be developed in a given engine (and the rate of expansion to be employed) to secure greatest economy for such engine, but also the method of determining the engine (and the ratio of expansion employed) to develope a given or desired amount of horse-power with the greatest economy. Such extract reads:

"To prevent the possible rise of such an erroneous impression, we will ask you to be kind enough to reprint a portion of the reading matter of the diagram accompanying the first portion of our paper in the June, 1881, issue of THE AMERICAN ENGINEER. Such portion reads:

'To apply the diagram to the design of an engine to supply a given amount of horse-power, assuming such a knowledge of the type of engine to be built that the mean effective pressure, water consumption and clearance for different ratios of expansion can be settled, as in the tables of engine performances given in the catalogues of Modern Engine Builders.

I—Determine the range of sizes of engines which may give the desired power for a given steam pressure and piston speed. For example—200 horse-power at 65 lbs. steam pressure may be given by a 30″×60″ non-condensing engine—1/10 cut-off—80 revolutions; by a 22″×44″ non-condensing engine—1/5 cut-off—100 revolutions; by a 20″×40″ non-condensing engine—1/4 cut-off—100 revolutions; by an 18″×36″ non-condensing engine—1/2 cut off—100 revolutions; by an 18″×36″ condensing engine—.35 cut-off—100 revolutions, etc.

II.—To the sizes selected, apply the method of the diagram and thus determine the most economical ratio of expansion for each size.

III.—Select the sizes for which the most economical ratio of expansion is equal to or near the ratio necessary to the development of the required power and determine the water consumption corresponding to the most economical ratio for each size.

IV.—Add together the cost of each engine per horse-power per hour, and the cost of steam required per horse-power per hour for its most economical ratio of expansion. Then other things being equal the size of engine for which this sum is least will be the cheapest engine to supply the given horse-power.'

'The above it will be noted covers all the general directions necessary for applying the method to the solution of the problem referred to.

'At this time, we do not desire to add any more than the following specific directions, which the working out of a number of special practical cases and deductions from our theoretical analysis permit us to add.

'In the design of an engine, which is to develop a desired amount of horse-power for the least current money cost of producing such power, proceed as follows:

'(1.) Use the highest steam pressure and number of revolutions allowable. High steam pressure and great number of revolutions contribute to economy in the sense of obtaining a given power at the least total current cost of money.

'(2.) Reduce the back pressure of steam and friction as far as possible.

'(3). Having thus determined upon the steam pressure and revolutions to be employed, and knowing probable back pressure and friction, assume any ratio of expansion x and proportion the diameter and stroke of engine, so as to give the desired amount of horse-power for such conditions. This is done by means of the well-known formula for horse-power.

'(4.) Calculate the total current cost of power and obtain the horse-power developed per dollar of expense.

'(5.) Apply the general method given by us in our problem on 'The Most Economical Point of Cut-off in Steam Engines.' (For convenient directions, see 'To Find the Most Economical Ratios of Expansion by this Diagram.' Diagram AMERICAN ENGINEER, June, 1881) to this engine and determine the ratio of expansion y, which would be most economical to use in the engine. In the use of this method when figuring the items of 'cost of full steam,' the interest, depreciation and repairs of the boilers and firemen's wages should be figured for a boiler capacity necessary to supply the cylinder with steam following full stroke plus percentage allowed for condensation for the probable best ratio of expansion. The use of the ratio y last determined will give either the same, a greater or a less horse-power in the assumed engine than the power desired.

(6.) Assuming this horse-power to be greater or less than is desired, use the new ratio y, and design the diameter and stroke of the engine for this ratio to develop the required horse-power, using the number of revolutions, initial pressure of steam, back pressure, and formula for horse-power as in (3).

(7.) Calculate the total current cost of power for this last case and thus obtain the horse-power developed per dollar of expense.

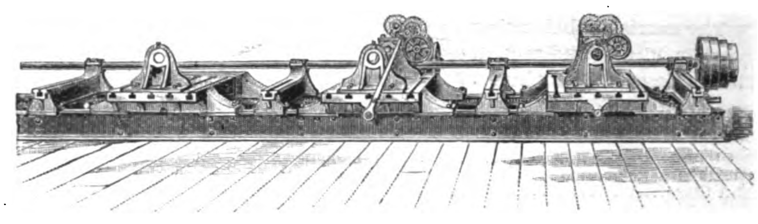
(8.) Apply the general method given by us in our paper on 'The Most Economical Point of Cut-off in Steam Engines,' (See 5) to this new second engine and determine the ratio of expansion, which would be most economical to use in this engine. This ratio would probably be found to equal the assumed ratio y. If, however, the ratio should be found to be z, the use of which in the second engine would give greater or less horse-power than is desired, then

(9.) Use the newly determined ratio z and design the diameter and stroke of the engine for this ratio to develop the required horse-power, using the number of revolutions, initial pressure of steam, back pressure and formula for horse-power as in (3). In all cases this last determined ratio z will be found to accord practically with the ratio which the use of the general method, exemplified in our diagram, will give as the best ratio.

(10.) Calculate the total current cost of power for this last case (9) and thus obtain the horse-power obtained per dollar of expense. The last engine will be found to be most economical engine for a given horse-power."]—EDITORS.

CHORD BORING MACHINE.

For some time past our large iron bridge building establishments have felt the necessity for a well-designed Chord Boring Machine, and as there was no such tool in the market for the work, they were forced to improvise such machines as they could for the purpose. The Betts Machine Company, of Wilmington, Del., now bring out a tool specially designed for boring chords, and the accompanying cut will give a tolerably clear idea of it.



The tool consists of two horizontal boring machines and an extra table to facilitate setting the work, so arranged that they can be adjusted and clamped on the bed-plate to suit the centers of the holes in the chords. It is of sufficient capacity to admit chords 3×2 feet; the bed-plate is made of 12-inch wrought iron I beams, 180 pounds per yard, so that its expansion and contraction shall, under all circumstances, be the same as the chords being bored. The cone pulleys have four changes for a 4-inch belt; the spindles are driven with worms and worm wheels, and they are made of steel, and have 12-inch traverse, with a rapid hand movement. They are self-feeding by cut cog cone gearing, giving three changes. It is provided with steady rests for the outer end of boring bars. The girts in the bed are three feet from centre to centre and the bed can be made any desired length. Weight, with 55-foot bed, 32,200 pounds. Speed of countershaft, 300 revolutions per minute. We learn that orders have already been placed for three of these machines.

FRASER BRIDGE, FOR CANADIAN PACIFIC RAILWAY.

The bridge, which was designed by Mr. C. C. Schneider, C. E., of New York City, crosses the Fraser River near Lytton, in British Columbia, on the line of the Canadian Pacific Railway. The Fraser River at this place has a deep and rapid current, which makes it impossible to erect temporary supports r˚ false works that would stand the force of the current. The distance from ordinary high water to base of rail is 125 ft., and the river rises occasionally in floods to the extent of 60 ft. To meet these conditions, the designer adopted the cantilever type for this bridge, which would be self-sustaining during erection.

The structure consists of two cantilever trusses of 210 ft. each and an intermediate span of 105 ft., making the total length of the bridge 525 ft. between centers of end pins.

The cantilever trusses are supported at their center by stone piers about 72 ft. high, 315 ft. apart, between centers built on the banks of the river. The trusses are 17 ft. apart between centers, divided into panels of 15 ft. The depth of the cantilever trusses over the piers is 35 ft., and at the ends 14 ft.

The shore ends of the cantilevers are attached to short links, revolving on pins anchored to the masonry. These links, besides forming the anchorage, serve as rockers, and allow for the expansion and contraction of the shore ends of the cantilevers. Expansion joints are also provided for at the connection of the intermediate span with the river ends of the two cantilevers, the intermediate span being suspended from the extreme ends of the river arms.

The method of erection is as follows: The shore arms of the cantilevers will be erected on false works in the usual manner. After the shore arms are in position and anchored to the abutments, the river arms will be built out panel by panel by means of traveling derricks, which advance as each panel is in place and its bracing adjusted. Thus the work progresses section by section, until the ends of the cantilevers are reached. Then the intermediate span of 105 ft. will be erected on a staging built on wire ropes swung across the gap between the two ends of the cantilevers.

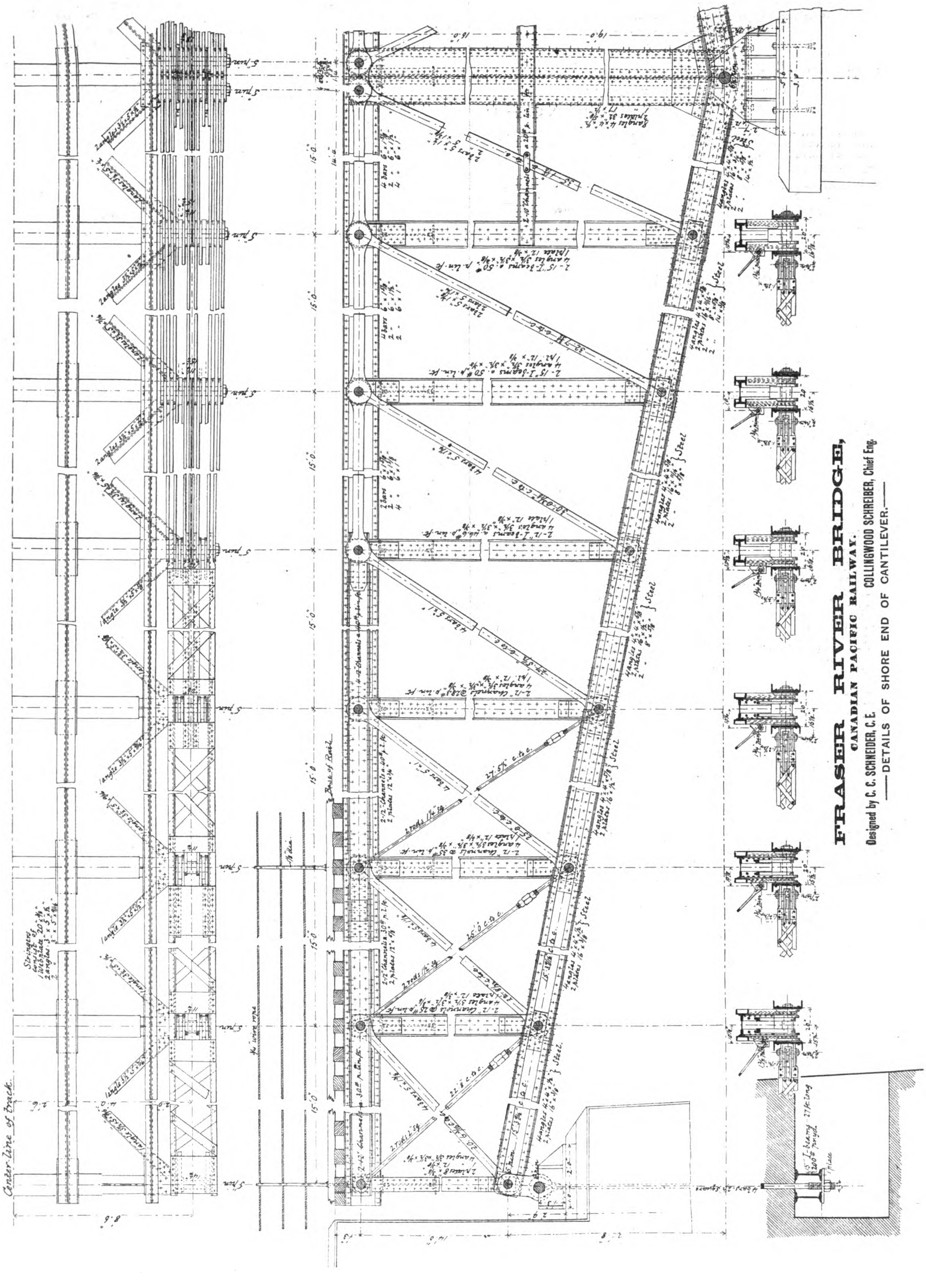
The structure has been proportioned to carry, in addition to its own weight and weight of woodwork and rails, a train-load of 2,500 lbs. per lineal foot, with two locomotives having an additional driver-load of 55,000 lbs. on 14 ft. wheel bases about 50 ft. apart, over and above the 2,500 lbs. per lineal foot. The floor system has been proportioned for the maximum strain produced by the train and locomotive loads specified, supposing the whole load to be carried by the central stringers, the outer stringers having two-thirds the capacity of central stringers.

The wind-bracing has been proportioned for a pressure of 40 lbs. per square foot, on a surface of twice the area of one face of the trusses, plus the area of face of floor system, plus the area of face of train taken as 10 ft vertical hight; the pressure on train area being considered as a moving load, and the remaining pressure as a uniform load.

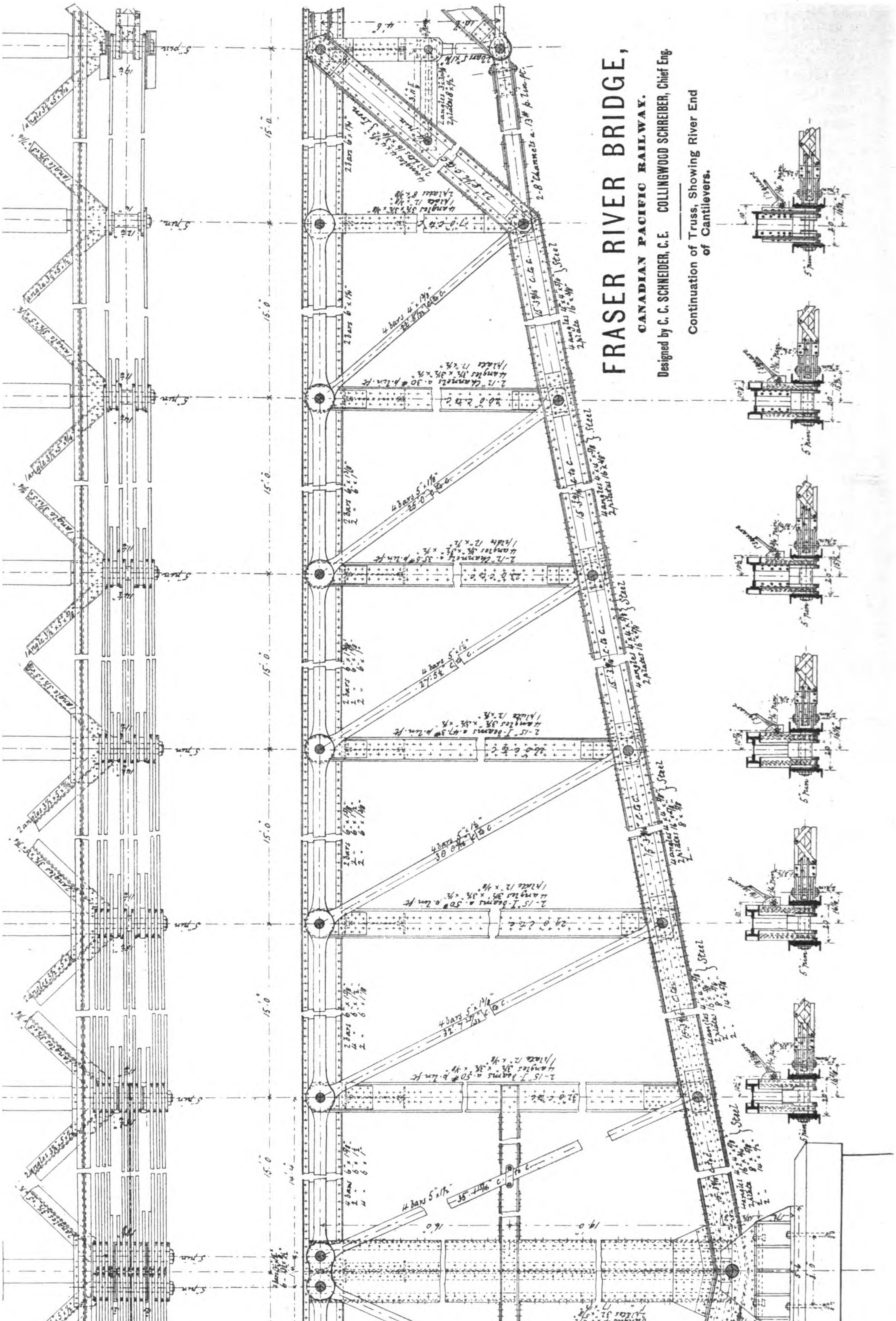
The strains resulting from the above-mentioned loads and wind pressures, together with the corresponding sectional areas of the various members are inscribed in the accompanying strain sheet, also the weight of the structure as distributed on each panel point. The material used for the superstructure is steel made by the open earth or Simens-Martin process and wrought iron. The lower chords and center-posts of cantilevers are made of steel; so are all the pins; the rest of the work is of wrought iron, with the exception of the pedestals on the masonry and filling rings, which are of cast iron.

The total weight of steel and iron in the bridge is 1,224,000 lbs., of which 243,000 lbs. are steel, 941,000 lbs. wrought iron, and 40,000 lbs. cast iron.

A. Onderdonk is the contractor for the entire work, including foundations and masonry. The steel and iron work has been manufactured by Messrs. Hawks, Crawshay & Sons, Gateshead-on-Tyne, England. Mr. J. Tomlinson, bridge engineer of the Canadian Pacific Railway has been inspecting the work at the shops and has now charge of the erection.



FRASER RIVER BRIDGE,
CANADIAN PACIFIC RAILWAY.
Designed by C. C. SCHNEIDER, C.E. COLLINGWOOD SCHREIBER, Chief Eng.
—DETAILS OF SHORE END OF CANTILEVER.—



FRASER RIVER BRIDGE,

CANADIAN PACIFIC RAILWAY.

Designed by C. C. SCHNEIDER, C.E. COLLINGWOOD SCHREIBER, Chief Eng.

Continuation of Truss, Showing River End of Cantilevers.

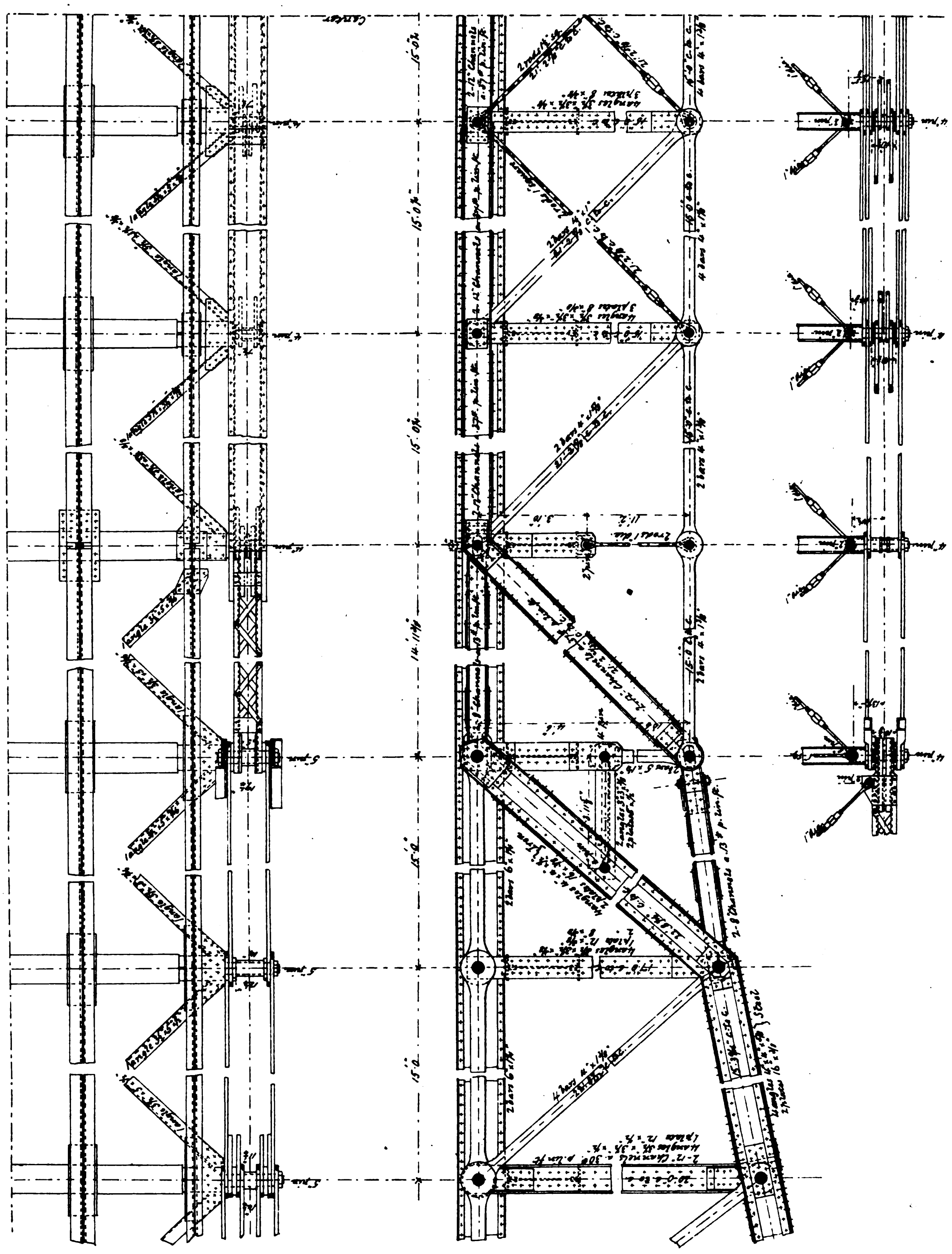
FRASER RIVER BRIDGE

CANADIAN PACIFIC RAILWAY.

DESIGNED BY
C. C. SCHNEIDER, C. E.

COLLINGWOOD SCHREIBER,
Chief Engineer.

Details of Intermediate Truss Showing its Connection With River Ends of Cantilevers.



length was brilliantly lighted by torches, to the Tunnel Station, which was lighted by electricity. Here a halt was again made, and the party were met by another set of guests, brought by M. Lapp from the Western portal. Great cheering of workmen and playing of military bands followed; and the two trains being united were transported by the locomotive to the Western entrance. As they emerged, after nearly five hours' stay in the tunnel, into the open air, music and cheering greeted the presence of the first men who had entered the Vovdrlberg Province by this new, difficult passage. The Minister of Trade then collected together the engineers, sub-contractors, etc., and read to them the announcement of various promotions and honors bestowed by the Imperial authorities. A luncheon offered by the contractors was then partaken of, and the train then returned through the tunnel to St. Anton. Ringing cheers and improvised lighting up of the scene with torches and Bengal lights welcomed the guests as they emerged from the Eastern portal. The day closed with a dinner given to 300 guests by the contractor, M. Ceconi and with the drinking of numerous toasts to the health of the Imperial author of the project, and of all (not forgetting the workmen) those who had been connected with the design or carrying out of the work. Numerous telegrams of congratulation were received, many of which were read to the guests. On the following morning the company dispersed, and the works of the tunnel renewed their ordinary aspect of vigor and activity.

OPENING OF THE CANTILEVER BRIDGE AT NIAGARA FALLS.

The opening of the Cantilever Bridge over the Niagara River, at the Falls side of the Railway Suspension Bridge, at Niagara Falls, was made quite an event in engineering annuals. Both the two trunk roads interested in its completion and the Bridge Company itself, who financed its construction, as well as the actual builders, the Central Bridge Company, of Buffalo, N. Y., all united in the most liberal spirit to make the opening an important and interesting ceremony. Special cars were run from both Chicago and New York—the former by the Michigan Central and the latter by the New York Central, railroads,—and we can speak without fear of being misinterpreted, when we say that under the attentive care and hospitality of Mr. O. W. Ruggles, General Passenger Agent, and Mr. J. A. Greer, General Freight Agent, of the Michigan Central, the Chicago party enjoyed perhaps the pleasantest and most comfortable railway trip ever undertaken by them.

Bad weather somewhat delayed the arrival of trains of the invited guests, so that the special ceremony of testing the bridge was not commenced until between 12 and 1 o'clock, Thursday, Dec. 20. This test was one of the heaviest ever applied to a bridge. It consisted of running trains abreast. First came a pair of locomotives side by side, followed by two pairs of heavily laden ballast cars; this was repeated, to the extent of three sets, all of course coupled up, and was followed by four pairs of heavy engines; these were again followed by pairs of engines with ballast cars until the bridge was covered, the four pairs of engines resting in the centre of the bridge over the intermediate span. Altogether there were 20 engines and 24 ballast cars resting on the bridge.

This enormous train was stopped at intervals, while levels were taken to calculate the deflection. One set of levels were taken while the centre span only was loaded.

The test occupied one hour and a half, when the great crowd of guests resorted to the "Monteagle," where a splendid lunch was ready. The large crowd, however, spoiled the effect of this in more senses than one. After a time, speeches were announced, the ball being opened by the Mayor of Chicago, of the Chicago party. Several speeches were made, when marching orders were given and the guests for the most part, betook themselves to the waiting trains. The weather became magnificent and a most interesting affair was unmarred in any particular. We regret that want of space prevents our going into details, but following these remarks we have reprinted a mass of general information, which was compiled by Mr. Lespinasse for the handsome pamphlet prepared by the Michigan Central for the occasion, and which is endorsed by the builders as correct. We hope very soon to be able to publish some drawings of the structure. By the way we would say, that the utmost deflection observed at the river ends of the cantilever under the heaviest conditions of the test was seven inches, which after deducting for compression in the piers, makes a good showing for the bridge, and was within the limits of calculation of possible deflection.

The affair was incorporated into a gala day by the surrounding towns, and crowds lined the gorge on both sides during the ceremonies.

The location of the bridge being a short distance below the Falls of Niagara, precluded the possibility of any supports in the center of the stream, which at this point is 500 feet from shore to shore at the water's edge; and the construction of a suspension bridge being unadvisable on account of the very great expense and interminable time involved, and also the inevitable wave-motion of that class of structures when loads are moved over them, necessitated a peculiar manner of construction, and the cantilever type was chosen.

The bridge is a double-track railroad bridge and is designed to connect the New York Central and Michigan Central Railways. It is located about 300 feet above the present railroad suspension bridge, where the width of the opening to be spanned, from bluff to bluff, is 860 feet. The general dimensions are as follows: Length of bridge proper, from center to centre of end pins, 910 ft. 1⅝ in.; divided into two cantilevers of 395 ft. 2 5/16 in. each, and one intermediate span of 119′ 9″. The towers are braced wrought-iron structures, 130 ft. 6½ in. high, resting upon masonry piers 39 feet high; the foundations under the towers are of beton, 8 ft. thick, directly on the rock, forming a uniform, solid and endurable mass.

The trusses are two in number, 28 ft. apart between centres; the panels are 25 ft. long, excepting those of the intermediate span, which are 24 ft., and the end panels of the shore arms of the cantilevers, which are 20 ft. 2 5/16 in. long. The depth of the cantilever trusses, over the towers, is 56 ft.; and at the ends, 21 ft. for shore ends, and 26 ft. at the river ends.

The structure has been proportioned to carry, in addition to its own weight, a freight train on each track at the same time, weighing one ton per lineal foot, with each train headed by two 76-ton consolidation engines. The factor of safety is 5. Wind bracing has been proportioned for a pressure of 30 pounds per square foot, on a surface twice the area of one face of the truss, plus area of floor system, plus the area of face of train taken at 10 ft. vertical height.

The material used in the superstructure is open-hearth steel and wrought iron. Towers and heavy compression members, such as lower chords and center posts, are of steel, as are all the pins. All tension members are wrought iron. The only use made of cast iron is in the pedestals on the masonry and in filling-rings; the castings at the top of towers are all steel.

The whole of the superstructure is pin-connected. The towers contain four columns each, and each column is made up of plates and angles in sections of about 25 ft. in length, braced with horizontal struts, and with tie rods. The batter of columns at right angles and the center line of the bridge is 1 in 8. In the cantilever trusses the lower chords and center posts are made of plates and angles latticed, the intermediate posts are made of 12-inch and 15-inch channels, latticed. The upper chords of the cantilevers are 8-inch eye-bars, the shore arm having a compression member 18 in. deep, composed of plates and angles packed between the chord-bars.

The shore ends of the cantilevers are attached to short links, revolving on pins anchored to the masonry; these links serve as rockers and allow for the expansion and contraction of the shore ends of the cantilevers. Expansion joints are also provided for at the connection of the intermediate span with the river ends of the two cantilevers; the intermediate span being suspended from the extreme ends of the river arms.

The floor-beams are 4 ft. deep, and are made of plates and angles; they are riveted to the posts. There are four lines of longitudinal stringers resting on top of the floor-beams; these stringers are plate girders 2 ft. 6 in. deep. The ties are white oak 9″×9″, spaced 18 in. between centres; every other tie projects to support a plank walk and hand railing, which latter is made of cast iron posts 6 ft. apart, and four longitudinal lines of 1¼ in. gas piping. The guard timbers are of white oak 8″×8″.

All masonry is built of Queenstown limestone, in courses of 2 ft. rise. The piers for the towers are 12 ft. square under the coping, and have a batter of ½-inch to the foot; each pair of piers is connected by a wall 3 ft. 9 in. thick at the top, and battering the same as the piers.

The anchorage piers are 11′ × 37′ 6″, under coping, wtth a batter of ½-inch to the foot. They rest on a platform consisting of twelve iron plate girders, 2 ft. 6 in. deep and 36 ft. long; under these plate girders are eighteen 15-inch I-beams, through which the anchorage bars pass, in such manner as to distribute the pressure over the entire mass of masonry. Each anchorage pier contains 460 cubic yards of masonry weighing 2,000,000 pounds; as the maximum uplifting force from the cantilevers, under the most unfavorable position of load, is only 678,000 pounds, it will be seen that this upward force is amply counterbalanced.

Work on foundations began April 15, and the introduction of the "beton coignet" began June 6 and was completed June 20 on the American side, and seven days later on the Canada side. The first stone for the piers on the American side was laid June 26, and on the Canada side July 13. The American piers were capped Aug. 20, and the Canadian Sept. 3. On Aug. 29 the first column of steel for the tower was lowered on the American side, and on the Canada side Sept. 10. The last section of the American tower had been laid two days previous, and on the Canadian tower it was put down Sept. 18. On the 24th the first iron for the cantilever was run out and both cantilevers were completed on the 17th of November. Temporary scaffoldings of timber were built from the bluff on either side out to the edge of the water on a level with the top of the tower. Upon these the shore-arms of the cantilevers were erected, one end resting on the steel towers and the other upon masonry on the bluff. The shore end was firmly anchored to this masonry, so that it will take an uplifting force of 1,000 tons at each end to displace it. This constitutes the counter-weight to balance the unequal loading on the river arm. As this, under the most unfavorable conditions, can never exceed 340 tons, the provision is ample.

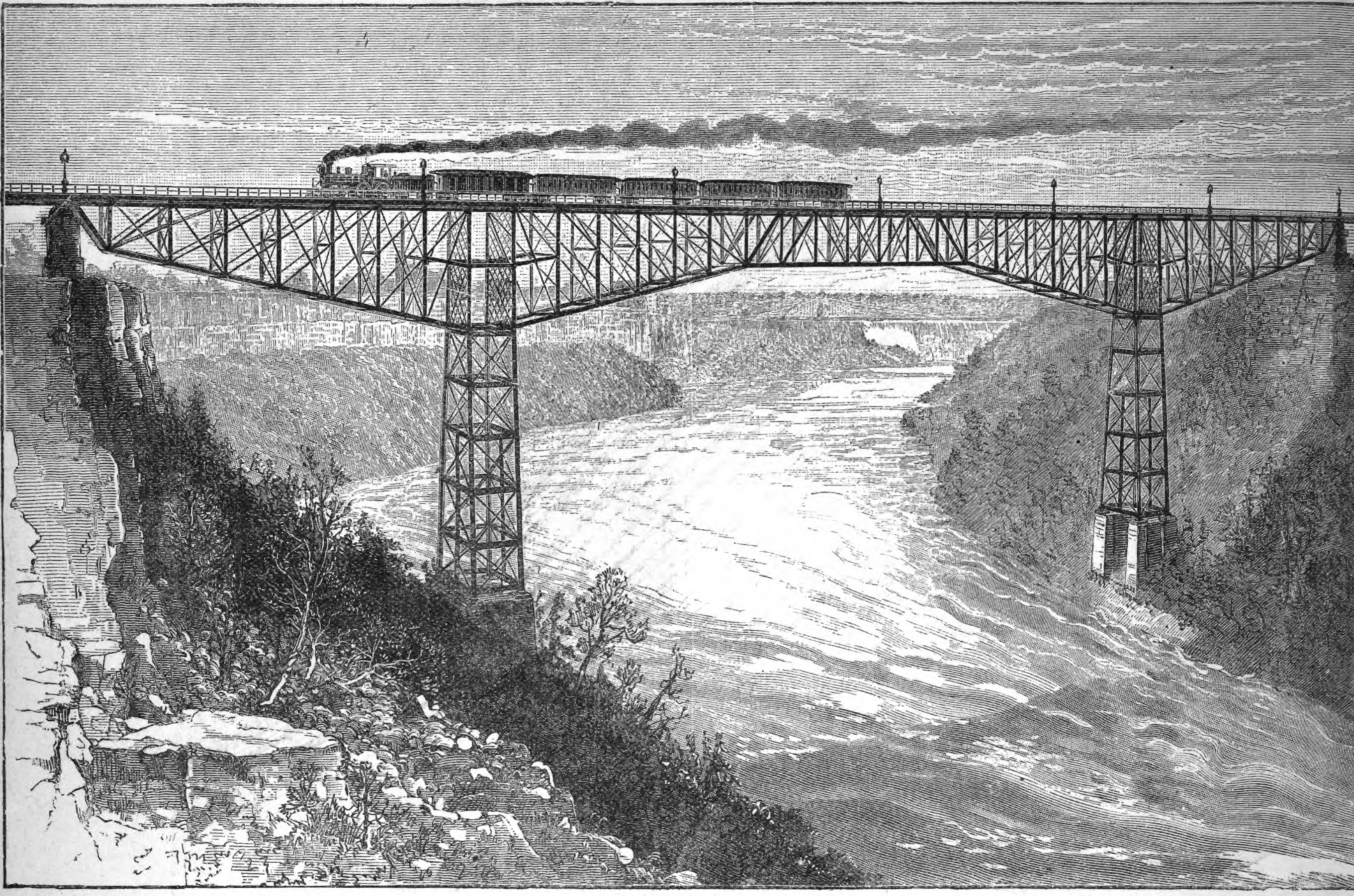
Four hundred thousand feet of timber and fifteen tons of bolts were consumed in the false work. The piers contain 1,100 cubic yards of "beton coignet," and the abutments of the approaches 1,000 cubic yards of masonry. The traveling derricks are the largest yet built. They are calculated to sustain a weight of thirty-two tons on the overhanging arm, and project 40 feet beyond any support. It is the only bridge of any magnitude completed upon this principle. The Firth of Forth Bridge, in Scotland, with a clear span of 1,600 feet, is to be built upon this plan, and also in this country the Fraser River Bridge, recently illustrated by us, 315 feet clear span, on the Canadian Pacific. These are the only examples of this design yet undertaken, but the principle especially recommends itself to long span bridges that must be erected without false work.

The total weight of the iron and steel entering into the composition of this massive structure is about 3,000 tons. The excavations were carried down until solid rock was reached, when blocks of "beton coignet" twenty feet wide and forty-five feet long and ten feet thick were put in. These form one single mass capable of withstanding a pressure almost equal to the best Quincy granite, interlocking with the boulders in sides and bottom of pit, and so distributes the load of 1,600 tons that comes upon each pair of steel columns as to produce a pressure on the natural formation much less than a fashionable young lady brings upon the heel of her French boot every time she steps. The total weight resting on each of the towers under a maximum condition of strain is in round numbers 3,200 tons. Each ingot of steel was submitted to a chemical analysis, and samples to a mechanical test. The standard of excellence adopted was more severe and exacting than usual, and all steel that failed to meet the requirements was rejected.

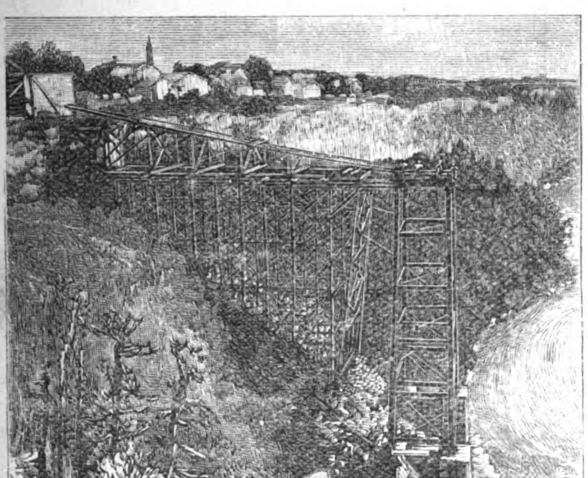
The superstructure was designed by Mr. C. C. Schneider, of New York City, and Mr. Edmund Hayes, of the Central Bridge Works, of Buffalo. General Field, of the latter Company, gave his personal attention for over seven months to all of the many questions connected with the building of such an important structure, and the entire field work has been under his directions.

The work was ordered Oct. 1st, 1883. The erection commenced Nov. 20th, 1883, and was completed Dec. 10th, 1883.

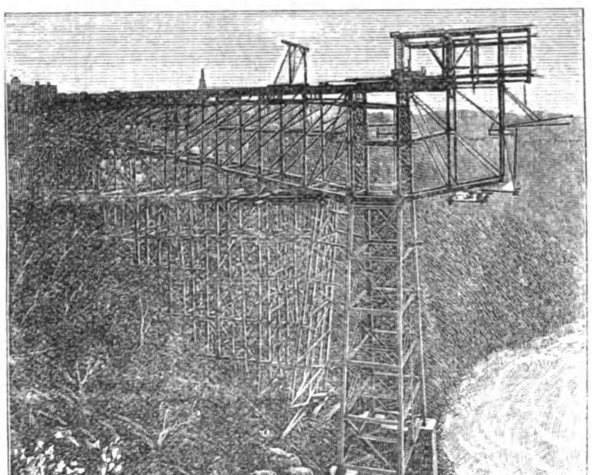
THE CANTILEVER BRIDGE ACROSS NIAGARA RIVER.



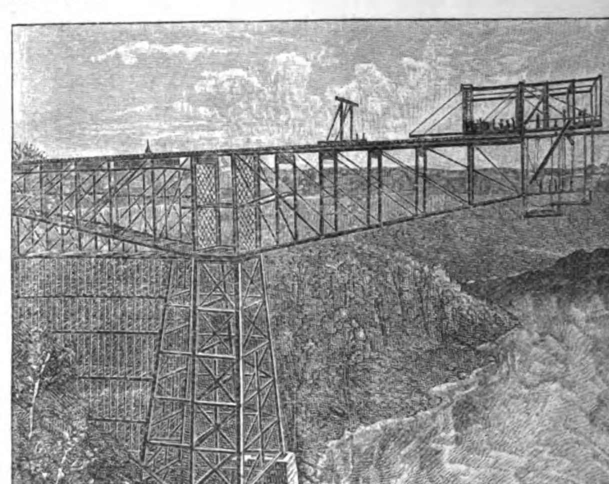
PROGRESS OF WORK ON THE BRIDGE.



SEPT. 13TH- AMERICAN SIDE.



NOV. 4TH—AMERICAN SIDE.



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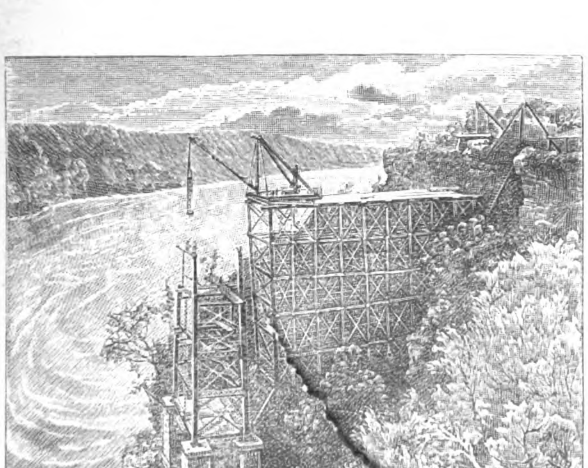
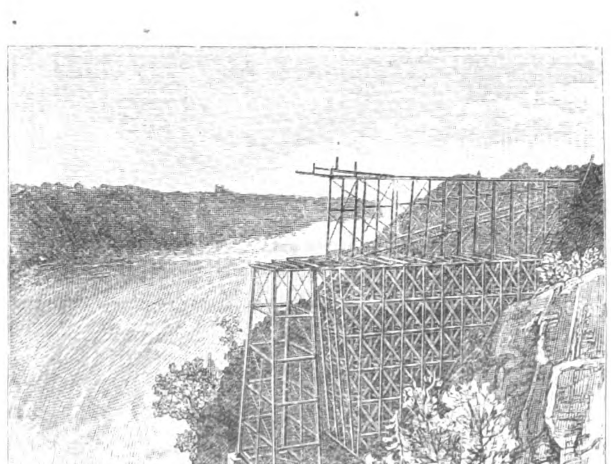
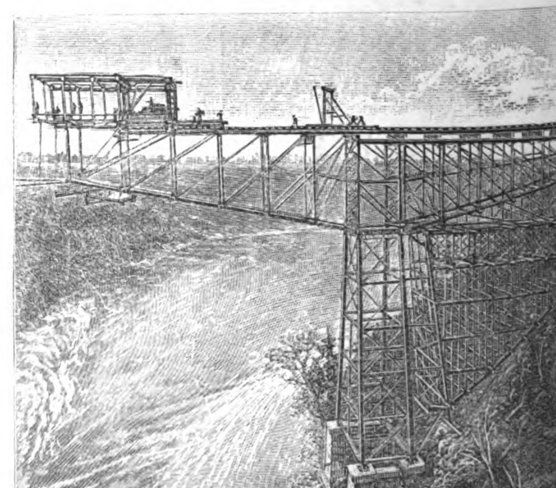


SEPT. 15TH—CANADA SIDE.



OCT. 3D—CANADA SIDE.



NOV. 12TH—CANADA SIDE.