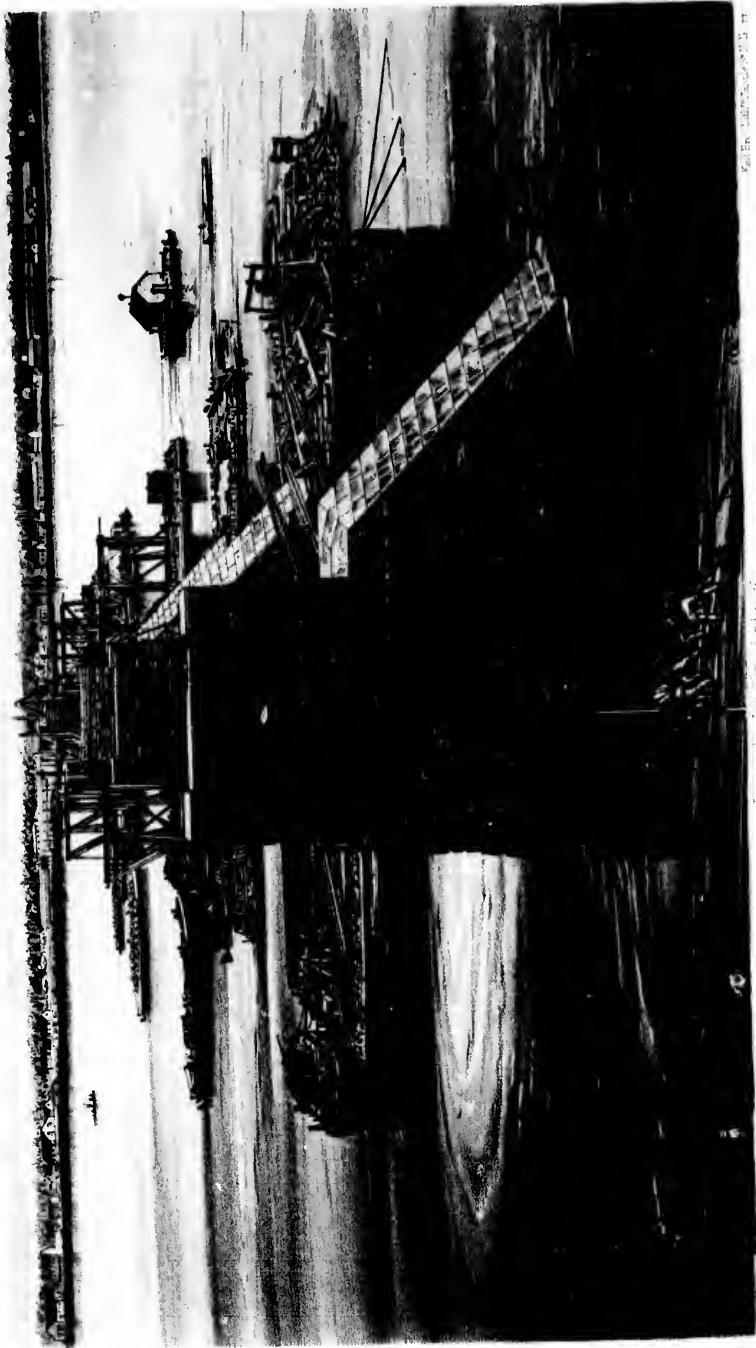
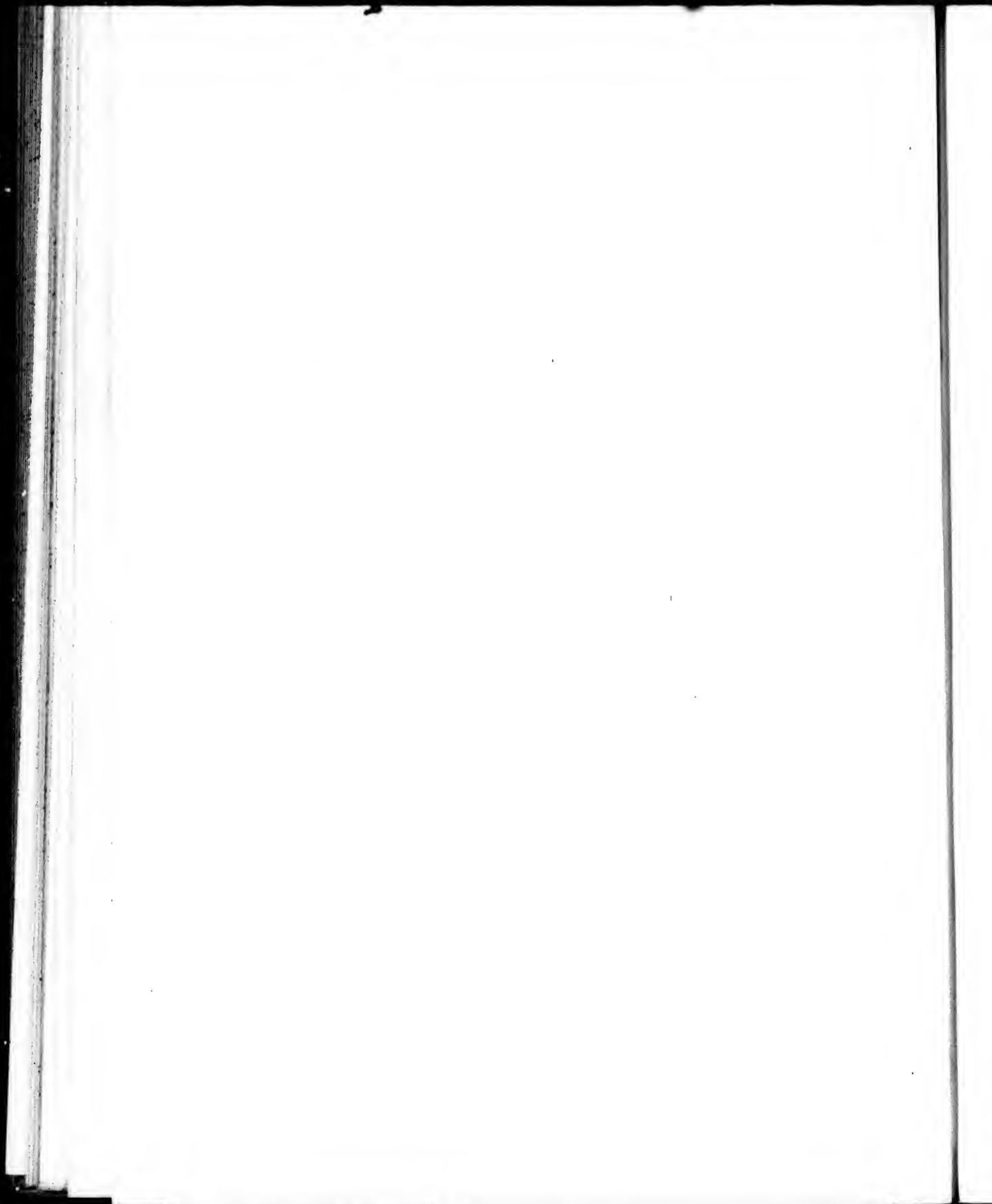
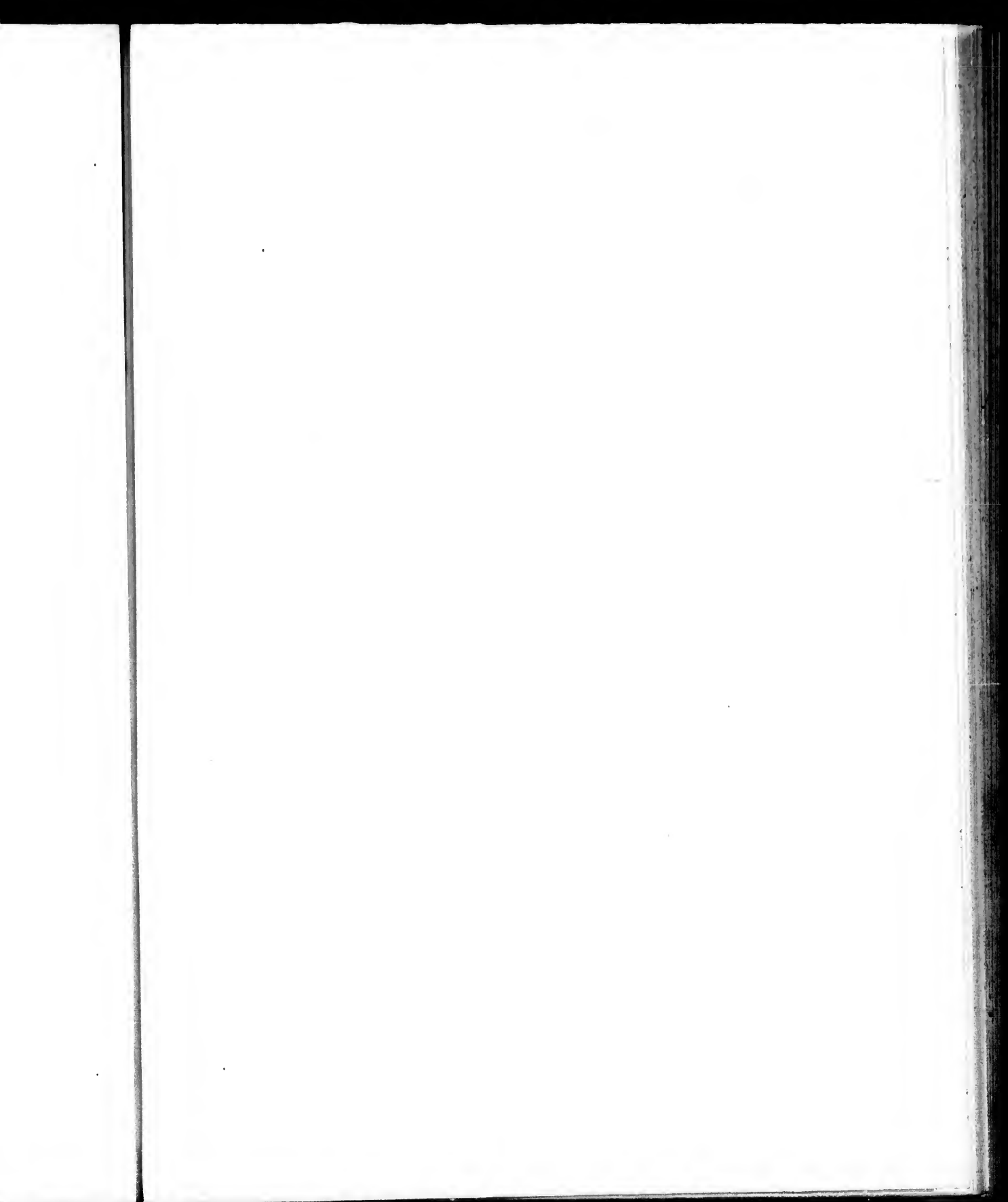


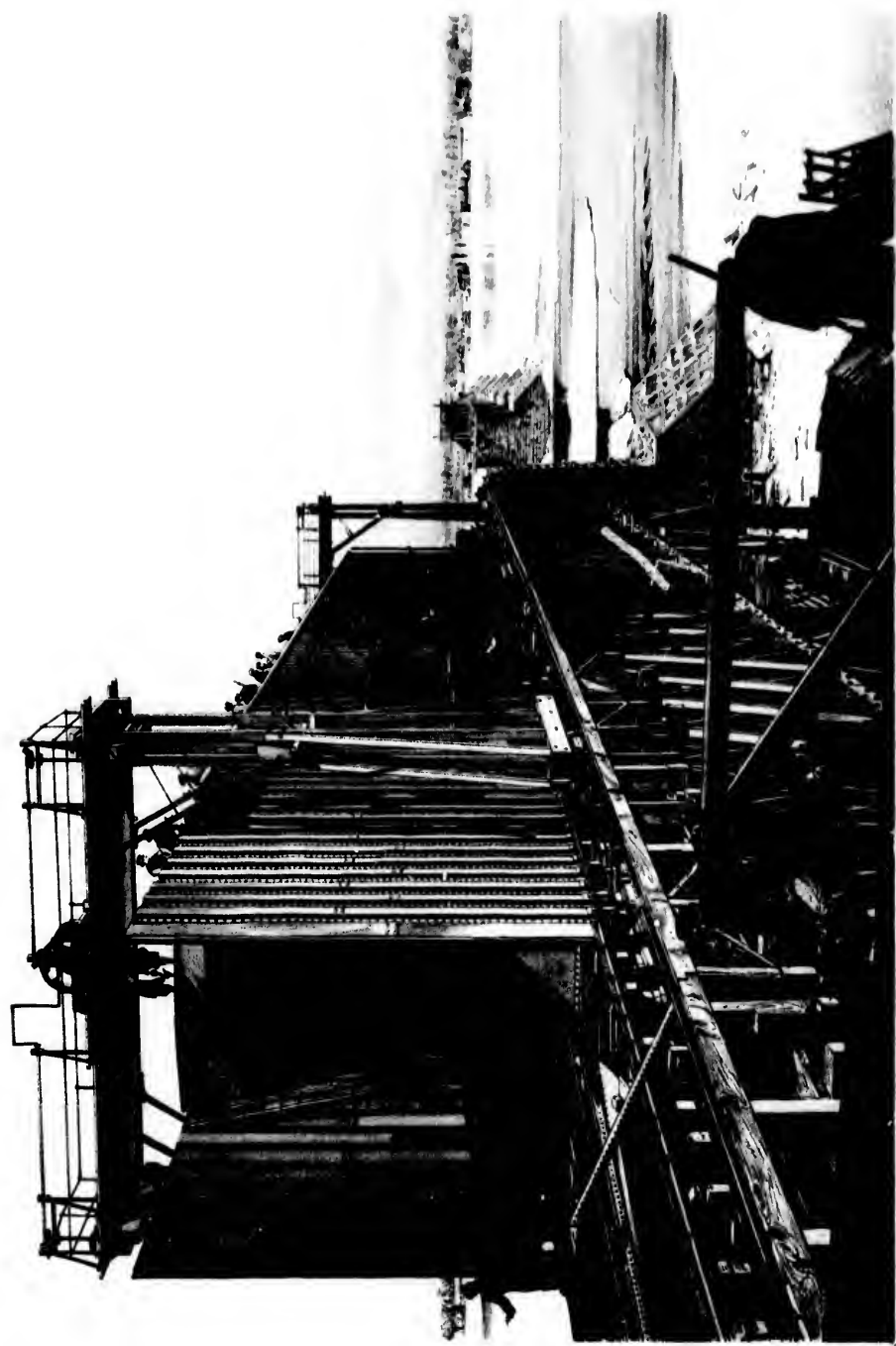
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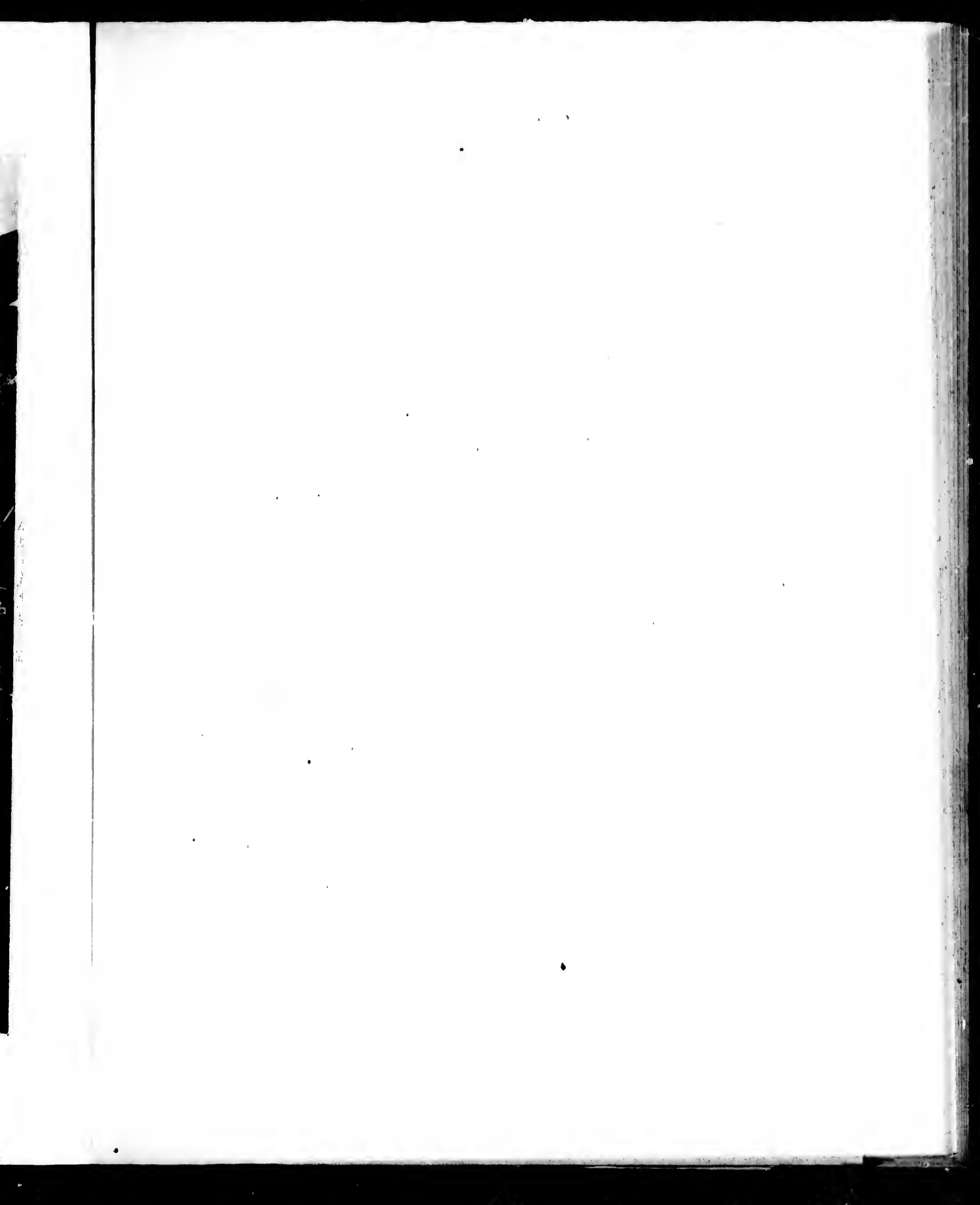
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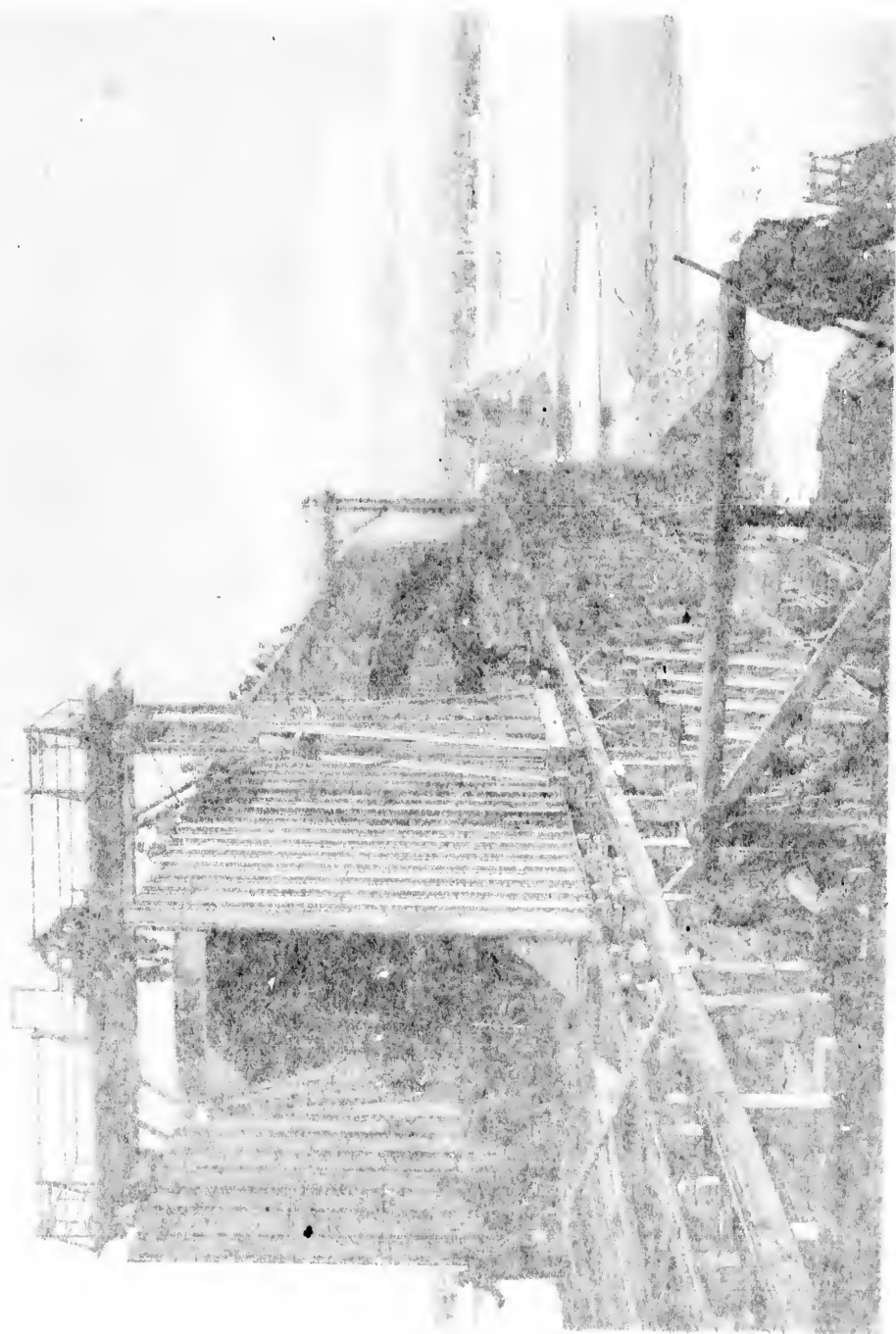
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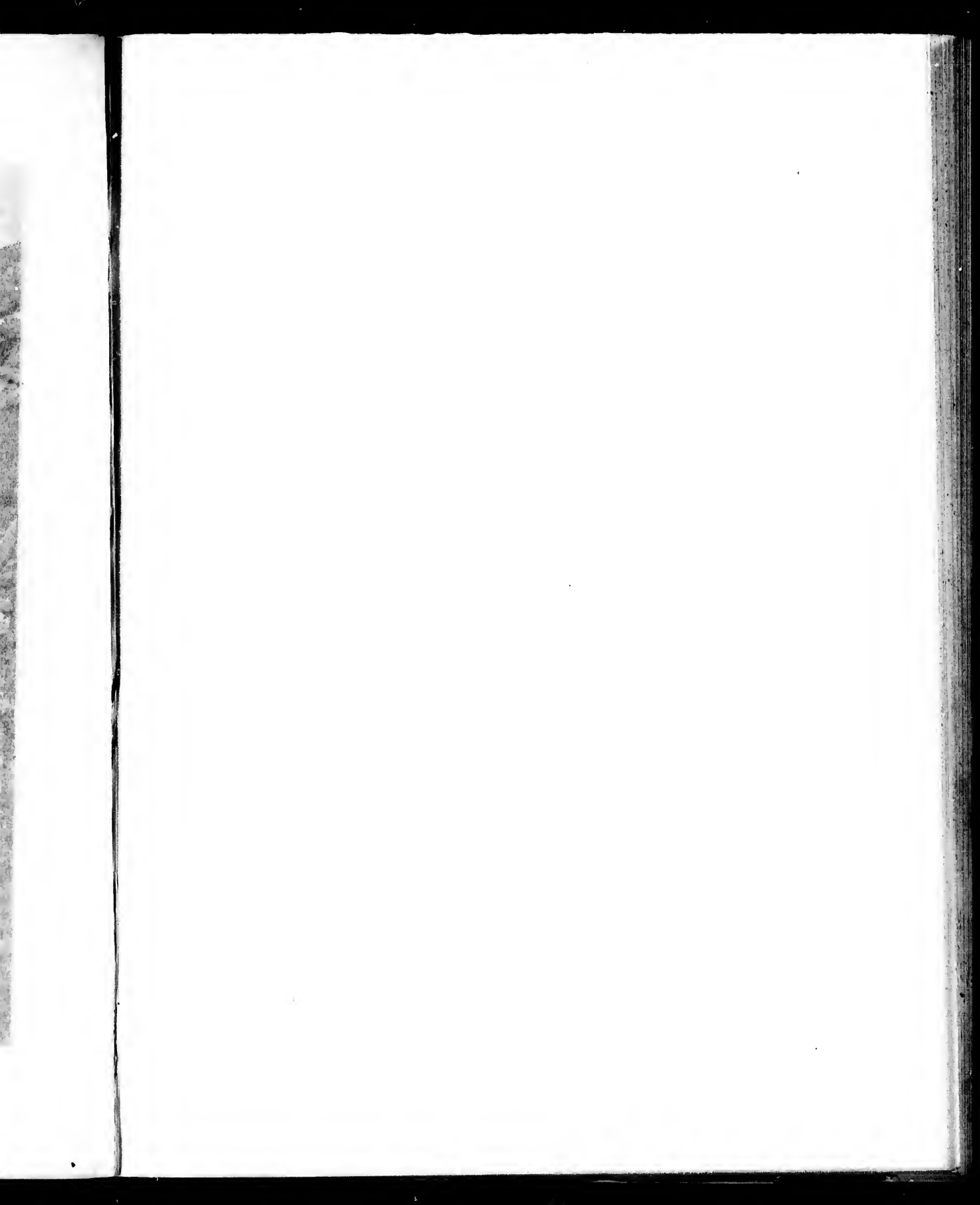














CHAPTER I

GENERAL PRINCIPLES

The first principle of the work is that the work should be done in a systematic and orderly manner, and that the results should be recorded and preserved in a permanent form.

The second principle is that the work should be done in a way that is consistent with the principles of the science, and that the results should be interpreted in a way that is consistent with the principles of the science.

The third principle is that the work should be done in a way that is consistent with the principles of the science, and that the results should be interpreted in a way that is consistent with the principles of the science.

The fourth principle is that the work should be done in a way that is consistent with the principles of the science, and that the results should be interpreted in a way that is consistent with the principles of the science.



CHAPTER XII.

WORKS. [1859.]

THE ice bridge formed this year about the middle of the first week in January. Page 47 shows the position of the shovings, of the grounded ice, and of the air holes, after the river had become safe for crossing.

Gangs of men were set to work to form roads upon the ice for the conveyance of materials to the centre tube ; and, at the same time, the carpenters were vigorously at work completing the stagings, which fortunately were uninjured by the ice.

January 10th, 11th, and 12th, were the coldest days experienced in Canada for many years, the thermometer at the bridge registering no less than 36° below zero, Fahrenheit. An incline of timber framing was formed from the packed ice in front of the temporary pier in centre span to the top of No. 12 pier, upon which a tramway was laid. At the bottom of the incline a small crane was erected for transferring the iron from the sleighs to the trucks, which were then drawn to the top of the incline by a chain passing over rollers from an engine fixed on the packed ice in front of No. 12 pier. Attached to this engine were force pumps and hose, so arranged that, in case of fire, a stream of water could at any moment be thrown over any part of the staging. Watchmen were employed night and day, and the engine kept constantly in full steam in case of such an emergency.

Upon No. 12 pier, at the head of the incline, was arranged a traversing platform, upon which the trucks laden with materials were moved to the centre line of the bridge ; and from thence, upon a track laid down as the work progressed, to every part of the tube. The staging incline and steam hoist were completed and ready for work, and the plating of the bottom of the tube was fairly commenced on Monday, 31st January. By the 9th February, the plating of the bottom was well advanced, and as many as forty gangs of rimmers were at work night and day preparing the holes for the riveters. (See Plate 9 for tools used.) These gangs followed each other up as fast as the holes were prepared for them. The gangs working at night were lighted by large fires in

braziers. During the extreme cold, or when the thermometer was more than 20° below zero, Fahrenheit, if there was any wind at all, the men could not work, as at such times the smallest portion of the body left exposed was frozen instantly. The greatest care was, therefore, requisite. The men had to work in thick gloves, and with heavy coats on. Fur caps covered their ears, and heavy handkerchiefs were worn over the greater part of their faces, so that only a very small portion was visible. Even with all this care they occasionally got frost-bitten.

The vapour from the open water below the bridge in extremely cold weather was exceedingly troublesome, particularly during the night. At such times, when there was any air up-stream, the workmen in a very short period would become covered with icicles, and be driven from their work.

During the erection of this tube, scores of men were frozen in their hands, noses, ears, and face. Some had to go to the hospital in consequence; yet not a man lost either finger or toe; neither was any man seriously injured during the time the tube was in progress. There were, indeed, fewer casualties than usually occurred in the summer season upon similar work. And this is to be accounted for by the excessive precautions that were taken, in consequence of the certain knowledge that the slightest carelessness would produce fearful mutilation, and very probably loss of life itself.

On the 12th of February the first pair of side plates were erected. They were riveted together at the workshops by the machine, in lengths of three plates, making about ten feet, and were brought to the work upon sleighs as the tube progressed.

The cambre of the tube was now finally adjusted, and by instructions from the engineers this was not allowed to exceed six inches, which was supposed to be sufficient to cover all subsidence of stagings, packings, &c., during construction. The height from the bed of the river to the underside of the tube was about 85 feet, with a current of at least eight miles per hour constantly scouring away at the foundation. The force of this current, added to the number of joints and the thicknesses of the timbering, each of which (with a weight of over 800 tons pressing upon them) must give a little, caused during the progress of the work some apprehension lest greater subsidence should take place than was provided for.

The ends of the tube rested directly upon the piers, with planking only between them and the masonry; therefore at these points no subsidence during construction could take place. Consequently, as the work progressed, and subsidence occurred in the centre, the cambre was constantly altering. This may not probably be a matter of

any moment where the subsidence is not great, yet it is, nevertheless, a defect, and if the staging is not exceedingly rigid, such subsidence becomes of vital importance; for if, after the work is well advanced, any great amount of lifting is required to adjust the cambre, some portions of the work must be subjected to strains such as they are not calculated to sustain, and permanent injury to the tube might be the result. It is also probable with ordinary staging that unequal subsidence may take place. This is always a source of trouble; for, without any consideration for that which has already shown itself to be the weakest part, the workman crowds on the screw-jacks at that identical spot, and in all probability puts double the strain upon it that it ought to have. The fear of this, together with the knowledge that there would be no time for adjustments, led to the use of the continuous truss, which, although costly in the first instance, fully repaid itself by the advantages gained in the great uniformity of support which it afforded.

On the 28th of February the bottom was completed and riveted, 180 feet of the sides were in place, and 100 feet of the top was plated.

On the 11th of March the greater part of the iron was in place, and the cambre of the tube, from subsidence and compression of packings, was reduced from six inches to four and a-half inches.

On the 15th of March a fearful storm destroyed a great portion of the temporary scaffolding used upon the sides of the tubes. This storm was followed by heavy rains, covering the ice bridge with water, and awakening fears that the river would break up early. Thermometer at 50°. Ice getting very rotten.

On the 21st of March the whole of the plating was completed, and 18,000 rivets only were required to finish the tube. The Wellington cranes and inclines were in course of removal.

March 24th. The ice at this time was getting very rotten, with a great deal of water upon it. The thermometer was at 40°, with heavy rain. The riveting was well advanced: only 5600 more rivets to finish. We now made preparation for striking the wedges. The cambre of the tube at this time was four and a-half inches, the subsidence for the last week having been exactly one hundredth of a foot daily.

Friday, the 25th. First movement of the ice. About 2 o'clock several faintly dark lines like ridges made their appearance upon the ice about half-a-mile above the bridge. For some time it was very questionable if they were new, and surprise was

expressed that they had not been observed before. An experienced man was sent to examine them, and the men continued at their work. Before he returned it became evident that the ridges were not only new, but that they increased, and that the whole of the ice in the La Prairie Basin, of some twenty miles area, was in motion, shoving upon the Middle Shoals and upon the south shore of the river.

A panic immediately seized all hands, and most of the men were for running for the shore, but as that was nearly a mile off, while the ice in motion was only half that distance, it was thought wiser to remain upon the tube. In a few minutes all movement of the ice ceased, and the men turned to their work again with a quaint remark or two.

This day we commenced slacking wedges, taking out all except those immediately over the temporary piers.

Under the tube, in the centre of the span, fifteen bottle screw-jacks were placed, it being thought that these would put less lateral strain upon the tube, if a movement of the staging should take place, than if it was left supported by wedges. For this reason, the whole of the wedges, excepting those immediately over the temporary piers, were removed.

Saturday, 26th. A sharp frost made the ice much more safe, and most of the men returned to their work, so that by night very few rivets were required to make the tube complete.

By noon the cambré of the tube, left yesterday at two and a-half inches, was reduced to half an inch, the wedges left in being crushed, the seats of the screw-jacks embedded in the timber, and the screws so bent that they could not be moved.

In the afternoon, while taking away the remainder of the now crushed wedges, the whole of the screw-jacks buckled almost simultaneously, and gave way with a considerable surge, throwing the weight that they had hitherto sustained upon the wedges and packings, crushing them still more. When these were cut away, the tube was found to be three inches below the straight, giving a deflection, from the time the wedges were first slacked, of seven and a-half inches, and from the first laying of the tube, of nine inches.

The pleasurable excitement that would have been experienced by all upon the work when the wedges were cut away and the tube was for the first time seen un-

ported excepting at the ends, was very much lessened by the surge produced from the breaking of the screw-jacks, particularly when it was discovered that the under side of the tube, instead of being straight, or having a little cambre as the other tubes always had, was below the straight some three inches. In every other respect, however, the tube was all that could be desired, being as true to line and as sound in workmanship as any tube that was ever constructed.

The surge caused by the breaking of the jacks was increased in the imagination of most of those present by the springing back of the truss, upon which the jacks stood, into its original position.

To understand this, it is necessary to explain that the jacks were not placed immediately over a temporary pier where there was no elasticity, but in the middle of the tube, and, consequently, between the temporary piers. As the wedges, therefore, became compressed or were cut away, the additional weight thrown upon the jacks caused a deflection of some two and a-half or three inches in the truss, which, as soon as the jacks broke, sprung back to its original position with great force. There was much more alarm felt by those upon the temporary staging than by those within the tube.

March 27th.—Ice unsafe ; men not able to get out to centre tube.

28th.—Ice breaking up, and shoving very heavily, just eight weeks from the commencement of tube, being certainly one week earlier than anticipated.

Upon an inspection of the temporary piers after the shoving was over, it was discovered that the ice had racked or shoved them bodily down the stream some two feet. Otherwise they were uninjured. The same thing occurred at No. 7 staging, where the temporary piers were forced some three feet down stream, causing great alarm to the workmen who were upon it at the time, some of whom narrowly escaped from falling off by the concussion produced during the shoving.

The writer cannot avoid mentioning the anxiety that every one engaged upon the centre tube felt about its being completed before the breaking up of the ice. The general opinion was, that unless this was accomplished it would in all probability either fall into the river or be so crippled that it would be necessary to take it to pieces and reconstruct it.

Perhaps it is in some degree to this apprehension that we are indebted for its completion in so short a period and in such inclement weather. Indeed every man

seemed to imagine that success depended upon his own individual exertion, and all worked with this feeling as if for very life, irrespective of remuneration.

I have frequently witnessed in cases of emergency great enthusiasm displayed by a few men, but I never saw anything so universal or so continued as upon this occasion.

I have before noticed that the whole of the iron work for the tubes was prepared at the Canada Works, Birkenhead (an establishment erected by Messrs. Peto, Brassey, and Betts expressly for the manufacture of the bridge work and rolling stock for their Canadian contracts). At these works every plate, &c., was finished ready for putting in place. I have likewise endeavoured to show with what care and accuracy the whole of this was done; but I trust I may be excused for again drawing attention to the extraordinary perfection attained in the preparation of this ironwork. In the centre tube, consisting of 10,309 pieces, in which were punched nearly half a million of holes, not one piece required alteration, neither was there a hole punched wrong! The importance of this accuracy may be estimated by considering that had any portion been carelessly prepared, or even wrongly marked, a failure might have been the result, involving the delay of a year in the opening of the bridge, and a loss of many thousands of pounds. Therefore, to Mr. George Harrison, the manager of the Birkenhead works, &c., and to his able assistants, Messrs. Alexander and Heap, is due as great credit for the successful completion of this work as to those engaged in its erection. For details of tubes, see Plates 24 and 24a.

April 4th.—The "Musk Rat" made her appearance at Montreal, being the first boat in harbour.

The removal of the centre staging was the first work that claimed attention. It was proceeded with as soon as the craft could be got up from their winter-quarters; for, till this was done, and the opening cleared of all obstruction and made free for the navigation, No. 11 pier could not safely be commenced.

Great trouble, difficulty, and annoyance were anticipated this year, from the river being so full of obstructions to the navigation. These it was necessary still further to increase, and that too in the most frequented and, indeed, only available channel. The dams being some 200 feet apart, or rather leaving openings of 200 feet clear between them, had hitherto given sufficient space for any rafts to clear that had been driven out of their course. But this 200 feet had now to be again divided by the temporary piers requisite for tube staging, which reduced the openings to something like 80 feet. It consequently became apparent that a raft, 250 feet by 40 feet, managed only by a few

Indians, would, in bad weather, have great difficulty in getting through without injury either to themselves or the works. The greatest number of rafts ever seen at one time from the bridge works was thirty-five.

The current, as before stated, being very rapid, and cribs in the centre of the spans absolutely requisite for the temporary staging, some means had to be devised of putting them down rapidly, so that little risk might be run of their being carried away by rafts when probably half constructed, or perhaps when just finished, and only requiring weight to make them stable. To facilitate the work, a barge was fitted with a huge triangular-sided skeleton framing, about thirty feet wide (see Plate 13), hinged to the deck by means of a strong transverse timber, and held up clear of the water by blocks and falls attached to a lofty derrick. The framing was so constructed that when the barge was moored in position it could be lowered in a few minutes, so that the four legs of the framework would rest upon the bed of the river, with only a few feet of the top out of water. As soon as it was fairly upon the ground, stones were laid upon a platform prepared to receive them, which, as the framework was only skeleton, offered very little obstruction to the current, and was easily kept in position.

Planks were then laid on the sloping part against the stream, which were pushed down till they reached the ground. When the whole was covered with planking, the weight caused by the rush of water up the sloping face kept the mass perfectly firm, and formed an eddy in which cribwork could be framed and sunk with the greatest dispatch and facility. As soon as the crib was sunk and weighted, the turnwater (as the machine was called) was removed to another place, which operation, after the removal of the sloping planking and stones, was easily accomplished. This turnwater was used very successfully in some instances, but failed in others; nevertheless it was a valuable machine, and if it had been constructed at an earlier period of the work, might have simplified operations very materially.

On the 3rd of May, long before the centre span was clear and free for the navigation, an attempt was made to commence No. 11 pier, although it was now the only channel available both for steamboats and rafts. For this purpose the barge and turnwater were moored in position, and the apron, or sloping planking, put in successfully.

On the 5th of May, the cribwork intended to form a portion of the dam head was commenced, and everything was proceeding favourably in the eddy formed by the turnwater, although the current was now increased to over eight miles per hour. At this time, however, it was observed that the lake was full of rafts, and very shortly fifteen could be counted from the bridge.

Boats were immediately manned and placed in readiness, it becoming quite evident from the course the rafts were taking that they could not absolutely clear the work now in course of construction. Fortunately, none of the earlier rafts struck the work itself. But it was no pleasant situation to be in with these heavy masses, each of them composed of many hundreds of pieces of oak timber, crushing against the sides of the barge and of the turnwater, and threatening every instant to carry all away.

Two more rafts now only remained above, one of which was evidently coming full upon us. This raft struck and was brought to a stand by the mooring chains of the barges; and after remaining poised for a few minutes, as if undecided which side to go, it swung round, and at the same time that one end was crushing and grinding past the turnwater, the other was broken up by No. 12 pier; the length of the raft being more than equal to the opening, which exceeded 250 feet.

We had scarcely time to recover from the excitement of this occurrence, and congratulate ourselves upon having escaped without injury, when the last raft was close upon us, broadside on. This raft, composed of large baulks of oak, was manned by thirteen Indians. It was evident that it must strike us, and likewise pretty certain that the raft and temporary work must all be swept away. A yell arose from the Indians who manned the raft, and who, up to the time it was within one hundred yards of the work, appeared to have been panic stricken.

The raft struck the mooring chains of the barge in about the centre of its length, and in an instant, as the huge unwieldy thing was swept round by the current, the whole of the men were in the water, struggling amidst the baulks of timber, which were borne down like straws by the river, and sunk on each side of us. To save many of them seemed impossible. Two or three were hauled on board, but the remainder were whirled down in the eddies under the barge and behind the turnwater, where they could be distinctly seen in the clear blue water struggling to free themselves from the tangled mass of timber. One very old man was seen from the barge for a long time, the sun which shone on his bald head rendering him very conspicuous. We almost gave him up for lost, but he was eventually picked up by one of the boats, very much exhausted, but still clutching a handkerchief, in which were the remains of his dinner.

After the mass of timber had been held for a few minutes, a portion became detached, but still immense quantities were entangled with the turnwater, which was now discovered to be so much damaged as to be useless, even though it remained in position till the whole of the raft was gone. Orders were accordingly given to cut

all away as quickly as possible. Every axe was instantly at work, and in a very short time the work of this season, together with the remainder of the raft, was swept away, and floated *en masse* down the river, leaving us thankful enough that the men on the turnwater had escaped without injury.

Our next anxiety was to discover how many men were missing, for as soon as the screaming of the raftsmen told that collision was inevitable, every boat was manned; and, by the time the raft had struck, eight or ten boats' crews were straining every nerve to arrive in time to render assistance. As soon, therefore, as the men were disentangled from the raft and could get out of the eddy so as to be able to reach the surface, plenty of assistance was at hand, and it fortunately proved that not a man was lost, although some of them were picked up half a mile below the point at which they had struck.

The first attempt at the commencement of No. 11 dam having failed, fresh measures were immediately taken. Two scows, 80 feet by 20 feet, were obtained the same afternoon, and upon the deck of one of them cribwork was commenced of the same dimensions and shape as the scow. Instructions were given to build this cribwork of such height above the deck that when the scow was scuttled the cribwork should be level with the surface of the water. The other scow was heavily laden with stone, strong mooring-chains were attached to her, and she was then taken some hundred yards above the site of No. 11 dam and sunk.

The scow with the cribwork framing upon deck, securely bolted down, was towed up to the work, a barge was placed on each side of her, and being held in position by the heavy mooring-chains attached to the sunken scow, she was scuttled on the 19th of May as near the centre of the dam head as possible. (See Plate 14.) As soon as this was done, the cribwork was raised some three feet and very heavily weighted with stone. In the eddy thus formed, wedge-shaped pieces of cribwork were constructed and sunk, which spreading out fan-like were continued till a sufficient width was obtained for the whole of the dam head.

These various cribs were then well bound together at the top and weighted, so that the rafts could do no further injury than by tearing away a portion of the upper part of the cribs, which could always be repaired at leisure.

Sufficient width having been gained, the work was fairly set out; dormitories and workshops erected, and the framing of the sides of the dam was proceeded with in safety. The work now consisted of an equilateral triangle framework of timber, with sides

100 feet, and a depth of 25 feet, laden with stone some 1500 tons weight, and sunk in a current running seven miles per hour. It is necessary to realise this to form an adequate idea of the extent of temporary work that was put together in a few days, to enable the permanent work of this dam to be commenced, and to afford it adequate protection.

As soon as the cribwork forming the sides and stern of dam were framed, sunk, and planked over, a tramway was laid down for the steam pile engine, and the outer row of piles of puddle chamber were driven, divers having first carefully examined the bed of the river and removed all boulders and large stones, some of which were so large that they had to be lewised by divers, and hoisted and raised by blocks and falls. The outer row of piles were 12 inches by 12, shod with cast shoes; the inner piles were 12 inches by 8. The ground upon which these piles were pitched was closely examined by divers several times; first before pitching the piles, then after dredging was done, and finally after the inner row was in place, just before the puddle was put in.

By driving the inner row of piling after the dam was puddled, the piles were in some measure kept from twisting, and were driven more regularly than they could have been before the puddle was in place. The pile driving, the framing of the inside cribwork, the clearing of the puddle chamber by divers, the dredging, the fixing of pumps and machinery and the puddling, progressed almost simultaneously; indeed, at one period, the whole of these operations might be seen progressing at one time.

Such a busy scene as this dam now presented is seldom witnessed. The works presented a small island of cribwork surrounded by barges laden with stone, timber, steam-engines, puddle clay, traveller stagings, and pumping machinery, in the midst of which were crowds of men apparently in the greatest confusion. This, added to the shoutings of the workmen, the noise of the pile engines, the "yeo-heave-yeo" of the British boatmen unloading materials on one side, enlivened by a chorus of French Canadians chaunting their boat songs to the time of their work on the other, amidst a torrent of waters rushing past, with the surging and creaking of the barges as they tugged and tried to break adrift, formed, at first sight, such a bewildering scene of apparent disorder and confusion as can scarcely be described.

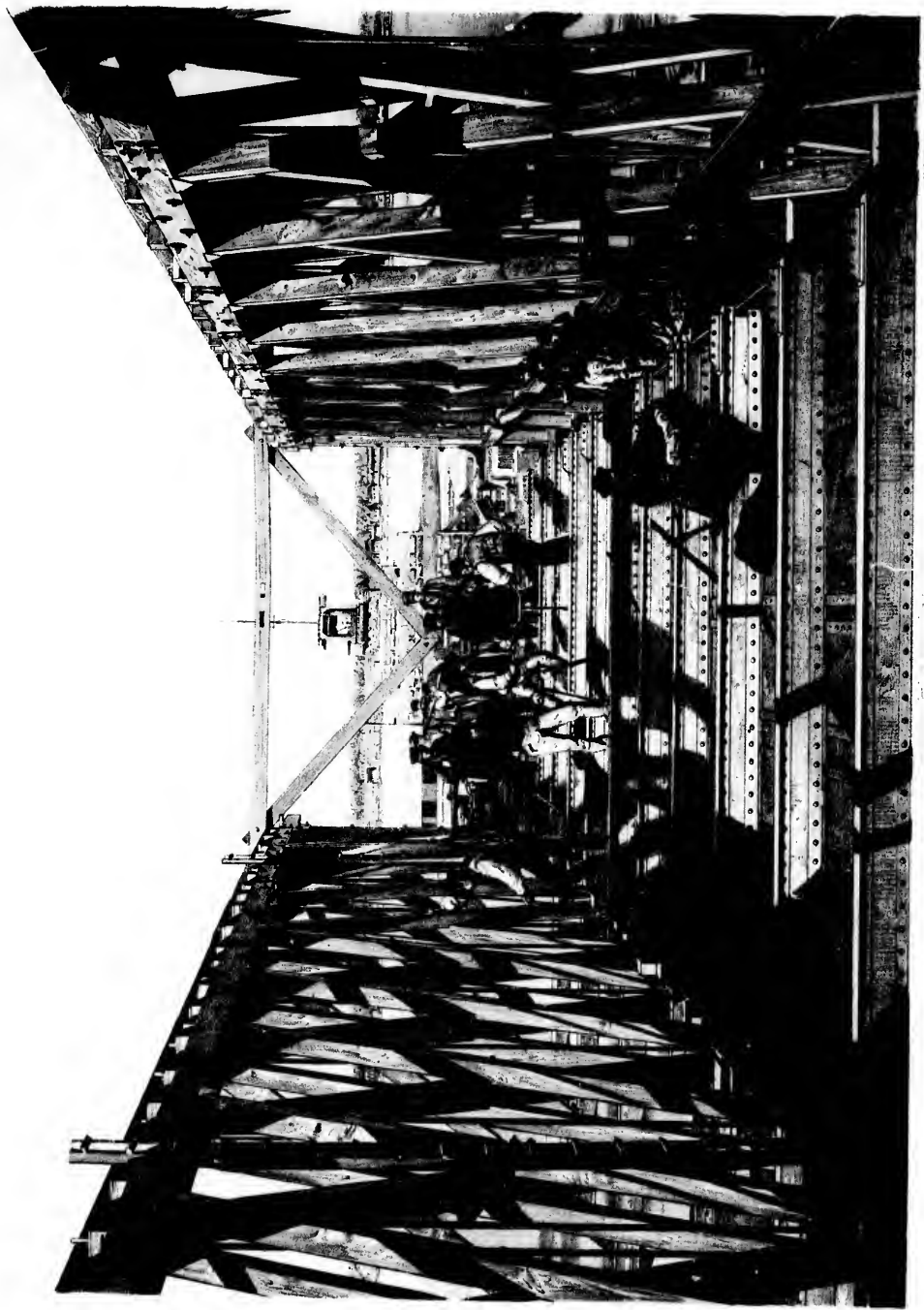
A careful survey, however, must have satisfied the observer, that instead of confusion, everything was order. Observing the gang of men driving piles with a steam engine at one place, he would not fail to notice that they were as indifferent to what was going on around them as if not a soul was there but themselves. So with a body of mechanics putting up pumping apparatus, or with the divers—the men working the air-pumps as unconcernedly and with as much confidence as a philosopher would pro-

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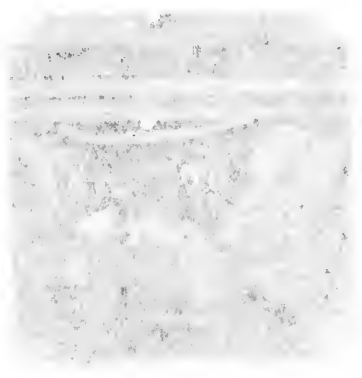
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secute experiments in a closet. At another place, the dredging machine, worked by a steam engine, would be seen scooping every bit of loose material from the puddle chamber, while in the rear were men wheeling puddle into the cleared space, each side of which was lined with men armed with rammers, puddling and working the clay into every hole and corner, so that there might be no leakage. The various works progressed so simultaneously and rapidly, that on the 2nd of August, at 10:30 A.M., the engine was started, and pumping commenced. At 6:30 P.M., we were scrambling over the slippery boulders forming the bed of the river, while outside the dam the mighty waters rushed madly past at the rate of eight or nine miles per hour.

Fires were immediately made on the bed of the river, and two gangs of men were set to work, one party clearing away all boulders, &c., from the site of the pier for the excavation to be commenced, while the others were employed sinking a sumpt hole to the rock. When this was accomplished, the pumps were shifted, gullet driven, and the excavation for the first length of masonry taken out by the 11th of August. The illustration is from a stereoscopic view taken of the work at this period, the transverse timbers in the foreground being the lower pieces of the inside cribwork, which, previously to the commencement of the excavation, rested upon the bed of the river. On the 12th of August the foundation stone of this now called last pier of the Victoria Bridge was laid in the presence of some 300 spectators, and in just six weeks two days from this date 108,000 cubic feet of masonry were laid, the pier being complete by the 26th of September, 1859.



All that remained in this season's work, in order to insure the completion of the bridge, was the erection of temporary stagings upon which the tubes were to be put together. These stagings, as the centre of the river was approached, almost ceased to appear like temporary works,—the depth of the water, the rapidity of the current, and the danger from rafts, rendering it imperative, in order to ensure safety, that they should be as well and as strongly constructed as permanent works usually are.

The turnwater was used with great success in putting in these cribwork foundations as far as No. 11 pier, up to which point one crib or pier to each opening was sufficient. The cribs were constructed as shown upon drawing No. 15. At Nos. 11, 12,

14, and 15 spans, however, two temporary piers were used ; the current being so strong that it was impossible with the available means at hand, to keep in place a framing of cribwork of sufficient width for the purpose required against such a torrent of waters and subject to so many casualties. More than once, even after the temporary piers had become so far advanced as to be grounded and weighted with nearly 100 tons of stone, a raft coming against it, the rolling of a boulder upon which the crib had rested at the bed of the river, or the scouring away of some ground, would set the crib in motion, and in a few minutes the work perhaps of a week or a fortnight would be swept away.



For these openings, therefore, it was decided that two narrow cribs should be sunk, keeping them as near as possible to the cribwork of the old dams. Several points of advantage were gained by this. Not only

was the resistance of a narrow crib less, but, as it was placed in a less rapid part of the current, it could be framed close to the old work. When ready for sinking it could also more easily be shoved off, and eventually, by running some of the upper transverse timbers on to the old dams, it could be framed or trenailed to it and made secure. After the temporary piers were in place, the work was easy enough. Piles were driven through pockets or chambers left in the cribs for that purpose. Upon these the uprights carrying the platform were erected, and as the piles had considerable play allowed them, any concussion or



shock upon the crib was not communicated immediately to the superstructure. To this precaution, as will presently be seen, the safety of two of the tubes is mainly indebted.

The piles being driven, and the hard wood sills upon them, the erection of the superstructure proceeded very rapidly, the facilities for the prosecution of this work being very great. Plate No. 16 shows our steam floating derrick, which needs little explanation, excepting that, being of a very light draught of water, it could be taken to any part of the work. It consisted of two scows, 12 feet beam, each 66 feet long, placed 8 feet apart, with a strong framed deck passing over all. Upon this was placed a

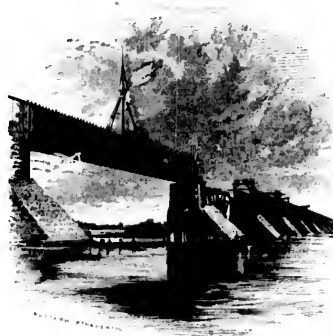
derrick of sufficient height and power to lift the largest piece of timber required for the work sixty feet high, and deposit or hold it in place while being fixed in any part of the structure. By the aid of a small engine, the largest piece of timber could in a few minutes be taken from the deck of a barge and hoisted into position wherever it might be required.

The whole of the work was prepared and framed upon shore; each piece of timber when loaded upon the barge being placed in order as required, and having a mark showing its position in the work.

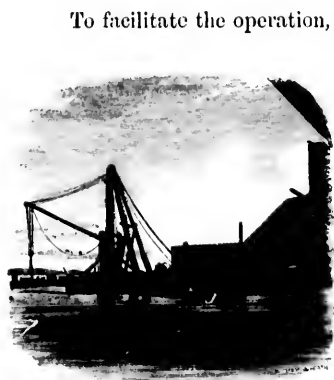
Great efforts were made to get the centre span clear for the navigation, but the immense quantity of materials of which the staging was composed, could not be got away before the 18th of May. After that period the steamboats and rafts made use of this opening to the great relief of the work generally. Still, occasionally, from casualties beyond control, rafts continued to be driven out of their course and carried against the temporary stagings. At one time as many as thirteen rafts, manned by more than 150 men, were driven by a sudden squall against the work. The debris so completely blocked up spans Nos. 19, 20, 21, and 22, that men were seen walking at the water level across those openings. Fortunately no lives were lost; and in the course of a few days, by great perseverance, this immense jamb of timber was gradually liberated. A loss of time was occasioned by this accident equal to nearly a fortnight's labour; but we were thankful enough to escape so lightly, for certainly, in the construction of our temporary works, we had not contemplated such a contingency as having to arrest in its progress a mass of timber equal to 500,000 cubic feet, moving at the rate of five miles per hour.

The last staging (No. 14) was finished in October.

As soon as the season was sufficiently advanced, and the temperature of the water favourable, we commenced the removal of



the cribwork of the dams. Some of these gave a great deal of trouble, being put together with rag bolts and filled with stones to a great depth; while in the dams constructed during the last two years, the stone-filling extended to only some four or five feet below the water.



To facilitate the operation, powerful steam cranes were erected upon barges (see Plate No. 17), strengthened and prepared with steadying piles. The whole of the stones were removed from the inside of the cribs by hand-nippers and hooks made for the purpose, but sometimes divers had to be employed. When the stones were removed, very little difficulty was experienced in removing the timber work, which was ripped up by the machine above mentioned in pieces twenty to thirty tons weight.

At each of the stagings a force pump was fixed, and upon the platform a tank was kept constantly full of water in case of fire. A watchman was also kept on duty night and day at each of the stagings. Nevertheless several stagings very narrowly escaped being burned. Occasionally the rivet boys carelessly let hot rivets fall on the platform, which, igniting the dry chips or timber work, would set the staging in a blaze at once. On one occasion, but for the timely assistance of the crew of the "Beaver," No. 10 staging would have been destroyed, the flames having got fairly hold of the superstructure.

On the 9th of November, during the time that No. 11 dam was being taken to pieces, an accident occurred, which for some time threatened to destroy No. 12 staging, an accident which would have caused the tube, then two-thirds finished, to have fallen into the river. The removal of the stones, which was the first operation in the clearing away of the dam, had been completed, and provision was being made for the removal of the cribwork upon the scow in the centre of the dam head, when, without any notice, the scow with the crib-framing upon it swung round, and, before anything could be done to stop it, was floating in the full strength of the current, broadside on to one of the cribs upon which was erected the staging of No. 12 tube. The concussion produced by the sudden stoppage of this heavy body, eighty feet long and drawing twenty feet of water, was sufficient to drive the whole of the staging, supported by this pier, some two feet down the river, carrying the blockings upon which the tube was being erected with it, and letting down the tube till it rested upon the longitudinals some



The removal of the dams. Some of these gave a great deal of trouble, being put together with rag bolts and used with slams to a great extent, while in the dismantling during the last five years, the slams being replaced by only some four or five feet below the piles.

To facilitate the operation, powerful steam cranes were erected upon barges (see

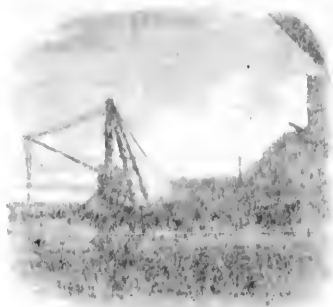


Plate No. 17) strengthened and prepared with standing piles. The whole of the steers were removed from the inside of the criss by beam nippers and hooks made for the purpose, but sometimes divers had to be employed. When the masts were removed, the cranes were used to remove the piles, and the piles were then removed by the cranes.

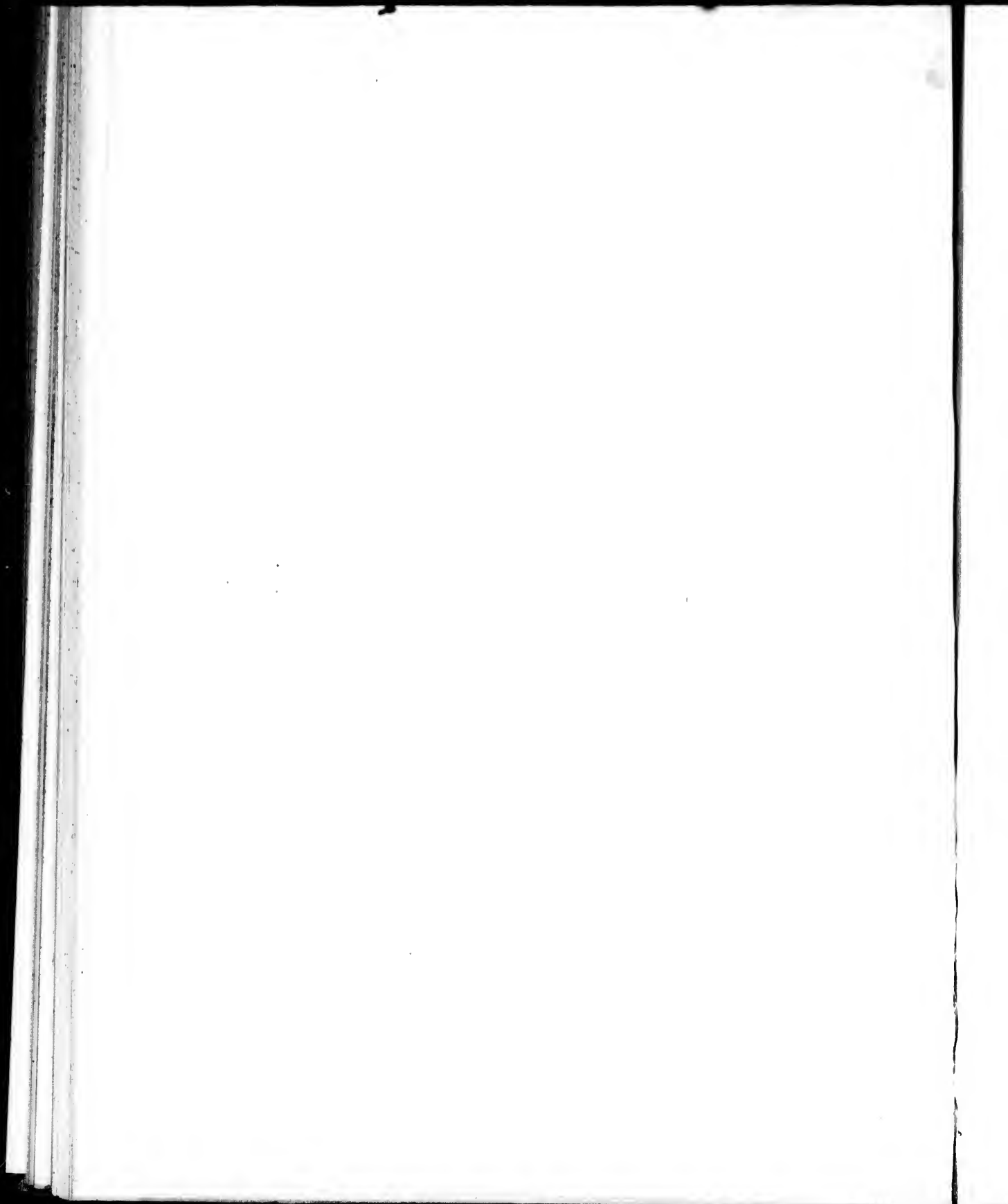
Occasionally the piles were cut by the cranes. A standing was also kept in the cranes to day to work of the cranes. No piles were removed by the cranes, they were removed by the cranes. Occasionally the piles were cut by the cranes, but they were not cut by the cranes, which is the only way of work, would get the cranes in a position to work on one occasion. In fact, the cranes assisted in the cranes of the cranes. No 10 cranes would have been destroyed, the cranes being cut by the cranes.

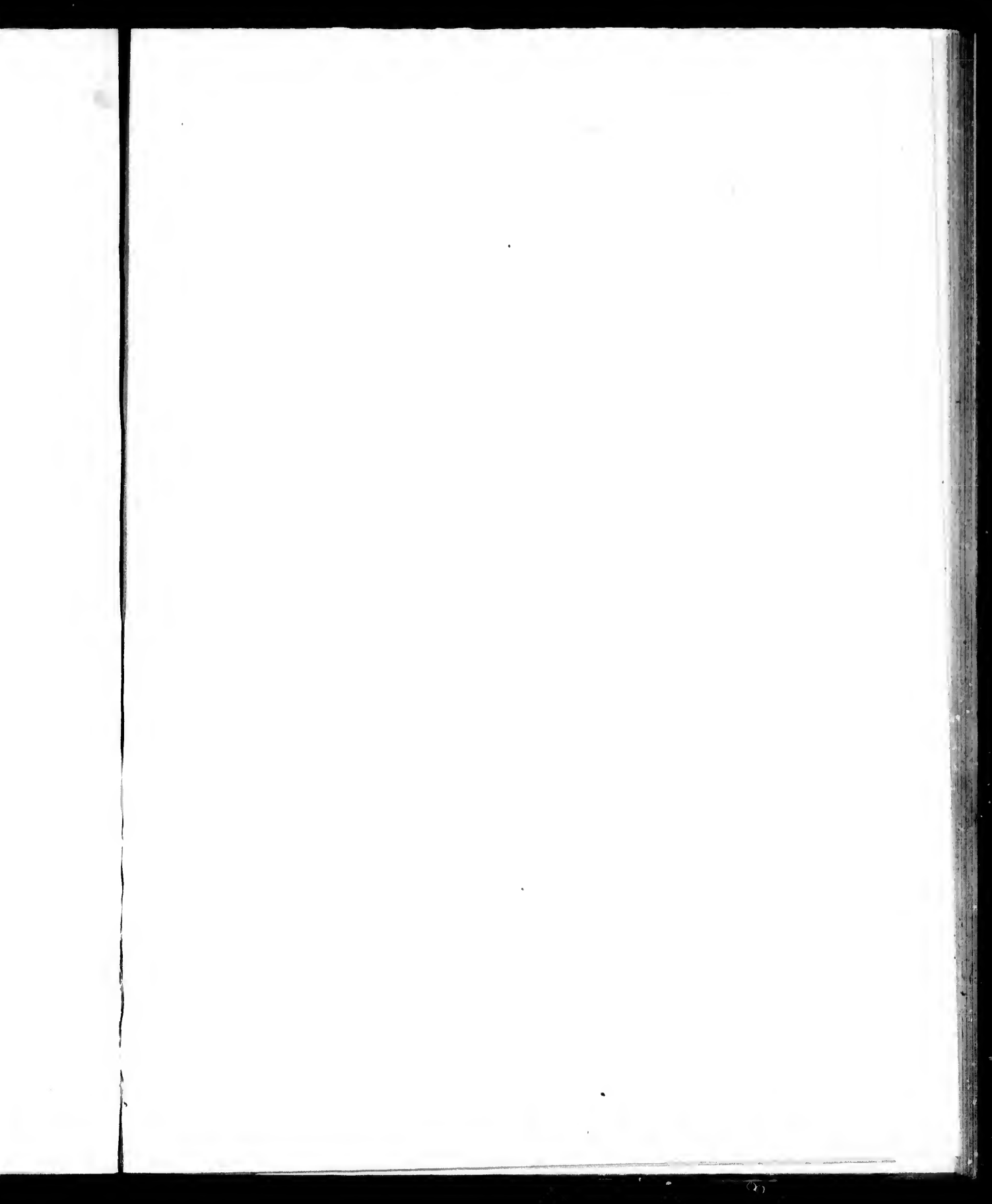
On the 9th of November, during the day, the cranes were destroyed by an accident. The cranes were destroyed by an accident, the cranes were destroyed by an accident, the cranes were destroyed by an accident.

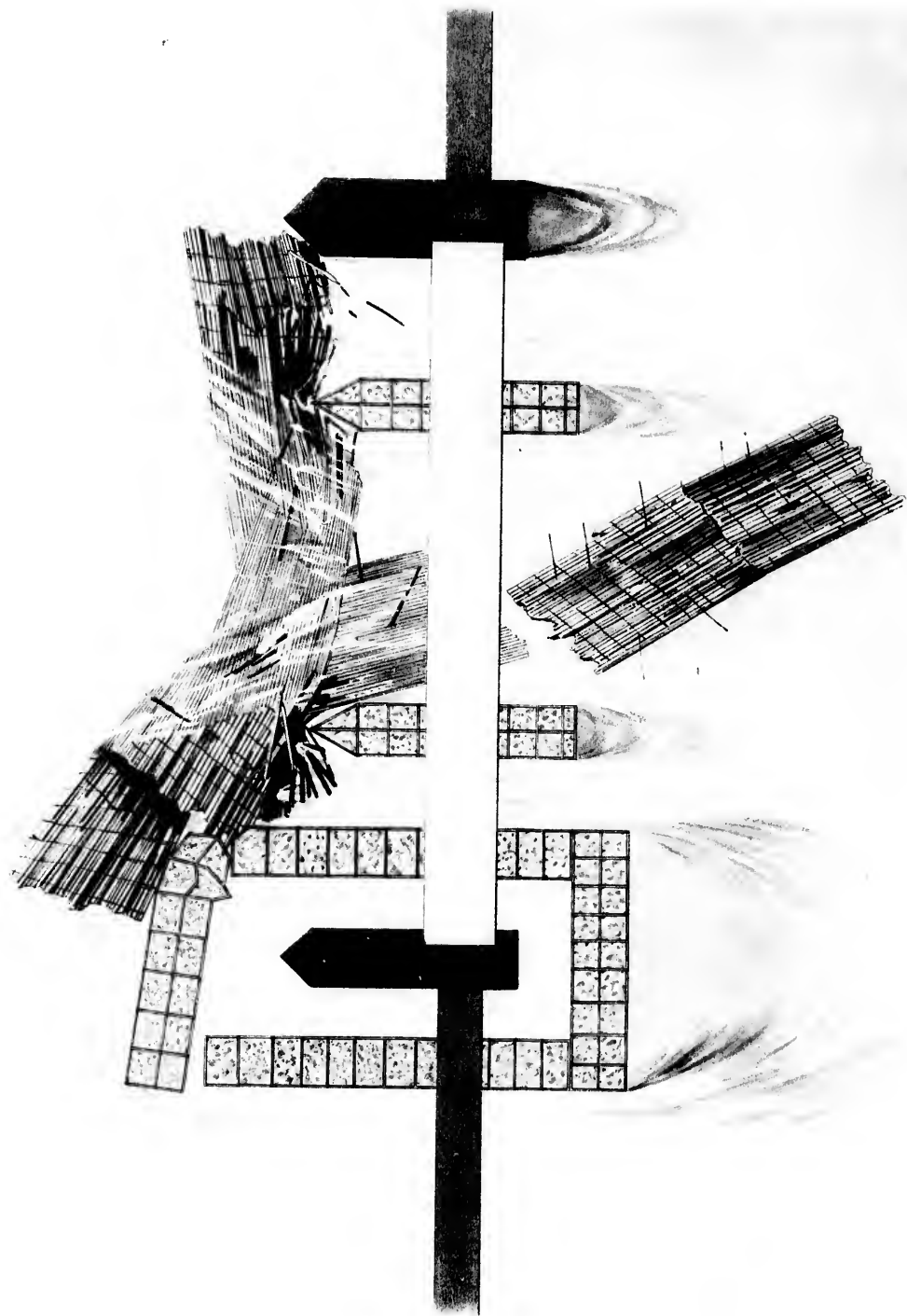
The cranes were destroyed by an accident, the cranes were destroyed by an accident, the cranes were destroyed by an accident, the cranes were destroyed by an accident.

The cranes were destroyed by an accident, the cranes were destroyed by an accident, the cranes were destroyed by an accident, the cranes were destroyed by an accident.









MISSISSIPPI VALLEY BRIDGE

The bridge... were nicely poised across the end of the... heavy purchases... When one started... the hearty cheers of our work... they might see the... deposits of the river. Beyond the...



At noon... No. 14... the bridge...

The bridge... No. 14... the bridge...

The bridge... No. 14... the bridge...

The bridge... No. 14... the bridge...



two feet lower. The scow and cribwork were so nicely poised across the end of the crib pier, that it remained there for several hours; and it was not till heavy purchases by means of blocks and falls were applied, that it could be moved. When once started, however, it was soon swept away by the torrent amidst the hearty cheers of our workmen, who for several hours had been in dread that at any minute they might see the staging toppling down, and the unfinished tube deposited in the river. Beyond the loss of a couple of days, very little mischief resulted from this accident. No lateral movement of the tube took place, and the cambre was readily adjusted as soon as the staging was repaired and strengthened.

An accident of a similar nature occurred at No. 14 staging, where some three or four rafts driven out of their course came against the temporary pier, and threatened to carry it away. Happily, however, these were also eventually got off without damage, and with only the loss of a few days' work.



These mishaps, so near the completion of the work, caused more anxiety than even more serious disasters at an earlier period. Perhaps this very anxiety begat increased energy and care; and as energy and care are of great value at such a time, it is not impossible that these casualties may have been of service to the work.

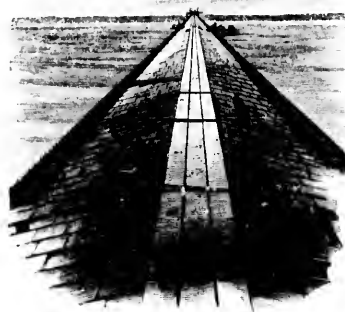
The removal of the dams was completed before the season closed, as was also the removal of the stagings for the tubes, and the cribs upon which they were erected, excepting those at Nos. 12 and 14.

At No. 12 the staging was cleared away, and the stone filling of the cribs taken out, so that the ice might clear that part away at the first shoving. At No. 14, however, there was not time to remove the superstructure of the staging, so the stone was cleared away from the cribs, and the staging left to its fate.

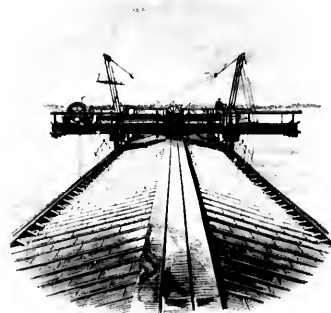
The 17th of December was the day appointed for the first passage of trains through the bridge. About an hour before the first train was timed to pass, a fearful crash was heard. We were all much frightened, but on running to discover the cause of the uproar, we found the staging drifting down the river with the ice, leaving the bridge perfectly clear of all its temporary works. The result of this accident was to

clear the river of every obstruction to the passage of the ice, excepting such as was caused by the masonry of the piers themselves. This circumstance, occurring just at the particular moment it did, added to the *éclat* of the day's proceedings.

During this season, the making up of the embanked approaches, the rip-rap stone work to protect the earth against the shoving of the ice, together with the erection of the abutment walls, and the coping to and pedestals at the end of embankment, were proceeded with and completed.



The roofing of the bridge was also put on. This roofing was of wood covered with tin, which was so laid as to allow the snow and water to run off from it. Upon the top of the ridge was a footway for workmen, two feet broad. Immediately over the sides of the tubes, rails were laid upon longitudinals of oak, bracketed up to allow for the passage of water under them. The rails were designed to carry a traveller bestriding the tube, to be used for painting, &c., and called the painting traveller. (See Plate No. 19.)



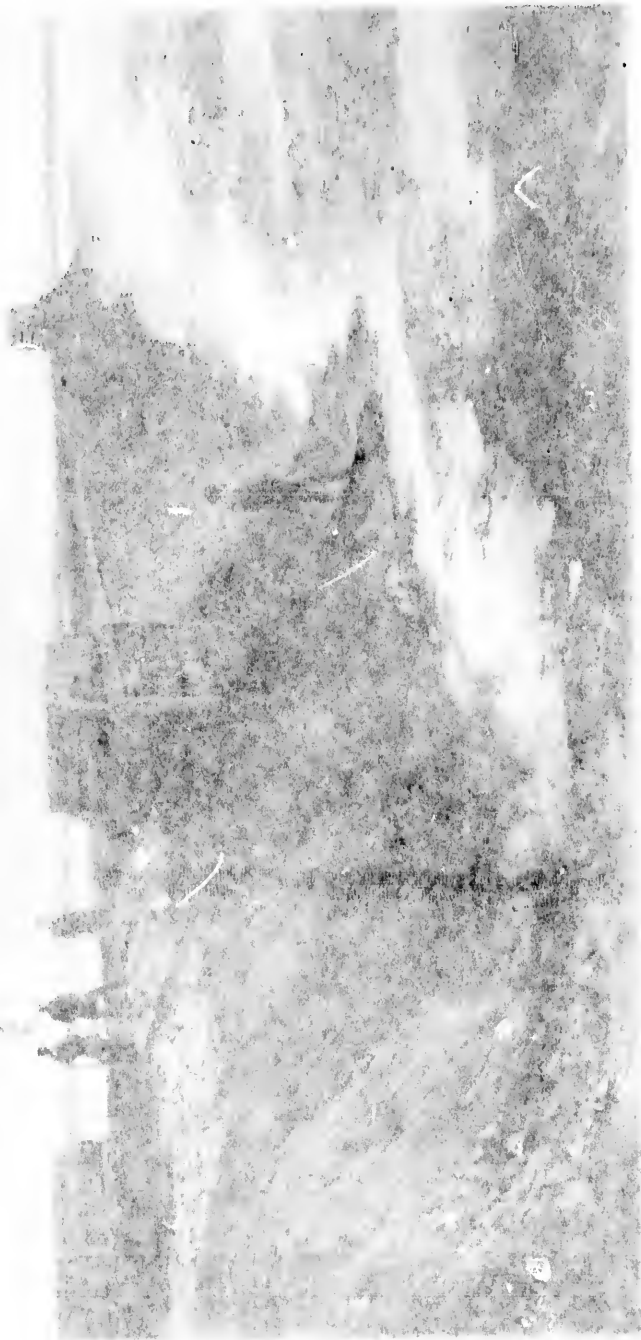
This traveller was made of iron, but as light as possible. It was so constructed that it could be moved to any part of the bridge, and from it any part of the outsides of the tubes could be inspected or painted. Two travellers were made, one for each side of the bridge. From the great facility they afford, the whole of the outside of the tubes can be painted in five weeks.

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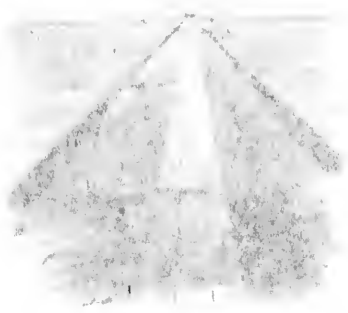
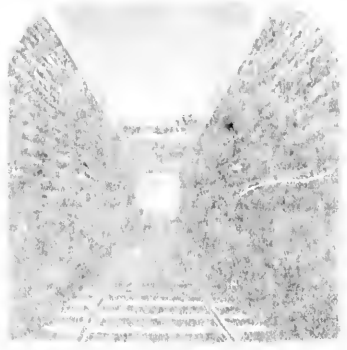
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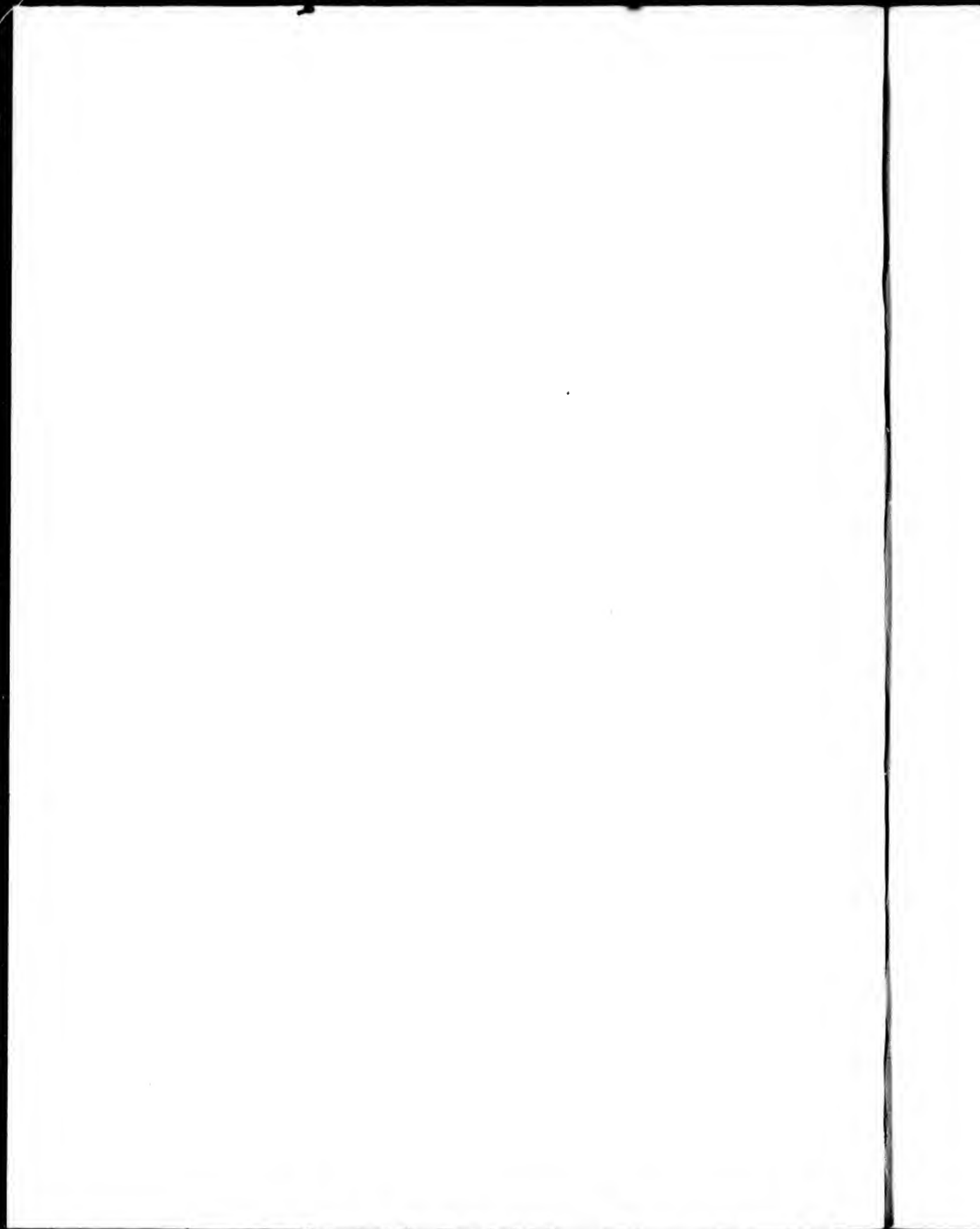
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When it is requisite to pass a pier with one of these machines, the bolts at the centre of the bottom, and which hold the sides together, are drawn. The bottom is then lowered, and by means of the purchase on the top, the sides are moved outwards till they clear the piers. The bottom is readily held or moved into any position by the endless screw working into a rack on the side framing, and by means of which the workmen raise or lower the side platforms at pleasure.

The permanent track through the tubes was also laid. The rails are of the U pattern, 63 lbs. to the yard, laid upon longitudinal timbers, 14 inches by 12, framed into one continuous beam, and well bolted at the joints. These beams are connected by transverse pieces of oak 14 feet apart.

Over the piers upon which the tubes are stationary, or where there are no expansion rollers, the longitudinal timbers are well bolted and keyed to the tubes, so that no creeping can possibly take place. At all other places the longitudinals are notched upon the keelson bars, and in the bolting of them down a space is allowed for expansion corresponding with the distance for the fixed piers.

This continuous beam of timber being, therefore, held in place and keyed to the tubes at all the points where no expansion takes place, is not affected by the movement of the tubes from variation of temperature.

The rails are fastened to the longitudinal timbers with dogs, and secured at the joints by chairs of rolled iron. The weight of the chair was 14 lbs.

The tubes are lighted from the sides, in which holes are cut at every 60 feet. The interior is so light, that on a clear day every rivet-head inside of the tube is distinctly visible. The machine used in cutting these holes is shown in Plate 20.



A footway, 4 feet wide, is laid on one side of the iron track.

CHAPTER XIII.

CONCLUSION.

SUCH were some of the labours and difficulties encountered in the construction of this enormous work. They were due to the character of the situation and foundation for the works ; to the rapidity and power of the current of the river ; to the difficulty of obtaining, and to the still greater difficulty of controlling, labour ; and, even beyond all this, to the shortness of the seasons, to the severity of the climate, and the limited period into which, latterly, the work was obliged to be compressed. Those who have had practical experience, in however limited a degree, of the effect of such difficulties, will be best able to estimate their importance, and appreciate the way in which they were surmounted. The writer will only say that, for his own part, he did his best, by the aid of those about him, to turn the difficulties of his position to account,—to render even the ice, the current, and the temperature subservient to purposes of convenience, expedition, and security in the progress of the works.

That his great task was successfully accomplished is, primarily, owing to the spirit and inspiration he derived from the confidence reposed in him by his employers. Looking back at all the various difficulties, practical and financial, by which this work was from time to time embarrassed, it scarcely admits of doubt that, in the hands of other and less energetic and persevering contractors than Messrs. Peto, Brassey, and Betts, it would not have seen the successful issue to which it has been brought. Amid every discouragement they stood stoutly to the task ; and when the hearts of all around them seemed about to fail, their encouragement, enterprise, and assuring confidence kept everything going. As Mr. Robert Stephenson enunciated, in the course of an address on the subject of the bridge at a dinner given to him in 1853 by the engineering profession of Canada, at Toronto, “ the contractors left even the engineers themselves little more than the poetry of engineering.”

Next to them, the writer feels in duty bound to record his most grateful acknowledgments and thanks to all his assistants and subordinates. It was not only that they zealously seconded his efforts : they did much more. The novel character of the work and its various vicissitudes afforded scope for the exercise of their ingenuity, and elicited

their talents. During the six years the works were in progress, the writer had constantly to acknowledge useful and valuable suggestions of a practical character from those by whom he was surrounded, and he is bound to record that the work is mainly indebted for its success to the aid he thus received.

Nor must the writer omit to say how much is due to the devotion and energy of large numbers of his workmen. Once brought into proper discipline, they worked as British workmen alone can work. They leave behind them in Canada an imperishable record of British skill, science, and perseverance, in the bridge which they assisted to construct. The writer cannot omit to record an anecdote, which will show that, in another form, they have left behind them, he hopes, an equally imperishable record of their humanity, charity, and good feeling.

Before steam was employed for the emigrant traffic between Great Britain and America, the vessels that were sometimes used for that purpose were of the most wretched character—ill-provided, without proper accommodation for a long passage, and entirely without means for ventilation. In these miserable tubs hundreds of poor creatures were crowded, almost to suffocation, below deck. After enduring sometimes twelve or fifteen weeks of suffering and sickness, those who survived the long voyage emerged into daylight, and were put on shore at Quebec or Montreal, with the seeds of pestilence implanted in them in the shape of a ship-fever. In hot, unhealthy seasons, such as engender or favour the prevalence of cholera, this pestilence was a fearful scourge to the city of Montreal, and indeed to the whole of Canada, where hundreds of these poor wretches were landed without home or place of shelter, many of them in the very last stages of this most dreadful plague.

The years 1846 and 1847 were perhaps the most fatal that Montreal ever experienced. Many hundreds of the inhabitants of the city died from this contagious disease. It was ultimately found necessary to establish a quarantine, and to erect buildings away from the city, for the accommodation of emigrants. These "Emigrant Sheds," as they are now called, were built at Point Charles, near the northern end of the Victoria Bridge.

During these two years (1846 and 1847) some 6000 poor emigrants died in these emigrant sheds, and were interred in a large pit or grave common to the whole, in much the same manner as those are described to have been buried who died of the plague which devastated London.

To the honour of the inhabitants of Montreal it should be recorded that

numberless instances are related of the devotion with which the inhabitants, and especially the Sisters of Charity, attended these poor creatures. Many, very many, died while thus so nobly comforting and attending them, and amongst the number some of the most opulent persons in Montreal.

The burial place above-mentioned was near to our Bridge approach. A small mound and a cross only marked the sacred spot; yet this was sufficient, throughout the whole of our work, to preserve this spot sacred, and the ground was never broken.

Towards the close of the work, when the workmen were thinking of leaving Canada, the remains of their poor countrymen were not forgotten. A wish was

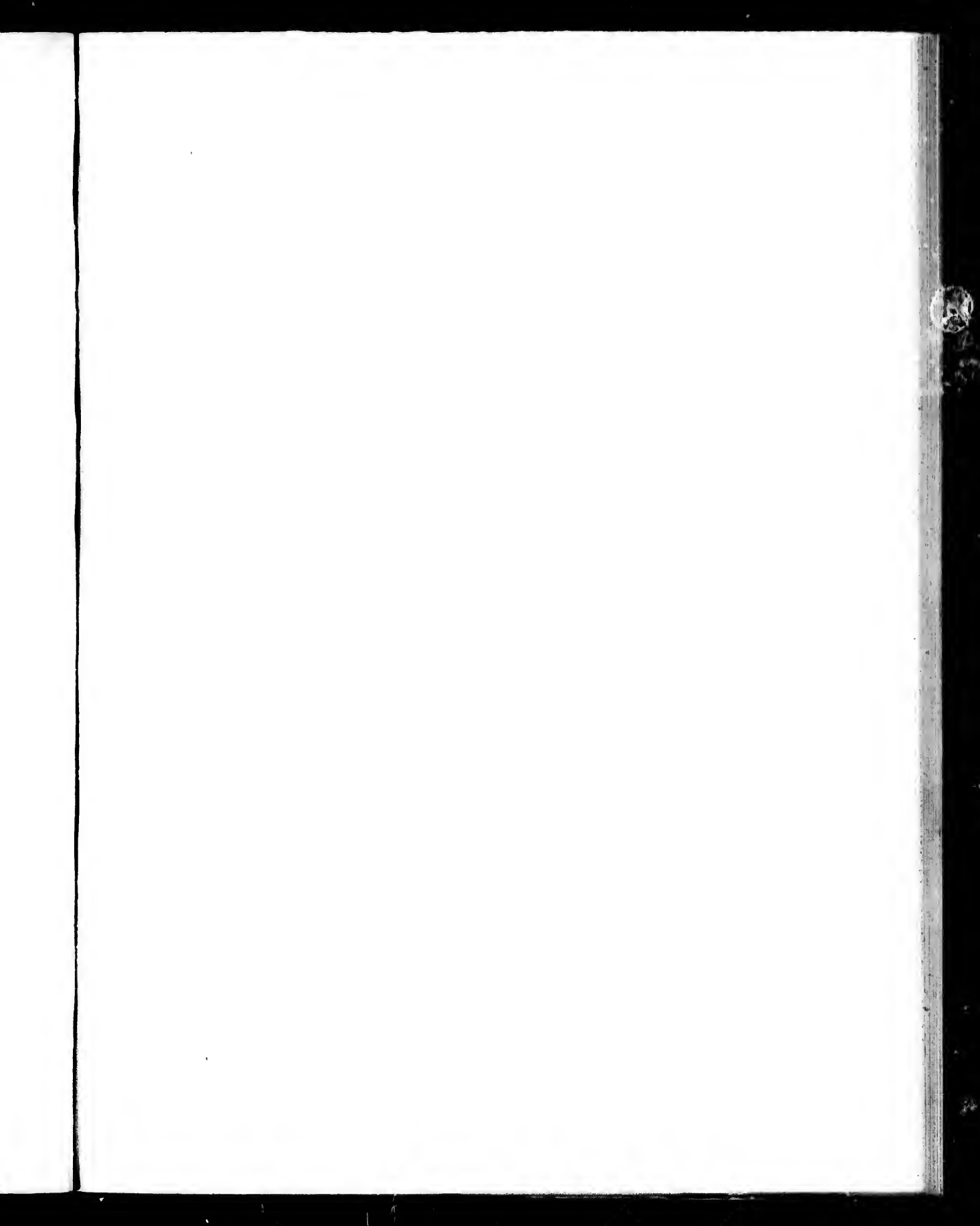
expressed that the spot should be fenced in. Not only did they undertake to do this themselves, but they determined to erect a monument upon the spot. A large granite boulder, weighing some thirty tons, was selected, which was placed upon a pedestal some six feet high, and which it may be hoped will to future generations preserve the remains of the dead from desecration.



On the 1st of December, 1859, the Rev. Canon Leach (who during the pestilence, to the infinite credit of our Church, did his duty as faithfully as the kind Sisters of Charity did theirs), in the presence of the Bishop of Montreal, the Rev. Mr. Ellgood, and the assembled workmen, set the stone in its place. The following inscription was cut upon it.

TO PRESERVE FROM DESECRATION
THE REMAINS OF 6000 EMIGRANTS WHO DIED OF SHIP FEVER IN 1816 AND 1817,
THIS STONE IS ERECTED
BY THE WORKMEN OF MESSRS. PETO, BRASSEY, AND BETTS, ENGAGED IN
THE ERECTION OF THE VICTORIA BRIDGE.
1859.

Having spoken of the devotion of the Sisters of Charity during the ship fever, the writer may perhaps be allowed to mention the kind attention that the workmen received from them during the time any of them were in St. Patrick's Hospital, where two wards, with twenty-five beds, were provided for cases of casualty.





THE 1914-15 SEASON

The total amount of work done during the season was 1,175,000 man-hours. Twenty-six thousand tons were lost by drawing. Nearly every man on the bridge was a good swimmer and it seldom occurred that any part of the overhead and spars were actually raised to the point that they were being pulled over his own head.

In the work done across the bridge, the work done was 1,175,000 man-hours. It is estimated that the work done was 1,175,000 man-hours.

THE 1914-15 SEASON

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The total number of lives lost during the six years the work was in progress was twenty-six. Most of these were lost by drowning. Nearly every man on the bridge was a good swimmer; but it seldom occurred that any man who fell overboard, and was drawn into the eddy caused by the torrent that was rushing past, was ever saved, even though life-buoys and boats were in readiness at every point.

In all work carried out by Messrs. Peto, Brassey, and Betts, ample medical attendance is uniformly provided for those who receive injury or are sick. Our medical staff for the Victoria Bridge consisted of—

Dr. Macdonell, Principal Surgeon, St. Patrick's Hospital.

Dr. David.

Dr. Robillard.

Dr. Godfrey.

Dr. Howard, Oculist for Snow Blindness.

To the whole of these gentlemen the thanks of all connected with the work are due, for the attention and humanity they uniformly displayed, and for their zealous devotion to their duties.

The cost of this staff exceeded £1000 annually. The writer would scarcely mention this, but for the fact that, during the early part of the work, the attention paid to the welfare of the workmen was not duly appreciated at Montreal. The reflections, however, which were cast upon those who conducted the works were more than compensated for by the favourable opinion expressed by the Bishop of Montreal, and which, in order completely to dispel all imputations on this score, the writer must be permitted to quote. At the entertainment given at the completion of the work in 1859, his Lordship said—

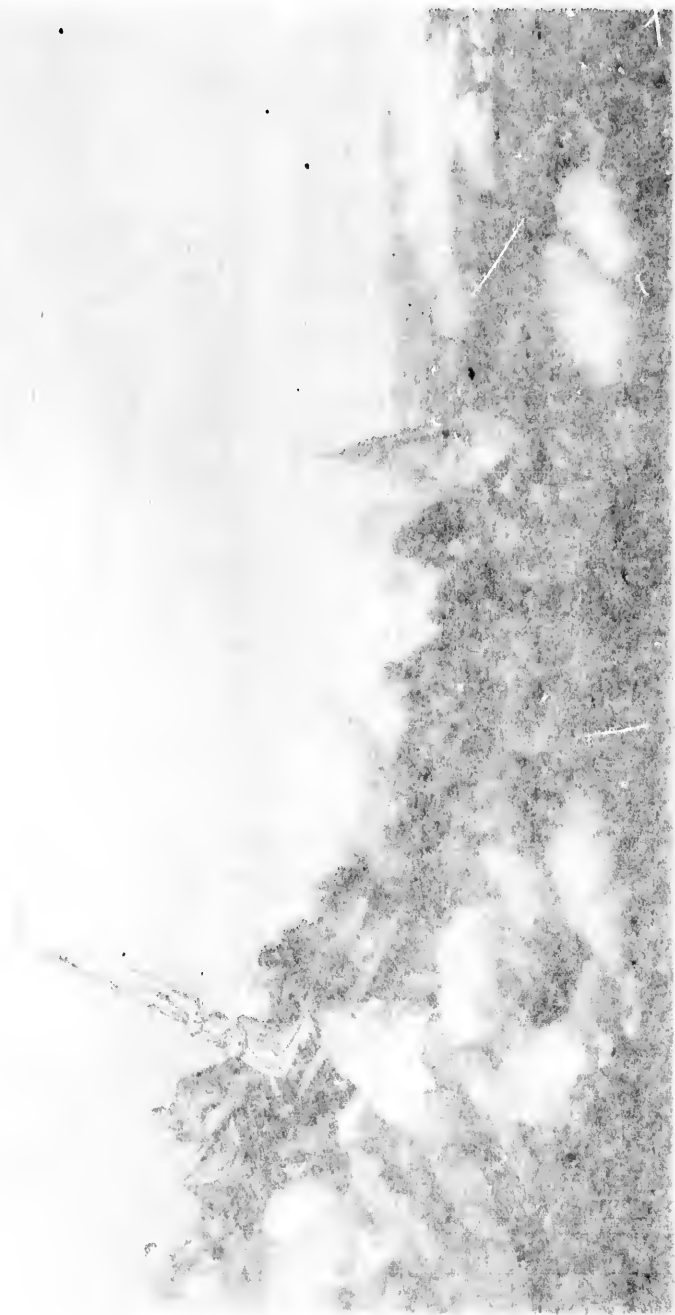
“He was there because he wished to pay the tribute of his personal respect to Mr. Hodges, to testify his high sense of that gentleman's integrity and of the Christian principle with which he had provided for the education and spiritual supervision of all the people connected with the work. He looked on this gentleman's example as one which all employers should follow. They had no right to congregate large bodies of people without making provision for their spiritual wants. Mr. Hodges, with the approbation of his principals, had acted so as to secure this great blessing for the people employed by him, and the integrity of character, high moral principles, and Christian philanthropy which had actuated Mr. Hodges, would remain on perpetual record.”

With regard to the provision made for the workmen, it should be mentioned that they were provided with a comfortable range of dwellings close to their work. A portion of the range was fitted up as a chapel and school-room. It was used for Divine

Service every Sunday, the Rev. Mr. Elligood officiating as our chaplain, and being occasionally relieved by the Bishop of Montreal himself, while at Point Chair the Rev. Mr. Flanigan officiated as chaplain. On the week days, the building was used as a school-room for the children, and as a library for the workmen. There were sometimes as many as eighty children at the school, and we provided the library with as many as 1000 volumes of books.

Before the completion of the Victoria Bridge, the crossing of the St. Lawrence, during the time the ice bridge was forming and breaking up, was a most perilous proceeding, and one which few would attempt except from absolute necessity. The passengers were compelled to seat themselves or to lay down in the very bottom of the canoe. The canoe was manned by some ten or twelve Canadians, who, after watching for a favourable opportunity, when there appeared to be a larger space of open water than usual between the fields of ice, launched the frail boat into the troubled sea of ice and water, and paddled it through the circuitous and intricate channel, amidst thousands of floating islands. Thus they continued their journey towards the opposite shore until their progress was entirely prevented by the icy barrier, or probably by the meeting of two of the floating ice islands, between which they had been threading their course. Then the canoe was obliged to be lifted altogether out of the water, and every man jumped upon the ice, and helped to carry the boat over its uneven surface. Guided by one of their number, who having attained some temporary eminence upon the blocks of ice, directed them to the nearest open water, they again launched their canoe and paddled onwards. Sometimes a great portion of the distance had to be passed through small detached pieces of ice, not sufficiently large to carry them upon its surface, in which case the passengers had to keep rocking the canoe to prevent it from becoming frozen amidst these masses, while the boatmen, poised upon the gunwale of the boat, with their feet outwards, took advantage of any piece of ice sufficiently large to carry them. A crossing of this sort, when attempted under unfavourable circumstances (as was frequently the case, for the purpose of carrying over the mail bags, &c.), occupied several hours, and was fraught with such danger that instances have been known where death has ensued simply from fright. Of course the landing was made at any point where the shore could be reached; and sometimes it was miles beyond the point from which they started. The canoes used were those made from the solid tree called Dug-outs.

It only remains for the writer to give some few details respecting the form and dimensions of the tubes, &c., which may assist in explaining the Tables which will be found in the Appendix. He will first mention that the beams of the Victoria Bridge are 16 feet wide; they are 18 ft. 6 in. high at the abutments, increased to 22 feet in the

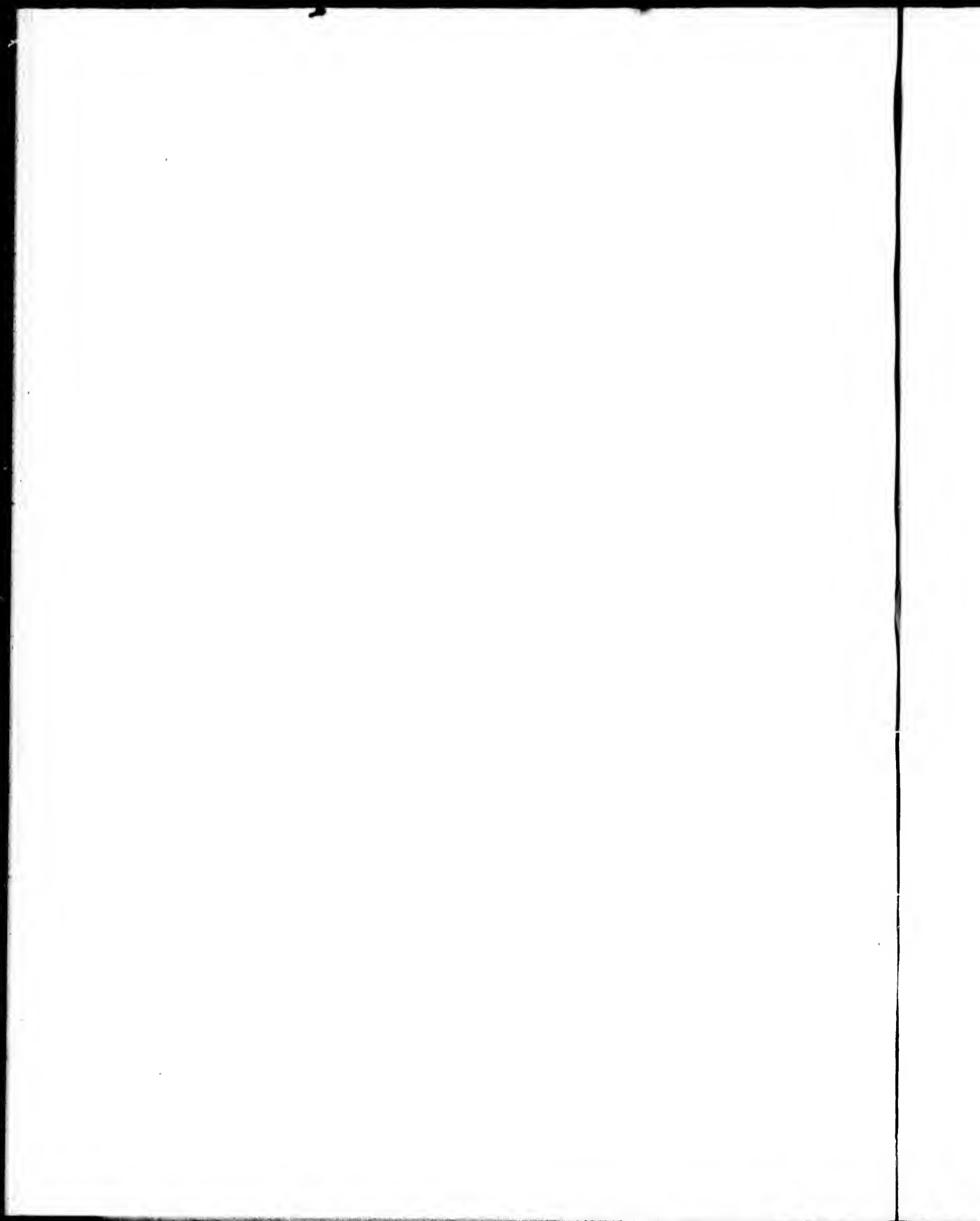


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centre, and constructed of iron plates on the tubular principle, the same as those at the celebrated Britannia Bridge over the Menai Straits, except that there are no cells either at top or bottom.

The spans are 25 in number, viz., 24 of 242 to 247 feet, while the centre span for the navigation is 330 feet.

The height above the water at centre is 60 feet.

The height above the water at abutments is 36 feet ; giving an incline of 1 in 130, or about 2 feet for every opening.

The piers, 24 in number, are of solid masonry, composed of heavy stones, weighing from 5 to 20 tons each. The sloping stones forming the ice-breakers are bound together with iron cramps. Their dimensions at summer water level are, for 22 of them, 90 + 18 feet, while at tube level they are 33 + 16 feet. The centre piers are of greater thickness, being 28 feet at summer water level, and 24 feet at tube level.

The abutments, 240 + 90 feet, are of masonry of similar description ; while the massive embanked approaches are protected on face by 5 to 8 feet of stone work, sloped to meet the shoving of the ice.

In building the tubes, the greatest increase of cambre which occurred in one day, consequent upon the difference of temperature between bottom and top of tubes, was 1½ inch.

The thermometer in the sun on the top reading	124°
„ „ „ in shade at bottom	90°
	—
Making a difference of	34°

The thermometer during the previous night was so low as 57°. It is therefore only fair to infer that as the bottom was in shade, it would not be of the same temperature as the atmosphere, and that this increase of cambre of 1½ inch, was due to a difference of temperature of probably as much as 50° Fahrenheit.

The greatest expansion of a single tube from the centre of the resting pier to the extremity of the roller end, say 258 feet, with a variation of temperature of — 27° to + 128°, or equal to 155° Fahrenheit, was 3¾ inches. This was ascertained by an index, locked up for twelve months.

The greatest lateral movement caused by difference of temperature in sides of tubes was 1½ inch.

It has been already explained that when the bottom of a tube was fairly riveted together and completed, the engineer in charge of the work gave level marks at every 20 feet distances, showing the exact cambré to which the bottom was adjusted. These level or bench marks were adjusted daily, and the workman made his work as it progressed correspond as nearly as possible with them. Nevertheless, it frequently happened with all his care that, if the staging subsided, the work, when it was completed and ready for launching, would not show precisely the same cambré as that first laid down. This variation is shown in the second column of Table No. 1, while the third column shows the difference, which is called "subsidence during construction." The fourth column shows the position of the underside of the tube immediately after the wedges were struck, and it was left unsupported; while the fifth shows the position some few days before the final testing of the tubes on the 1st of December, 1859, after the roof and permanent way were laid. The last column was not so accurately ascertained as the others, or rather as the levels could not be taken immediately upon the same places as those by which the work was constructed, it is probable there may be in some instances a variation of probably $\frac{1}{4}$ th of an inch from what they might have been if taken upon the original marks. They are, however, very near the truth; and if they do nothing more than show the accuracy with which the work was done, the writer has the greater pleasure in giving publicity to this Table, as a tribute of praise to those assistants who had the entire charge of these levels, and of the setting out of the whole of the work, in addition to the onerous duties of superintending the work itself.

In tubes Nos. 11, 12, 14, and 15, the permanent way was laid, or rather the materials for it were in place, before the wedges were struck, which will to some extent explain why there was not so much of subsequent subsidence or deflection as with the others. It should also be mentioned that, at the time of striking the wedges, some of the tubes were more heavily burdened with spare materials, both on the top and inside, than others. This was unavoidable, and may explain why the deflection or subsidence, from the time of striking the wedges to the time of testing, was greater in some than in others. Although this may appear to detract from the extreme accuracy which would have given greater value to these observations, yet they are such as will be understood by practical men.

The mode of testing the tubes was very simple. A piece of steel wire, about as large as common wire, of No. 16 gauge, and which by experiment was ascertained would bear a weight of 380 lbs. without breaking, was strained along the side of each tube. One end was fastened to a bracket at one extremity, while the wire passing over a grooved wheel attached to the other end of the tube, was kept in a state of tension by means of a weight of over 300 lbs., and which, although sufficient to keep the

250 feet of wire nearly straight, and almost as tight as a fiddle string, was not sufficient to break it.

This weight always acted freely upon the wire irrespective of any movement or deflection caused by the passing of a train, the versed sine of the natural curve being always the same. The wire in this state was used as a datum from which the deflection caused by the passing of a train was measured.

Wires such as these described were strained throughout the whole of the tubes ; and at intervals of 60 feet, strips of cardboard were so placed and attached to the tube that the wire just played upon without actually touching them.

These arrangements being completed, and a mark made upon the cardboard to correspond with the position of the wire when the tubes were not loaded, similar marks were made when the load was in the different positions shown in the diagram. The actual deflection was thus very readily ascertained.

In the spring of 1858, Mr. Stockman, who had been employed under Mr. George Robert Stephenson in making the working drawings for the whole of the tubes and girders used in the construction of nearly 1000 miles of the Grand Trunk Railway, was sent to Canada by Mr. Robert Stephenson, for the purpose of inspecting the tubes and ascertaining whether any defects, either in design or workmanship, could be discovered in any of the works, so that in making designs for future works, advantage might be taken of the experience that was thus to be obtained. During his visit, the tubes of the Victoria Bridge which were completed were fully tested. For result see diagram. Mr. Stockman reported the workmanship and material of the tubes to be unexceptionable.



Again, in December, 1859, just before the Victoria Bridge was opened, Mr. Bruce, an engineer of great experience, and who had for many years enjoyed Mr. Robert Stephenson's confidence, visited Canada, accompanied by Mr. Stockman, and witnessed the final testing of the whole of the tubes. The result is given, Plate 25. This latter visit was in accordance with a wish expressed by the late Mr. Robert Stephenson a short time before his death.

The bridge was first opened for the passage of trains on the 19th of December, 1859. The formal inauguration by his Royal Highness the Prince of Wales, who visits Canada for the purpose, is appointed for the 25th of August, 1860, when, under God's blessing, this work, of such great social and international importance, will be duly dedicated to the great purposes for which it is designed.

The following are the inscriptions at the entrance of the Bridge :—

[ON THE OUTER LINTEL.]

ERECTED A.D. MDCCCLIX.

ROBERT STEPHENSON AND ALEX. M. ROSS,
ENGINEERS.

[ON THE INTERIOR LINTEL.]

BUILT

BY

JAMES HODGES,

FOR

SIR S. MORTON PETO, BART., THOMAS BRASSEY,
AND
EDWARD LADD BETTS,
CONTRACTORS.

DATES.

First part of north abutment collar-dam towed into place 24th May, 1854.	First stone of bridge laid 20th July, 1854.
	First train passed over the bridge 17th December, 1859.

DIMENSIONS, WEIGHTS, &c.

Total length of tubes, 6592 feet.	Number of spans, 25; twenty-four from 242 to 247 feet each; one, 330 feet.
Total length of bridge, 9144 feet.	Quantity of masonry in piers and abutments, 2,743,095 cubic feet.
Height of bottom of centre tube above surface of water, 60 feet.	Greatest depth of water, 22 feet.
Height of bottom of tubes at abutment, 36 feet.	Average rate of current, seven miles an hour.
Rise of tubes to centre, 1 in 130.	Quantity of timber in temporary works, 2,280,000 cubic feet.
Weight of iron in tubes, 9044 tons.	Quantity of clay puddle used in dams, 146,000 cubic yards.
Number of rivets in tubes, 1,510,000.	
Painting—number of coats, 4; number of acres in each coat, 32. Total acres, 128.	
Number of piers, 24.	

FORCE EMPLOYED IN CONSTRUCTION.

Number of steam-boats, 6.	Number of men employed, 3040.
Number of barges, 75.	Number of horses, 144.
Tonnage of ditto, 12,000.	Locomotive engines, 4.
Power of steamers, 150 H.P.	

APPENDIX.

TABLE I.

STATEMENT SHOWING LENGTHS OF TUBES, THEIR WEIGHTS, AND THE NUMBER OF DAYS OCCUPIED IN ERECTION.

No. of Spans.	Date of Commencement.	Date of Completion.	Number of days occupied in erection.	Length of tubes between bearings.	Weight of one Tube.		Weight of one Pair of Tubes.	Weight of Brackets, Roller Plates, Rollers, &c.	Weight of Roof, Permanent Ways, Footpaths, &c.		Total Weight.
					Tons.	cwt. qrs. lbs.			Tons.	cwt. qrs. lbs.	
1	12th August, 1857	3rd November, 1857	6	214 0	296 14 0	7	588 12 0	33 12 3 14	57 16 2 16	689 1 2 13	
2	24th June, 1858	29th August, 1858	74	241 3	301 18 0	4	588 12 0	33 12 3 14	57 16 2 16	678 8 3 14	
3	19th August, 1858	5th November, 1858	75	241 3	301 1 0	5	587 3 3 12	33 12 3 14	58 3 1 16	685 6 0 12	
4	6th September, 1858	2nd December, 1858	58	243 11	301 11 3	12	590 2 3 3	33 12 3 14	58 7 3 16	700 18 0 36	
5	27th September, 1858	10th December, 1858	50	243 4	301 17 3	26	608 17 1 24	33 12 3 14	58 3 2 16	708 9 1 17	
6	13th October, 1858	28th March, 1859	64	242 11	289 13 2	6	613 5 3 24	35 19 3 5	56 10 0 2	771 11 3 27	
7	12th January, 1859	23rd June, 1859	70	243 2	300 9 0	25	613 1 0 18	35 19 3 5	50 5 3 16	708 6 3 11	
8	2nd April, 1859	8th September, 1859	39	243 6	297 5 2	19	609 13 3 10	33 12 3 14	58 10 0 16	701 16 3 12	
9	25th July, 1859	3rd October, 1859	46	245 10	311 11 3	5	501 3 2 3	33 12 3 14	58 1 0 16	686 6 3 11	
10	10th August, 1859	7th November, 1859	46	245 3	311 7 0	12	504 9 3 9	33 12 3 14	57 18 3 16	682 15 1 5	
11	14th October, 1859	30th November, 1859	45	247 3	301 18 3	12	504 9 3 9	33 12 3 14	58 1 0 16	686 6 3 11	
12	8th November, 1859	26th March, 1860	47	239 0	286 4 0	11	584 12 1 23	33 12 3 14	57 16 2 16	676 1 3 25	
13	31st January, 1860	26th October, 1860	44	247 5	293 4 2	12	500 3 2 7	33 12 3 14	57 12 0 16	681 8 2 9	
14	21st October, 1859	12th December, 1859	50	245 11	309 16 2	6	783 1 2 25	437 4 0 24	754 19 2 26	3043 6 1 19	
15	29th September, 1859	29th November, 1859	59	245 6	300 2 3	26					
16	3rd October, 1859	29th October, 1859	48	245 1	309 10 3	12					
17	17th August, 1859	8th October, 1859	45	241 7	292 3 3	26					
18	13th July, 1859	2nd September, 1859	44	240 8	288 19 2	5					
19	14th January, 1859	15th March, 1859	51	243 5	290 5 2	15					
20	25th October, 1858	16th December, 1858	46	243 0	304 4 0	22					
21	21st September, 1858	12th December, 1858	71	243 4	294 1 2	22					
22	19th August, 1858	12th November, 1858	78	242 5	290 10 3	1					
23	24th July, 1858	16th October, 1858	63	242 0	292 11 3	19					
24	2nd July, 1858	17th September, 1858	66	242 0	297 11 2	16					
25	21st December, 1857	31st March, 1858	84	242 0	297 11 2	16					

The tubes being in pairs, with the bottom plates continuous throughout, it was necessary that the tube in each pair first shipped should have with it that portion of its fellow as was sufficient to extend the bottom past the resting-per. Hence the difference in the weights, which are taken from the invoice of shipment.

TABLE II.
STATEMENT SHOWING CAMBRES TO WHICH TUBES WERE LAID, SUBSIDENCE DURING CONSTRUCTION, DEFLECTION
OF TUBES, &c.

No. of Tube.	Cambrer of bottom when laid.	Subsidence during construction.	Cambrer before wedges were struck.	Deflection due to weight of tube.	Cambrer retained after wedges were struck.	Cambrer, 10th December before testing, but permanent way laid and not on.	REMARKS.
1	3 inches.	13 inches.	14 inches.	21 inches.	- 1 inch.	- 14 inches.	Built separately, and allowed to take its bearing. Connected at top and sides only before wedges were struck.
2	5 1/2 "	11 1/2 "	3 3/4 "	2 1/2 "	+ 1 1/2 "	+ 1 1/2 "	These tubes were connected upon resting pier before striking the wedges.
3	4 1/2 "	0 "	4 "	1 1/2 "	+ 2 1/2 "	+ 1 1/2 "	These tubes were connected upon resting pier before striking the wedges.
4	4 1/2 "	0 "	4 1/2 "	2 1/2 "	+ 2 "	+ 1 1/2 "	These tubes were built separately and allowed to take their bearing, and joined after.
5	4 1/2 "	0 "	4 1/2 "	2 1/2 "	+ 2 "	+ 1 1/2 "	Ditto
6	4 1/2 "	1 1/2 "	3 "	2 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
7	4 1/2 "	1 1/2 "	3 1/2 "	2 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
8	4 1/2 "	1 1/2 "	3 1/2 "	2 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
9	4 1/2 "	2 1/4 "	2 1/4 "	2 1/4 "	+ 3 "	+ 1 1/2 "	Ditto
10	4 1/2 "	1 1/2 "	3 1/2 "	3 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
11	4 1/2 "	1 1/2 "	3 1/2 "	3 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
12	4 1/2 "	2 "	2 1/2 "	3 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
13	6 "	1 1/2 "	4 1/2 "	2 1/2 "	- 3 "	- 4 "	Ditto
14	4 1/2 "	2 1/4 "	2 1/4 "	2 1/4 "	+ 1 1/2 "	+ 1 1/2 "	Ditto
15	4 1/2 "	2 1/4 "	2 1/4 "	3 1/2 "	+ 1 1/2 "	+ 1 1/2 "	Ditto
16	4 1/2 "	0 "	2 1/2 "	3 1/2 "	+ 1 1/2 "	+ 1 1/2 "	Ditto
17	4 1/2 "	0 "	4 1/2 "	1 1/2 "	+ 0 "	+ 3 "	Ditto
18	4 1/2 "	1 1/2 "	1 1/2 "	1 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
19	4 1/2 "	3 1/2 "	3 1/2 "	3 1/2 "	+ 1 1/2 "	+ 1 1/2 "	Ditto
20	4 1/2 "	2 "	3 1/2 "	2 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
21	4 1/2 "	0 "	4 1/2 "	3 1/2 "	+ 3 "	+ 1 1/2 "	Ditto
22	4 1/2 "	0 "	4 1/2 "	2 1/2 "	+ 2 1/2 "	+ 2 1/2 "	Ditto
23	4 1/2 "	1 1/2 "	4 1/2 "	2 1/2 "	+ 2 1/2 "	+ 2 1/2 "	Ditto
24	4 1/2 "	1 1/2 "	3 1/2 "	2 1/2 "	+ 2 1/2 "	+ 2 1/2 "	Ditto
25	6 "	2 1/2 "	5 1/2 "	3 1/2 "	+ 1 1/2 "	+ 2 1/2 "	Ditto

Control span.

These tubes were connected on resting piers, but before the wedges were struck, sufficient rivets were put in to take their bearing, and were reconnected ten days afterwards.

These tubes were connected before striking the wedges.

Built separately, but connected to No. 25 before wedges were struck.

Both separately and allowed to take its bearing.

III.

LETTER OF ROBERT STEPHENSON, ESQ., M.P., TO THE DIRECTORS OF THE GRAND TRUNK RAILWAY, ON THE DESIGN FOR THE VICTORIA BRIDGE.

To the Chairman and Directors of the Grand Trunk Railway of Canada Company.

GENTLEMEN,

Having learnt that some doubts have been expressed respecting the fitness of the design for the Victoria Bridge across the St. Lawrence at Montreal,—that it is more costly than necessary, and that other systems of structure less expensive, yet equally efficient, might with propriety be adopted,—I feel called upon to lay before you in some detail, the considerations which influenced me in recommending the adoption of the design which is now being carried out. In doing so I beg to assure you that the subject was approached in the outset, both by Mr. Alexander Ross, your engineer in Canada, and myself, with a thorough consciousness of the enormous expense which must inevitably be involved, whatever description of structure might be adopted, also of the large proportion which this cost must bear to the entire outlay of the undertaking of the Grand Trunk Railway of Canada. We were, therefore, fully alive to the imperative necessity of studying the utmost economy in every part of the work, consistent with our notions of efficiency and permanency.

It will be my endeavour, in the following remarks, to satisfy you and those interested in the undertaking that these objects have been steadfastly kept in view.

It would evidently be unreasonable to expect that amongst professional men an absolute identity of opinion should exist, either in reference to the general design or in many of the details of a work, intended to meet such unusually formidable natural difficulties, as are to be contended with in the construction of a bridge across the St. Lawrence.

You will remember, that at the time I first entered upon the consideration of the subject, these difficulties were deemed by many well acquainted with the locality, and publicly stated by them, to be, if not insurmountable, at all events of so serious a character as to render the undertaking a very precarious one.

The information I received respecting these obstacles, when my attention was first drawn to this project, was so striking, that I reserved forming an opinion until I had visited the spot, had well considered all the detailed information which Mr. Alexander Ross had collected during several months' previous residence in the country, and had heard the opinion of many intelligent residents regarding the forces exhibited by the movements of the huge masses of ice during the opening of the river in spring.

The facts gathered from these sources fully convinced me, that although the undertaking was

practicable, the forces brought into action by the floating ice as described were of a formidable nature, and could only be effectively counteracted by a structure of a most solid and massive kind.

All the information which has been collected since I made my first report, has only tended to confirm the impressions by which I was then guided.

For the sake of clearness and simplicity, the consideration of the design may be divided into four parts: *first*, the approaches; *secondly*, the foundations; *thirdly*, the upper masonry; and *fourthly*, the superstructure or roadway.

The approaches, extending in length to 700 feet on the south or St. Lambert side, and 1300 feet on the Point St. Charles side, consist of solid embankments, formed of large masses of stone heaped up and faced on the sloping sides with rubble masonry. The up-stream side of these embankments is formed into a hollow shelving slope, the upper portion of which is a circular curve of sixty feet radius, and the lower portion or foot of the slope has a straight incline of three to one, while the down-stream side, which is not exposed to the direct action of the floating ice, has a slope of one to one. These embankments are being constructed in a very solid and durable manner, and from their extending along that portion of the river only, where the depth at summer level is not more than two feet six inches, the navigation is not interrupted, and a great protection is by their means afforded to the city from the effect of the shoves of ice which are known to be so detrimental to its frontage.

For further details on this subject I beg to refer you to the report made by Mr. Ross, and myself, on the 6th of June, 1853, to the Honourable the Board of Railway Commissioners, Quebec.

Advantage has also been taken of the shallow depth of water in constructing the abutments, which are each 212 feet in length, and consist of masonry of the same description as that on the piers, which I am about to describe, and from their being erected in such a small depth of water their foundations do not require any extraordinary means for their construction.

The foundations, as you are aware, are fortunately on solid rock, in no place at a great depth below the summer level of the water in the river.

Various methods of constructing the foundations suggested themselves, and were carefully considered; but without deciding upon any particular method of proceeding, it was assumed that the diving-bell, or such modifications of it on a larger scale, as have been recently employed with great success in situations not very dissimilar, would be the most expedient. The contractors, however, or rather the superintendent, Mr. Hodges, in conjunction with Mr. Ross, after much consideration on the spot, devised another system of laying the foundations, which was by means of floating "coffer-dams," so contrived that the usual difficulty in applying coffer-dams for rock foundations would be, it was hoped, in a great measure obviated. When in Montreal, I examined a model of this contrivance, and quite approved of its application, without feeling certain that it would materially reduce the expense of construction below that of the system

assumed to be adopted by Mr. Ross and myself in making the estimate. In approving of the method proposed by Mr. Hodges, I was actuated by the feeling that the engineers would not be justified in controlling the contractors in the adoption of such means as they might consider most economical to themselves, so long as the soundness and stability of the work were in no way affected. This new method has been hitherto acted upon, with such modifications as experience has suggested from time to time during the progress of the work, and although successfully, I learn from the contractors that experience has proved the bed of the river to be far more irregular than was at first supposed, presenting, instead of tolerably uniform ledges of rock, large loose fragments, which are strewed about, and cause much inconvenience and delay.

They are, therefore, necessitated to vary their mode of proceeding to meet these new circumstances; and it may be stated, that all observations up to this time show the propriety, notwithstanding the difficulty with dams, of carrying the ashlar masonry of the piers down to the solid rock, and that any attempt at obtaining a permanent foundation by means of concrete, confined in "caissons," would be utterly futile. However, if it were assumed to be practicable, there would be extreme danger in trusting such a superstructure of masonry upon concrete, confined in cast-iron "caissons" above the bed of the river; indeed, considering the peculiarities of the situation, and the facts which have been ascertained, this mode of forming foundations is the most inappropriate that can be suggested, as it involves so many contingencies that to calculate the extreme expense would be utterly impossible.

These considerations lead me therefore to the conclusion that the present design for the foundation is as economical as is compatible with complete security.

We are now brought to the question as to whether the upper masonry is of a more expensive description than necessary, or whether it can be reduced in quality. This question is exceedingly important, since the cost of the masonry constitutes upwards of 50 per cent. of the total estimated cost of the bridge and approaches. The amount of the item of expenditure for the masonry is clearly dependent upon the number of piers, which is again regulated by the spans between them.

The width of the openings in bridges is frequently influenced, and sometimes absolutely governed, by peculiarities of site. In the present case, however, the spans, with the exception of the middle one, are decided by a comparison with the cost of the piers; for it is evident that so soon as the increased expense in the roadway, by enlarging the spans, balances the economy produced by lessening the number of piers, any further increase of span would be wasteful.

Calculations based upon this principle of reasoning, coupled to some extent with considerations based upon the advantages to be derived from having all the tubes as nearly alike as possible, have proved that the spans which have been adopted in the present design for all the side openings, viz., 242 feet, have produced the greatest economy. The centre span has been made 330 feet, not only for the purpose of giving every possible facility for the navigation, but because that span is very nearly the width of the centre and principal deep channel of the stream.

The correctness of the result of these calculations obviously depends upon the assumption, that the roadway is not more costly than absolutely necessary; for if the comparison be made with a roadway estimated to cost less than the tubular one in the design, then the most economical span for the side openings would have come larger than 242 feet; and the amount of masonry might have been reduced below what is now intended. In considering the quantity of masonry in the design, you must therefore take it for granted, for the moment, that the *tubular roadway* is the cheapest and best that could be adopted, and leave the proof of this fact to the sequel of these remarks.

It may perhaps appear to some, in examining the design, that a saving might be effected in the masonry by abandoning the inclined planes which are added to the up-side of each pier, for the purpose of arresting the ice, and termed ice breakers.

In European rivers, and I believe in those of America also, these "ice breakers" are usually placed a little way in advance of, or rather above the piers of the bridges, with a view of saving them from injury by the ice shelving up above the level of (frequently on to) the roadway.

In the case of the Victoria Bridge, the level of the roadway is far above that to which the ice ever reaches; and as the ordinary plan of "ice breakers," composed of timber and stone, would be much larger in bulk, though of a rougher character, than those which are now added to the piers, I have reason to believe that they would be equally costly, besides requiring constant annual reparations; it was therefore decided to make them a part of the structure itself, as is now being done.

To convey some idea of the magnitude of ordinary "ice breakers," placed on the upside of the pier, and to enable you to form some notion of their cost, I cannot do better than quote the following from the excellent report addressed to the Hon. John Young by Mr. Thomas C. Keefer, whose experience in such matters from long residence in the country, entitles his opinion as to the proper character of such works to confidence.

"The plan I have proposed contemplates the planting of very large 'cribs' or wooden 'shoes,' covering an area of about one-fourth of an acre each, and leaving a clear passage between them of about 240 feet, a width which will allow ordinary rafts to float broadside between them. These 'islands' of timber and stone will have a rectangular *well* left open in the middle of their width, toward their lower ends, out of which will rise the solid masonry towers, supporting the weight of the superstructure, and resting on the rocky bed of the river. This enclosure of solid cribwork, all round the masonry, yet detached from it, will receive the shock, pressure, and 'grinding' of the ice, and yield to a certain extent, by its elasticity, without communicating the shock to the masonry piers. These cribs, if damaged, can be repaired with facility; and from their cohesive powers will resist the action of the ice better than ordinary masonry. During construction they will serve as 'coffer dams,' and being formed of the cheapest materials, their value as service ground or platforms for the use of machinery, the moving of scows, &c., during the erection of the work, will be at once appreciated. Their application to the sides of the piers is with particular reference to preventing the ice from reaching the spring of the arches, which will be the lowest and most exposed part of the superstructure, if wood be used."

In the first design for the Victoria Bridge, "ice-breakers" very similar to the above described by Mr. Keefer were introduced, but subsequently the arrangement was changed, partly with a view of gaining the assistance of the whole weight of the bridge to resist the pressure of the ice, before it became fixed, and partly for the purpose of obviating a considerable annual outlay.

I have not data at hand, to estimate correctly the cost of the ordinary "ice-breakers," as described, but I have little or no doubt that, as I before stated, they would have required to have been large and substantial masses of stone and timber, which in amount of cost would be scarcely less than, if not equal to, the inclined planes of masonry which have been added to the up-side of the piers. On this point, however, as well as upon others in reference to some reduction in the quantity of masonry in the piers and abutments, I intend to address Mr. Ross, who, being on the spot, will be able to determine with more accuracy than I can the amount of actual saving which can be effected in the masonry.

It is now necessary for me to say a word or two upon the style of the workmanship. It consists simply of solid ashlar, and, considering the severe pressure and abrasion to which it will be subjected by the grinding of the ice, and the excessively low temperature to which it will for months be periodically exposed, I am confident that it is not executed with more solidity than prudence absolutely demands; and, considering the difference of the rates of wages in Canada and this country, I believe the price of the work will come out nearly the same as any similar work let (here) by competition.

The description and style of the masonry is precisely similar to that adopted in the Britannia Bridge; the material is the same; and the facility of obtaining it is not in any important degree dissimilar.

The next point to be discussed is the construction of the superstructure, or roadway; and here, owing to the misconception which seems to exist on this subject amongst some engineers, I am compelled to enter somewhat into technical details, in reference to the treatment and construction of beams.

The matter has already been debated before the Institution of Civil Engineers, at great length, arising out of a paper read by Mr. Barton, on the construction of the bridge over the river Boyne, erected under the direction of Sir John Macneill.

In the design of this bridge, the engineer has adopted what is technically termed the "trellis" system of beam or girder, for the avowed purpose of saving material, as compared with the plain tubular system adopted in the Britannia, and now proposed for the Victoria Bridge.

It has been already stated that the design and cost of masonry materially depend upon the comparative expense which may be incurred in the construction of the roadway, since the spans or openings adopted are really governed by this item in the estimate. It is therefore doubly necessary that this part of the proposed design should be analysed with great care.

Notwithstanding the discussion which took place at the Institution of Civil Engineers, as to the

comparative merits of constructing beams in almost every variety of detail, it certainly appears, as far as I am able to form a judgment, that much error still prevails regarding the simple principles that should, and indeed must, govern the arrangement of every beam-bridge.

The tubular system is openly declared by some to be a wasteful expenditure of material for the attainment of a given strength; in short, that in the scale of comparative merit, it stands at the lowest point. This, if it were the fact, would not be extraordinary, since it was the first proposed for carrying railways over spans never before deemed practicable; but in the following remarks I hope to convince you in the simplest manner, that (except in particular cases) whilst it is not a more costly method of construction, it is the most efficacious one that has hitherto been devised.

At present there may be regarded as existing three methods of constructing wrought-iron girders or beams for railway purposes:—

First.—The *tubular girder*, or what is sometimes called the *box-girder*, when employed for small spans, with which may also be named the *single-ribbed girder*,—the whole belonging to the class known as “boiler-plate girders.”

Second.—The *trellis girder*, which is simply a substitution of iron bars for the wood in the trellis-bridges which have been so successfully employed in the United States, where wood is cheap and iron is dear.

Third.—The single triangle girder, recently called “Warren,” from a patent having been obtained for it by a gentleman of that name.

Now, in calculating the strength of these different classes of girders, one ruling principle appertains and is common to all of them. Primarily and essentially the ultimate strength is considered to exist in the top and bottom, the former being exposed to a compressive force by the action of the load, and the latter to a force of tension; therefore, whatever be the class or denomination of girders, they must all be alike in amount of effective material in these numbers, if the spans and depths are the same, and they have to sustain the same amount of load.

On this point I believe there is no difference of opinion amongst those who have had to deal with the subject. Hence, then, the question of comparative merit—amongst the different classes of construction of beams or girders—is really narrowed to the method of connecting the top and bottom *webs* so called. In the tubular system this is effected by means of continuous plates, riveted together; in the trellis girders it is accomplished by the application of a trellis-work, composed of bars of iron forming struts and ties, more or less numerous, intersecting each other, and riveted at the intersections; and in the girders of the simple triangular or “Warren” system, the connection between the top and bottom is made with bars, not intersecting each other, but forming a series of equilateral triangles; these bars are alternately struts and ties.

Now in the consideration of these different plans for connecting the top and bottom *webs* of a beam, there are two questions to be disposed of,—one is, which is the most economical; and the other, which is the

most effective mode of so doing. But while thus reducing the subject to simplicity, it is of the utmost importance to keep constantly in mind that any saving that the one system may present over the other is actually limited to a portion, or per centage, of a subordinate part of the total amount of the material employed.

In the case now under consideration, namely, that of the Victoria tubes, the total weight of the material between the bearings is 252 tons, which weight is disposed of in the following manner:—

Top of tube	76 tons
Bottom of ditto	92 tons
	— 168 tons
Sides of ditto	84 tons
	—
Total	252 tons.
	—

Assuming that the strain per square inch in the top and bottom is the same for every kind of beam—say four tons of compression in the top, and five tons of tension in the bottom—the only saving that can by any possibility be made to take place being confined to the sides, must be a saving in that portion of its weight, which is only about 34 per cent. of the whole. How, therefore, can 70 per cent. of saving be realised as has been stated out of the total weight, when the question resolves itself into a difference of opinion on a portion which is only 34 per cent. of such weight?

I am tempted to reiterate here much that was said by several experienced engineers on the subject, during the discussions already alluded to at the Institution of Civil Engineers, but the argument adduced on that occasion could only be rendered thoroughly intelligible by the assistance of diagrams of some complexity, and I think sufficient has been said to demonstrate that no saving of *importance* can be made in the construction of the roadway of the Victoria Bridge, as it is now designed, by the substitution of any other description of girder. Yet, lest this should be considered mere assertion, permit me to adduce one or two examples, where the close-sided tubular system and the open-sided system may be fairly brought into comparison with each other in actual practice.

The most remarkable parallel case which occurs to me is the comparison of the Victoria tubes, under consideration, with a triangular or "Warren" bridge, which has been erected by Mr. Joseph Cubitt over a branch of the river Trent, near Newark, on the Great Northern Railway.

The spans are very similar, and so are the depths. In calling your attention to the comparison, you must bear in mind that all possible skill and science were brought to bear upon every portion of the details of the Newark Dyke Bridge, in order to reduce the total weight and cost to a minimum.

The comparison stands thus:—

Victoria Bridge, as being erected.

Span, 242 feet. Weight, including bearings, 275 tons, for a length of 257 feet.

Newark Dyke Bridge, as erected.

Span, 240 feet 6 inches. Weight, including bearings, 292 tons, for a length of 254 feet. Which shows a balance 17 tons in favour of the Victoria tubes.

The Newark Dyke Bridge is only 13 feet wide, while the Victoria Tube is 16 feet, having a wider gauge railway passing through it.

This is a very important case, as the spans and depths are all but identical, and it will therefore enable you to form a judgment upon that point which has caused so much controversy at the discussion alluded to. It is true that in the Newark Dyke Bridge a large proportion of the weight is of cast-iron, a material I have frequently adopted in the parts of tubular bridges subjected to compression only, but from its brittle character I should never recommend it for exportation, nor for the parts of a structure that are liable to a lateral blow.

It has been suggested that there is much convenience in the arrangement of the trellis or "Warren" bridge, as it may be taken to piers and more conveniently and economically transported over-land than "boiler plates;" this may be correct under some circumstances, but it cannot hold good for a work like the Victoria Bridge over the St. Lawrence.

I am aware that girders upon the "Warren" principle have been adopted in India, and I am not prepared to call in question the propriety of their application in certain cases; but what I have been aiming at in these observations is, to prove to you that no economy over the plain tube can be effected in the case of the Victoria Bridge. I may add, that it has sometimes been urged that the workmanship in trellis or "Warren" girders is of a less expensive character than that required in tubes. I am bound to confess my utter inability to understand such a statement; for, after many years of practical experience as a manufacturer of iron work of every description, I do not know any class of workmanship that bears so small a proportion to the value of the material as "boiler-plate" work. If there be any difference in the cost, it ought certainly to be in favour of tubular beams.

Another example may be mentioned of a tubular beam, somewhat similar in dimensions to the last described, and one which is actually erected on a continuation of the same line of railway as that on which the Newark Dyke Bridge is situated, namely, over the river Aire, at Ferry Bridge. Although the similarity is not so great with this as with the Victoria Tube, yet I believe it is sufficiently so to form another proof that the advantage is in favour of the solid side.

As before:—

Newark Dyke Bridge.

Span, 240 feet 6 inches. Weight, 292 tons.

Ferry Bridge.

Span, 225 feet. Weight, 235 tons.

The difference between these weights is more than sufficient to compensate for the difference of span ; besides which, in the Ferry Bridge, made according to my designs and instructions, I was lavish in the thickness of the side-plates, and the bearings, which are included in the above weight, were stiffened by massive pillars of cast-iron.

For a further example, let me compare the Boyne trellis bridge (held by some to be the most economical) with the present Victoria tubes. The Boyne Bridge has three spans ; the centre one being 264 feet, and the height is 22 feet 6 inches. It is constructed for a double line of way, and is 24 feet wide. The total load, including the beam itself, the rolling load at 2 tons per foot, and platform, rails, &c., amounts to 980 tons, uniformly distributed.

The bridge is constructed upon the principle of "continuous beams," a term which signifies that it is not allowed to take a natural deflection due to its span ; but being tied over the piers to the other girders, the effective central span is shortened to 174 feet ; in fact, this *principle* changes the three spans into five spans. Now, the effective area given for compression in this centre span is 113½ inches, which gives a strain for the 174 feet span of nearly six tons to the inch in comparison.

The Victoria tubes are so dissimilar in form and circumstances to the Boyne Bridge, that it is a troublesome matter to reduce the two to a comparative state. However, the Victoria tubes are known to be 275 tons in weight, 242 feet in span, and of 19 feet average depth, the strain not being more than four tons per inch for compression, with a uniform load of 514 tons, which include its own weight, sleepers, and rails, and a rolling load of one ton per foot.

The Victoria Bridge has not been designed upon the principle of continuous beams, for practical reasons, including the circumstance of the deep gradient on each side of the centre span, and the great disturbance which would be caused by the accumulated expansion and contraction of such a continuous system of ironwork in a climate where the extremes of temperature are so widely different ; otherwise, the principle alluded to was first developed in tubular beams, namely, in the Britannia Bridge.

But since we are only now discussing the merits of the sides, let the Boyne Bridge be supposed to have sufficient area in its top to resist four tons per inch (the proper practical strain), and let the spans be not continuous ; it will be found by calculation that the area required at top will be 364 inches, instead of 113½ inches, and the weight of the span would be found by calculation to come out little short of 600 tons, whereas it is now 386 tons ; and if we suppose the Victoria tube to carry a double line of *way*, and 24 feet wide, with a depth of 22½ feet, even if we double the sides in quantity, the whole amount of weight will be certainly very little more than 500 tons for 242 feet span.

It will be necessary to conclude my remarks with some further observations relative to the comparisons under our notice, which are of vital importance in considering the design of such a bridge as that to be erected for the Grand Trunk Railway of Canada.

Independently of the comparative weights and cost, which I believe have been fairly placed before you, the comparative merit as regards efficiency has yet to be alluded to.

You may be aware that at the present time theorists are quite at variance with each other as to the action of a load in straining a beam in the various points of its depth, and the fact is now known that all the received formulæ for calculating the strength of a beam subjected to a transverse load, require remodeling; therefore, at present it is far beyond the power of the designers of *trellis* or *triangular* bridges to say with precision what the laws are which govern the strains and resistances in the sides of beams, or even of *simple solid beams*. Yet one thing is certain, which is, that the sides of all these trellis or "Warren" bridges are useless, except for the purpose of connecting the top and bottom, and keeping them in their proper position. They depend upon their connection with the top and bottom webs for their own support, and since they could not sustain their shape, but collapsed immediately they were disconnected from these top and bottom members, it is evident that they add to the strain upon them, and consequently to that extent reduce the ultimate strength of the beams.

In the case of the Newark Dyke Bridge, when tested to a strain of $6\frac{3}{4}$ tons to the inch, its deflection was 7 inches in the middle; and when tested with its calculated load of one ton per foot run, the deflection was $11\frac{7}{8}$ inches. The deflection of the Victoria tubes by calculation will not be more with the load of one ton per foot, than 1.6 inch; and we have had sufficient proof of the correctness of this calculation in existing examples. That of the Boyne Bridge, with a uniform load of 540 tons, was 1.9 inch, with the spans shortened in effect as described.

Many other bridges of similar spans to those above named have been constructed upon the "open-side" or "truss" principle, which are, in every sense of the word, *excellent* structures; but since no comparison of economy between them and the Victoria tubes has been offered, it would be improper to class them with those already named, which have actually been put forward as examples of economy to a large extent over the tubular system.

As an argument in favour of the trellis-beams, it has been stated that no formula has been used to value the sides of a plate-beam for horizontal strains; and therefore, since the sides are thrown away, except for the office they perform in connecting the top and bottom webs, it is asked, why should more material be placed in the sides than sufficient for that purpose? Now, I admit that there is no formula for valuing the solid sides for strains, and that we only ascribe to them the value or use of connecting the top and bottom; yet we are aware that, from their continuity and solidity, they *are* of value to resist horizontal and many other strains independently of the top and bottom, by which they add very much to the stiffness of the beam; and the fact of their containing more material than necessary to connect the top and bottom webs is by no means fairly established.

It is also said that the "trellis" or "Warren" beams are usually made deeper in proportion to their span than the tubes; and therefore, the strain being less, a less quantity of material is employed in the top and bottom webs. An important consideration should be named in reply to this, which concerns all the

classes of beams alluded to, which is, that *any change of proportion in the figure of a beam changes the amount of strain caused by the load, and consequently changes the weight of the beam itself.* The resistance to horizontal strain in the above classes of bridges, depends upon the distance between their top and bottom webs; such beams are said to vary in strength directly as their depths, and inversely as their spans. With regard to tubular beams, a practical rule has been established, which determines that the depth shall not be less than 1-15th of the span; but although this is the minimum depth given, there is no reason to consider it the maximum depth; indeed, the tubular bridges just named are of a greater depth than that proportion would give; for instance, the depth of Ferry bridge is 1-11th of its span, and that of the Victoria tubes, next the centre opening, is 1-12th of the span. These proportions are, I believe, very similar to those that are usually adopted for "Warren" or trellis-beams.

It is well known that the diagonal "struts" in these latter systems when under pressure deflect as if they themselves were beams, and any increase in the depth of the sides would be an increase of length in the diagonals, which in the "Warren" must be compensated by an increase in their sectional area; and in the trellis-beam, if they are not increased in area, they must be in number, so as to make more intersections; therefore an increase in depth of the sides of these systems would not only be a proportionate increase in their weight, but would be an increase per square foot of their surface. Now, the sides of a tube, from their nature, may be increased in depth up to a reasonable practical limit, without any increase in their thickness.

Having given you my views with respect to the comparative merits of the different kinds of roadway consisting of "beams," that may be adopted in the Victoria Bridge, I now proceed to draw your attention to the adaptation of the "suspension" principle, similar to that of the bridge which has been completed within the last few months by Mr. Roebling over the Niagara River near the Great Falls.

You are aware that during my last visit to Canada I examined this remarkable work, and made myself acquainted with its general details. Since then, Mr. Roebling has kindly forwarded to me a copy of his last Report, dated May, 1855, in which all the important facts connected with the structure, as well as the results which have been produced since its opening for the passage of railway trains, are carefully and clearly set forth.

No one can study the statements contained in that Report without admiring the great skill which has been displayed throughout in the design; neither can any one who has seen the locality fail to appreciate the fitness of the structure for the singular combination of difficulties which are presented.

Your engineer, Mr. Alexander Ross, has personally examined the Niagara Bridge since its opening, with the view of instituting as far as is practicable, a comparison between that kind of structure and the one proposed for the Victoria Bridge; and, as he has since communicated to me by letter the general conclusions at which he has arrived, I think I cannot do better than convey them to you, in his own words, which are subjoined below.

"I find, from various sources, that considerable pains have been taken to produce an impression in England, in favour of a Suspension Bridge in place of that we are engaged in constructing across the St. Lawrence at this place. This idea, no doubt, has arisen from the success of the Niagara Suspension Bridge, lately finished by Mr. Roebling, and now in use by the Great Western Railway Company, as the connecting links between their lines on each side the St. Lawrence, about two miles below the Great "Falls," of the situation and particulars of which you will no doubt have some recollection. I visited the spot lately, and found Mr. Roebling there, who gave me every facility I could desire for my objects. Of his last Report on the completion of the work, he also gave me a copy which you will receive with this. I have marked the points which contain the substance of his statement. I also enclose an engraved sketch of the structure. Mr. Roebling has succeeded in accomplishing all he had undertaken, viz., safety to pass over railway trains at a speed not exceeding five miles an hour,—this speed, however, is not practised; the time occupied in passing over 500 feet is three minutes, which is equal to three miles an hour. The deflection is found to vary from 5 to 9 inches, depending on the extent of load; and the largest load yet passed over is 326 tons of 2000 lbs. each, which caused a depression of 10 inches. A precaution has been taken to diminish the span from 800 to 700 feet by building up, underneath the platform at each end, about 40 feet in length, intervening between the towers and the face of the precipice upon which they stand, and struts have also been added extending 10 feet further. The points involved in the consideration of this subject are, first, *sufficiency*, and second, *cost*. These are in this particular case soon disposed of. First, we have a structure which we dare not use at a higher speed than three miles an hour. In crossing the St. Lawrence at Montreal, we should thus occupy three-quarters of an hour, and allowing reasonable time for trains clearing and getting well out of each other's way, I consider that twenty trains in the twenty-hours is the utmost we could accomplish. When our communication is completed across the St. Lawrence, there will be lines (now existing, having their termini on the south shore) which, with our own line, will require four or five times this accommodation. This is no exaggeration. Over the bridge in question, although opened only a few weeks, and the roads yet incomplete on either side, there are between thirty and forty trains pass daily. The mixed application of timber and iron in connection with wire, renders it impossible to put up so large a work, to answer the purposes required at Montreal. We must therefore construct it entirely of iron, omitting all perishable materials, and we are thus brought to consider the question of cost; in doing which, as regards the Victoria Bridge, I find that, dividing it under three heads, it stands as follows:—

" <i>First</i> .—The approaches and abutments, which together extend to 3000 feet in length, amount in the estimate to	£200,000
" <i>Second</i> .—The masonry forming the piers, which occupy the intervening space of 7000 feet between the abutments, including all dams and appliances for their erection	800,000
" <i>Third</i> .—The wrought iron tubular superstructure, 7000 feet in length, which amounts to	400,000
(about £57 per lineal foot	
Making a total of	£1,400,000

"By substituting a suspension bridge, the case would stand thus: the approaches and abutments

extending to 3000 feet in length, being common to both, more especially as these are now in an advanced state, may be stated as above at £200,000.

"The masonry of the Victoria Bridge piers ranges from 40 to 72 feet in height, averaging 56 feet, and these are twenty-four in number. The number required for a suspension bridge, admitting of spans of about 700 feet, would be *ten*, and these would extend to an average height of 125 feet. These ten piers, with the proportions due to their height and stability, would contain as much (probably more) masonry as is contained in the twenty-four piers designed for the Victoria Bridge; and the only item of saving which would arise between these, would be the *lesser* number of dams that would be required for the suspension piers; but this, I beg to say, is more than doubly balanced by the excess in masonry, and the additional cost entailed in the construction at so greatly increased a height. Next, as to the superstructure, which in the Victoria Bridge costs £57 per lineal foot, Mr. Roebing, in his Report, states the cost of his bridge to have been 400,000 dollars, which is equal to £50,000 sterling. Estimating his towers and anchor masonry at £20,000, which I believe is more than their due, we have £60,000 left for the superstructure, which, for a length of 800 feet, is equal to £75 per lineal foot, giving an excess of £18 per foot over the tubes, of which we have 7000 feet in length. By this data we show an excess of nearly 10 per cent. in the suspension, as compared with the tubular principle, for the particular locality with which we have to deal, besides having a structure perishable in itself, on account of the nature of the materials; and to construct them entirely of iron, would involve an increase in the cost which no circumstance connected with our local or any other consideration at Montreal would justify. We attain our ends by a much more economical structure, and what is of still greater consequence, a more permanent one; and as Mr. Roebing says—'No suspension bridge is safe without the appliances of stays from below.' No stays of the kind referred to could be used in the Victoria Bridge, both on account of the navigation and the ice, either of which coming in contact with them would instantly destroy them. No security would be left against the storms and hurricanes so frequently occurring in this part of the world.

"No one, however, capable of forming a judgment upon the subject, will doubt for one moment the propriety of adopting the suspended mode of structure for the particular place and object it is designed to serve at Niagara. A gorge, 800 feet in width and 240 feet in depth, with a foaming cataract racing at a speed of twenty to thirty miles an hour, underneath, points out at once that the design is most eligible; and Mr. Roebing has succeeded in perfecting a work capable of passing over ten or twelve trains an hour, if it should be required to do so. The end is attained by means the most applicable to the circumstances; these means, however, are only applicable where they can be used with economy, as in this instance."

My own sentiments are so fully conveyed in the above extract from Mr. Ross's letter, that I can add no further remark upon the subject, except, perhaps, that there appears to be a discrepancy in that part which relates to *cost*.

In dividing the £50,000 into items, Mr. Ross has deducted £20,000 for masonry, and left the residue, £60,000, for the 800 feet of roadway. Now it appears evident, that this amount should include the cost of the "Land-chains;" and assuming their value at about £15,000, there would be only £45,000

left for the 800 feet of roadway ; thus reducing the cost per lineal foot to be about that of the tube. But in the application of a suspension bridge for the St. Lawrence, the item £15,000 for "Land-chains," would, of course, have to be added to the cost of the 7000 feet of roadway, which would swell the amount per foot to a little over that of the tubes.

In all that has been said respecting the comparative merits of the different systems of roadway, you will perceive that a *complete wooden structure* has not been attended to ; because, in the first place, when the design for the Victoria Bridge was at first being considered, *wood* was deemed not sufficiently permanent ; in the second place, the structures alluded to in the report as being inferior to that now in progress, are proposed to be constructed of stone and iron work ; and, as a third reason, the construction of the tubular roadway is already so far advanced, that any alteration, to the extent of abandoning *iron* and adopting *wood*, must involve monetary questions of so serious a nature as to render the subject beyond discussion, or even being thought of in this Report.

In conclusion, therefore, I have to state to you (my deliberate opinion) that the present design now being carried out for the Victoria Bridge is the most suitable that can be adopted, taking all the circumstances into consideration, to which the question relates. In making this statement, I must ask you to bear in mind that I am not addressing you as an advocate for a tubular bridge. I am very desirous of calling your especial attention to this fact ; for really much error prevails upon this point, through the impression that in every case I must appear as an advocate : no one is more aware than I am that such inflexible advocacy would amount to an absurdity.

I entirely concur in what Mr. Ross says respecting the propriety of applying the suspension principle to the passage across the Niagara Gorge ; no other system of bridge-building yet devised could cope with the large span of 800 feet which was there absolutely called for, irrespective of the other difficulties alluded to.

When such spans are demanded, no design of "beam" with which I am acquainted would be at all feasible. The tube, trellis, and triangular systems are all impracticable in a commercial sense, and even in a practical engineering question, the difficulties involved are all but insurmountable.

Over the St. Lawrence we are, fortunately, not compelled to adopt very large spans ; never so large, in fact, as have been already accomplished by the simple "girder" system. It is under these circumstances that the suspension principle fails, in my opinion, to possess any decided advantage in point of expense ; whilst it is certainly much inferior as regards stability for railway purposes.

The flexure of the Niagara Bridge, though really small, is sufficiently indicative of such a movement amongst the parts of the platform as cannot fail to argument, where *wood* is employed, before a long time elapses.

I beg that this observation may not be considered as being made in the tone of disparagement ;

on the contrary, no one appreciates more than I do, the skill and science displayed by Mr. Roebling in overcoming the striking engineering difficulties by which he was surrounded. I only refer to the question of flexure in the platform, as an unavoidable defect in the suspension principle; which, from the comparatively small spans that are available in the Victoria Bridge, may be entirely removed out of consideration.

I am, Gentlemen,

Your obedient servant,

(Signed) ROB. STEPHENSON.

P.S.—In my last communication, I stated that, in order to bring more clearly before you the comparative merits of different kinds of girders, now very generally used for railway purposes, I had designed some experiments, and intended that the results should be contained in this Report. They are in progress, but as they cannot be completed previous to my leaving this country for two months, I have been compelled to close my Report without them.

(Signed) R. S.

IV.

REPORT ON THE COMPLETION OF THE BRIDGE.

To the Chairman and Directors of the Grand Trunk Railway of Canada.

17th December, 1859.

GENTLEMEN,

We beg to hand you our joint Report on the state of the Victoria Bridge, at Montreal, which will be opened for public traffic on Monday next, the 19th inst.

At the time we commenced our final inspection of the Bridge there were two of the ordinary spans (Nos. 14 and 15) in an incomplete state, but the last of these (No. 14 tube) was completed on Monday, leaving nothing but the testing to be done previously to the bridge being opened for public traffic.

During the time that arrangements were being made for commencing the testing, we directed our attention to the works generally, and, with the exception of a few small matters to be finished up, which we shall enumerate hereafter, we are able to inform you that in every respect the works are of the most perfect description.

The piers and abutments are of the most substantial character, the masonry of which they consist being massive, well built, and finished most accurately. The approaches consist of solid material, and are constructed in a manner such as will render them thoroughly permanent.

The tubular beams comprising the superstructure of the bridge are formed of the best materials, and the workmanship is unquestionable. In fact, both as regards the quality of the iron in the plates, rivets, and other parts, and the manner in which the whole is put together, we believe that better work cannot be produced; and our views in this respect will, we believe, be fully borne out by the results of the tests to which we subjected the whole of the tubes.

As you may be aware, the Victoria Bridge was designed to sustain practically a load of one ton per foot run of its entire length; which load, added to the weight of the tubes themselves, it was intended should cause a horizontal tensile strain of five tons per square inch, and a compressile strain of four tons per square inch, and the load applied as a test was as near the above load as possibly could be provided. For the purpose of registering the deflections of the various tubes, a steel wire, extending throughout the entire length of the bridge, was strained as tightly as possible, being supported at every bearing of the tubes over pulleys with heavy weights attached, so as to keep an equal amount of tension upon it. This steel wire formed the datum line from which all the deflections were measured and marked on slips of card attached to vertical boards, which were fixed up at various points along the tubes.

The train forming the testing load was sufficiently long to cover a pair of tubes from end to end, and it was run first on to one tube, when observations were registered both in that tube, and in the adjoining empty one also, which was of course affected, owing to its connection with the loaded tube.

As the effect produced was the same in all the ordinary pairs of tubes, it will only be necessary to give you the observations taken in one pair, which were as follows:

While the load was in the first tube only, the deflection of that tube in the middle was $\frac{7}{8}$ of an inch, and the adjoining empty tube was lifted in the middle. The load then being placed over both tubes, the deflection was the same in each, and was $\frac{3}{4}$ of an inch, in the middle.

And when the load was run on to the second tube only, the effect on the two tubes was similar to that in the first experiment.

We next tested the large central span which is quite unconnected with any other tube, and the load extending from end to end caused a deflection not more than $1\frac{3}{4}$ inch, in the middle.

In all the experiments the tubes returned to their original position when the weight was removed.

The result of the tests applied to the whole of the twenty-five tubes is highly satisfactory, inasmuch as the actual deflections were considerably within the calculated deflections for such a load, according to

formlike well-known and generally made use of. We therefore consider the tubes excessively strong as regards the load they are designed to carry, and we attribute this to the perfect manner in which they have been fitted and riveted together, and the excellent quality of the iron of which they are composed.

In the 330-foot (central) tube, the smallness of the deflection is very remarkable, it being but little more than five-eighths of the calculated deflection.

It is also worthy of remark that it was a difficult matter to make up a train weighing the enormous weight of one ton per foot run; and it was just as much as three large engines could do to propel it. Such a load surely never can pass through the bridge in the ordinary way of traffic.

The works required yet to be done to complete the Victoria Bridge are—The laying about 250 lineal feet of coping in the south approach, and fixing the iron caps on twenty-two piers.

And we beg to say, in conclusion, that when these small matters are completed, we should recommend the Board of Directors of the Grand Trunk Railway of Canada to accept the Victoria Bridge from the hands of Messrs. Peto, Brassey, and Betts, the contractors, as being completed satisfactorily, and according to the true spirit and meaning of the contract.

We deeply regret that Mr. Robert Stephenson had not lived to see the end of this important work; but we feel enabled to assure you, in the most confident terms, that everything has been carried out with respect to it entirely in accordance with his wishes.

We are, Gentlemen,

Your obedient servants,

(Signed)

ALEXANDER M. ROSS.

GEORGE B. BRUCE.

B. P. STOCKMAN.

V.

TABULAR STATEMENT OF THE RESULTS OF TESTS APPLIED.

TABLE No. 1.						TABLE No. 2.					
No. of Tube.	Load per foot run in tons.	Deflection when twin tubes supply.	Center rise in twin tubes.	Deflection as per calculation.	Remarks.	No. of Tube.	Load per foot run in tons.	Deflection when both tubes were loaded.	Deflection as per calculation.	Remarks.	
1	80	55	45	72		1	126	87	97		
2	126	100	42	113		2	80	50	62		
3	80	62	40	69		3	126	75	93		
4	126	100	...	108		4	80	50	59		
5	80	62	40	66		5	126	83	88		
6	126	100	40	103		6	80	60	56		
7	80	60	25	62		7	126	70	81		
8	126	87	25	98		8	80	50	54		
9	80	62	18	59		9	126	69	79		
10	126	87	25	93		10	80	44	50		
11	80	62	18	56		11	126	81	76		
12	126	93	12	88		12	80	50	48		
13	130	125	...	...		13	...	...	...
14	125	137	...	137		14	...	...	...
15	80	100	...	68 1/2		15	...	...	...
16	126	137	...	137		16	...	...	...
17	80	62	...	59		17	...	...	...
18	126	...	25	93		18	97	56	65		
19	116	81	...	91		19	116	75	78		
20	97	62	...	76		20	57	58	68		
21	116	87	...	95 1/2		21	116	75	81		
22	97	62	42	79		22	97	56	72		
23	116	87	...	100		23	116	75	86		
24	97	60	40	83		24	97	62	75		
25	116	87	...	101		25	116	100	89		
25	97	80	40	87							

Signed } GEORGE B. BRUCE,
B. P. STOCKMAN.

January 5th, 1860.

VI.

CONTRACTORS' STAFF.

ENGINEERING DEPARTMENT.

JOHN DUNCAN	ENGINEER IN CHARGE OF WORKS.
CHARLES LEGGE	ASSISTANT DITTO SOUTH SIDE.
W. OLIVER GOODING	ASSISTANT-ENGINEER.
FRED. CUTBILL	"
WILLIAM GRAIN	"
H. H. KILLALY	" AND DRAUGHTSMAN.
J. W. WOODFORD	MECHANICAL ENGINEER.
JAMES DUNBAR	" DRAUGHTSMAN.

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DAVID AIKMAN	ASSISTANT ACCOUNTANT AND STOREKEEPER.
THOMAS COLE	CASH CLERK.

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SLATER	MASTER.
DAVIS	"
J. RYAN	"
THOMAS DUTTON	"
ROBERT DUNCAN	"
W. C. DUTTON	CLERK.

SUB-CONTRACTORS.

BENJAMIN CHAFFEY	FOR SOUTH DOCKMENT, AND FOR PIERS NOS. 24, 23, 22, 21, 20, 19, 13, 15, AND 14.
JOHN O. HODGES	FOR PIERS 10, 11, 12, AND 13.
MESSRS. BROWN AND WATSON	" " 5 AND 6.
WILLIAM NEWCOMBE	" QUARRYING AND CUTTING STONE AT POINTE LAHRE.
WILLIAM BISSANT	" SETTING MASONRY.
HILMAN	" "
JACQUES NORMAND	" CRIB WORK.
J. W. WILSTEAD	" " AND STAGING.
WALTER YARDLE	" STAGING.
JAMES L. DRINKSON	" ERECTION OF TUBES.
MARTINEAU	" TINNING OF ROOF.
THOMAS	" PAINTING.

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MILTON SESSIONS	"
L. KIRKUP, JUN.	INSPECTOR OF RIVETING.
W. R. BELL	" "
SIMON FOOTE	" "
GOULDER	" "
ALEX. SUTHERLAND	MASONRY.
J. HARRISON	" "
J. AKENHEAD	" "
J. HILL	" "
JOHN THOMPSON	" "
G. PYKE	PAINTING.
JOHN MELLVILLE	FOREMAN OF SHOPS.
JOHN Mc NEIL	" CARPENTERS.
S. BONNEVILLE	" "
JOSEPH KIRKBRIDE	" "
WILLIAM KIRKBRIDE	" "
DUNCAN Mc DONALD	" "
ED. WILLIAMS	" "
D. WILSON	MASONS.
J. TURNER	" "
SAMUEL RATCLIFFE	RIVETERS.
EDWARD COULTON	" "
GEORGE PERKINS	SUPERINTENDENT OF SAILORS.
ROBERT WILBAR	FOREMAN OF LABOURERS.
JOHN BAILEY	" "
BARNEY SEGREY	SUPERINTENDENT OF DIVERS AND BOATMEN.



