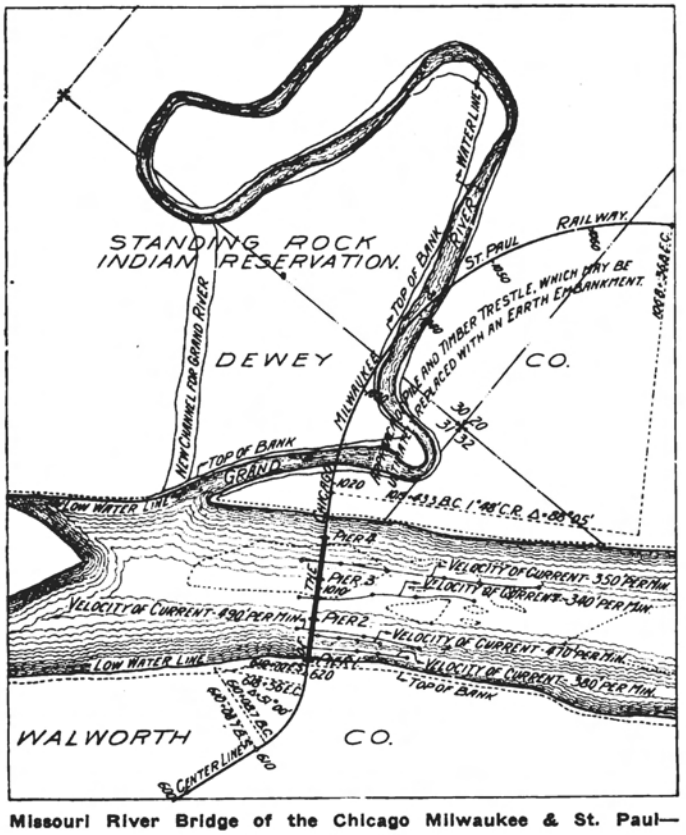
MISSOURI RIVER BRIDGE OF THE CHICAGO MILWAUKEE & ST. PAUL AT MOBRIDGE, S. D.

The extension of the Chicago Milwaukee & St. Paul Railway to the Pacific coast required the construction of a bridge across the Missouri river. The location chosen for this was about 12 miles west of Glenham, S. D., which point has been designated as Mobridge.

The designs for this bridge were made and are being carried out under the direct supervision of C. F. Loweth, engineer and superintendent of bridges and buildings, of



Missouri River Bridge of the Chicago Milwaukee & St. Paul—Location of Bridge.

the Chicago Milwaukee & St. Paul. J. J. Harding, engineer of masonry construction, has direct charge of the substructure work, and all of the designs of the company were prepared under the immediate direction of J. H. Prior, assistant engineer.

The track will cross the river at an elevation of 65.5 feet above low water, allowing for a vertical clearance above water of 50 feet. The high superstructure will consist of three 420-foot through pin-connected truss spans, flanked by two 125-foot riveted deck truss spans, with a framed trestle bridge at the west end about 2,900 feet in length.

The proposed extension from Glenham to the river was located in the winter of 1905 and 1906, and early in 1906, after a careful examination to determine the most satisfactory location for the crossing, preparations were made for making extended borings to determine the character of the underlying material. The soundings were first made by a wash boring method and taken at intervals across the river on the center line of the proposed bridge; test pits were later opened on the east bank of the river where shale cropped out at the water's edge. Still later on, when the locations of the piers had been decided upon, borings were made with a diamond drill and carried down to some considerable distance into the shale which was found at varying depths below the water surface.

Substructure.

The east abutment is located on the river bluff which comes close to the water's edge, and will be carried down through the overlying soil into disintegrated shale.

Pier I, which is on the east shore line at about low water's edge, is founded on shale. The shale comes to the surface at this point, but the diamond drill borings indicated a layer of soapstone at about 12 feet below the surface, and in order to protect the pier against any danger from sliding on the soapstone a pit 16 feet in depth and the full size of footing was dug and afterwards filled with concrete to the top surface of the shale, where the neat work of the pier was commenced.

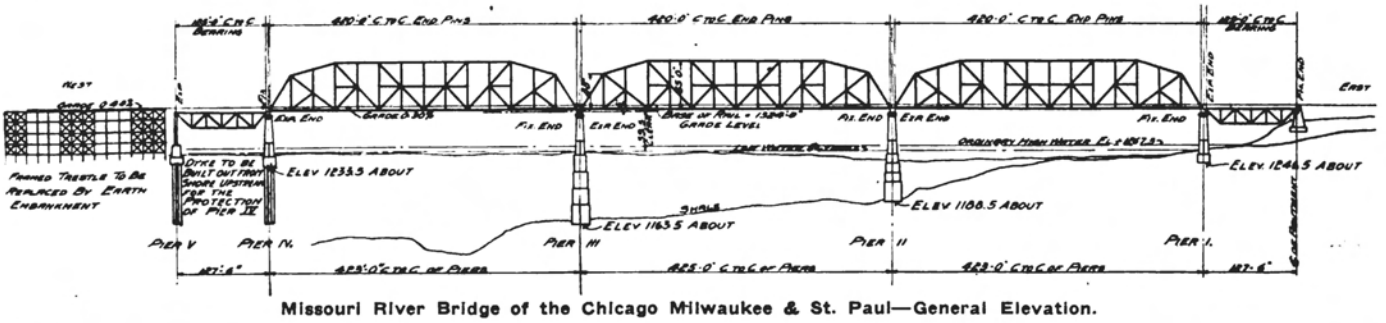
At the location of pier II, the soundings taken indicated a few feet of sand overlying about 8 feet of gravel, broken shale and large boulders. Under this there were sand and gravel and broken shale with a few large boulders. At a depth of 50 feet below low water, closely packed broken shale, mixed with hard black clay, was encountered and this material extended down to about 85 feet below low water, where hard shale was found. Borings were made into this shale at different corners of the pier to a depth of 100 feet.

At the location for pier III the borings indicated a mixture of sand and gravel and broken shale, easily penetrated, and continuing down to hard shale about 95 feet below low water elevation.

The soundings at pier IV indicated material similar to that found at pier III, except that the shale was not reached until 125 feet below low water.

It was early decided that foundations for piers II and III should be put in by the pneumatic process and carried to hard shale. At pier IV it was decided that the footings should be carried down to a depth of about 20 feet below low water and placed on piles. This decision was made for two reasons; in the first place, the fact that the shale was 125 feet below low water made the putting in of piers by the pneumatic process extremely difficult, and secondly, the lay of the west shore line above the bridge at this place made the construction of a dyke for the protection of this pier a comparatively easy matter. It was, therefore, determined to put in this foundation with an open coffer dam and protect the pier by the dyke.

Preliminary to the work on the permanent structure a large amount of work of a temporary character was necessary. A pile bridge at low grade was erected at a distance



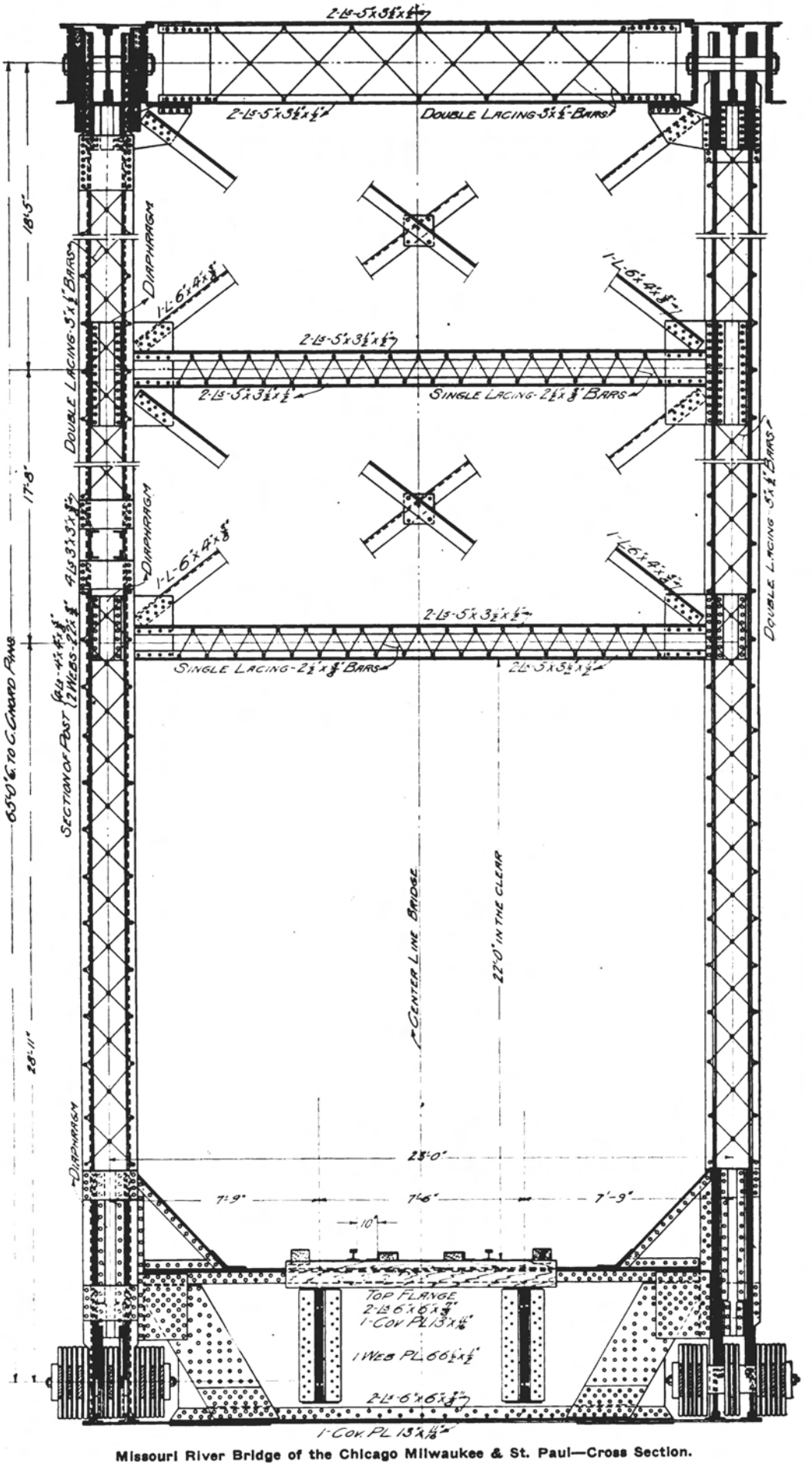
Missouri River Bridge of the Chicago Milwaukee & St. Paul—General Elevation.

of 90 feet above the center line of the permanent bridge. This temporary bridge curves across the permanent line between piers I and II and passes through a level portion of ground at the foot of the bluff, which is being used as a material yard.

On the east bluffs of the river a large camp has been constructed, including four bunk houses accommodating 50 men each, a large dining hall with kitchen, ice houses, office, officers' house, cement and tool houses, etc. A 10-kilowatt dynamo with gasoline engine has been installed to furnish electric light for the camp and construction work; also combination gas engine and pump to pump water from the river into settling tanks, from which the camp is supplied. Large storage bins have been erected in which stone and sand are placed and discharged through gates into push cars placed on the temporary track. Steam pipes were placed in these storage bins for the purpose of removing frost from the stone and sand, and the steam for this purpose is supplied from a 60-horsepower locomotive boiler.

Dump cars, divided into two compartments, one compartment of sufficient size to hold the stone required to make one batch and the other compartment gauged to hold sufficient sand for one batch of concrete, are used. The stone is discharged from the loading bins into these cars and the cars are moved out to the location of the pier by dinky engines. Two shifts of 10 cars each are used, so that one shift is being loaded while the other shift is out at the pier site being unloaded. The concrete mixer is located near the pier and the dump cars discharge the material dirctly into the mixer hopper. From the mixer the concrete is dumped into buckets and thence hoisted with a scow derrick to the pier.

All stone and sand used in the concrete work are unloaded directly from cars into the storage bins and when these bins are filled onto storage platforms, by the use



Missouri River Bridge of the Chicago Milwaukee & St. Paul—Cross Section.

of a 10-ton locomotive crane. This crane is also used for unloading cut stone and heavy machinery, timber and coal, and in fact has been found so useful on the job that it has been worked almost continuously, night and day.

Because of the large amount of preliminary work which was necessary, and also because of the fact that no material could be taken to the bridge site until the 12 miles of railroad (involving heavy work) had been constructed from Glenham to the river, the actual commencement of work was delayed so that the caisson for pier II was not landed until January, 1907.

Because of the low stage of water during the winter months it was necessary to drive piles at the pier location and build the caisson upon this false work. The caisson was afterwards lowered into the water by means of jacks. After the caisson was afloat the work of concreting was commenced and continued until the caisson has sunk through 15 feet of water and landed on the river bottom, when the air was put on.

The sinking of the caisson progressed rapidly until the layer of broken shale and boulders was reached. This material was found to be almost as solid as a pavement and exceedingly difficult to remove. Only a small percentage of it could be passed through the blow pipes and most of the material was taken out through the shafts in buckets. Not more than 5 to 6 inches per day was made, on an average, in passing through this material, but after reaching an elevation of 25 feet below low water, down to a level of 50 feet below low water, the sinking was comparatively easy, and from 2 feet to 4 feet per day were obtained.

At 50 feet below low water there was encountered compact shale and black clay which was found considerably harder to penetrate than the soundings had seemed to indicate. Before reaching this elevation there had been used a dry suction, but when this material was reached it was necessary to change to a wet suction. The material was cut up with mattocks, and further broken up by a water jet under 125 pounds pressure. After this material had been penetrated to a depth of 6 feet an inspection was made by the company's engineers, and the decision was reached that it would not be necessary to go entirely through this material to the shale.

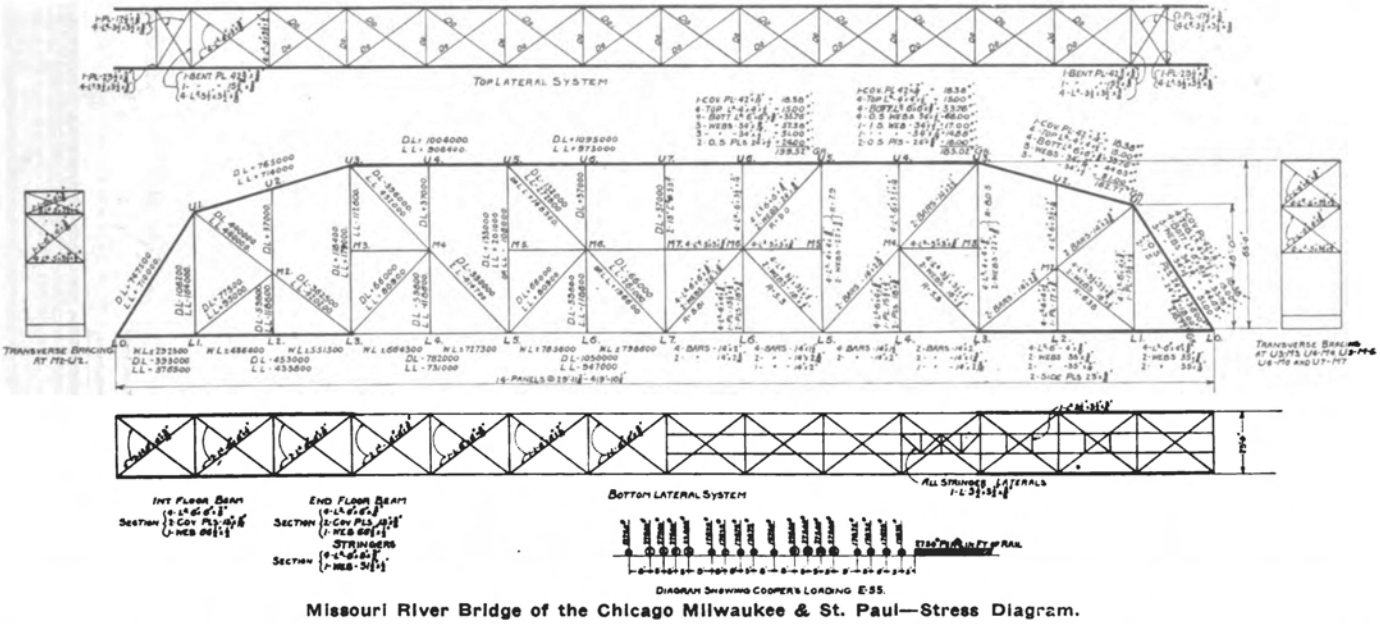
The cutting edge of the caisson is now about 10 feet into this clay, and will be carried about 10 feet farther, where the caisson will be landed.

A machinery barge, 96 by 50 by 5 feet, carrying the machinery necessary for use in connection with the pneumatic work, is anchored just below the pier. On this machinery barge are two 125-horsepower boilers, two 16 by 18-inch Ingersoll-Sargent straight line air compressors and one 16 by 9 by 12 inch Smedley pump. The barge is also fitted out with a work shop and rooms for the pressure men.

From an elevation 2 feet below low water up to an elevation 5 feet above high water, all of the piers will be faced with cut stone. The up-stream ends will be of Ortonville granite, and the sides and down-stream end of Kettle river sandstone. Above this elevation and up to the bridge seats all piers will be constructed of concrete. In the entire substructure there will be about 316 cubic yards of granite, 770 cubic yards of sandstone and 13,000 cubic yards of concrete.

The design of the caisson is clearly shown in one of the engravings.

For that part of the pier under water and above the 12 by 12-inch posts shown in the plan, 3 by 6-inch posts and 3-inch form lumber were used to form the sides of the pier. This form lumber is not caulked and the concrete is always kept well above the water's edge. One entrance shaft 3 feet 6 inches in diameter was used, and two supply shafts 2 feet in diameter. Special locks were provided for the top of the supply shaft, for use in removing material and placing concrete. The entrance shaft was designed so that any section could be used as a lock by moving the doors and the top section has at all times been used as a lock.



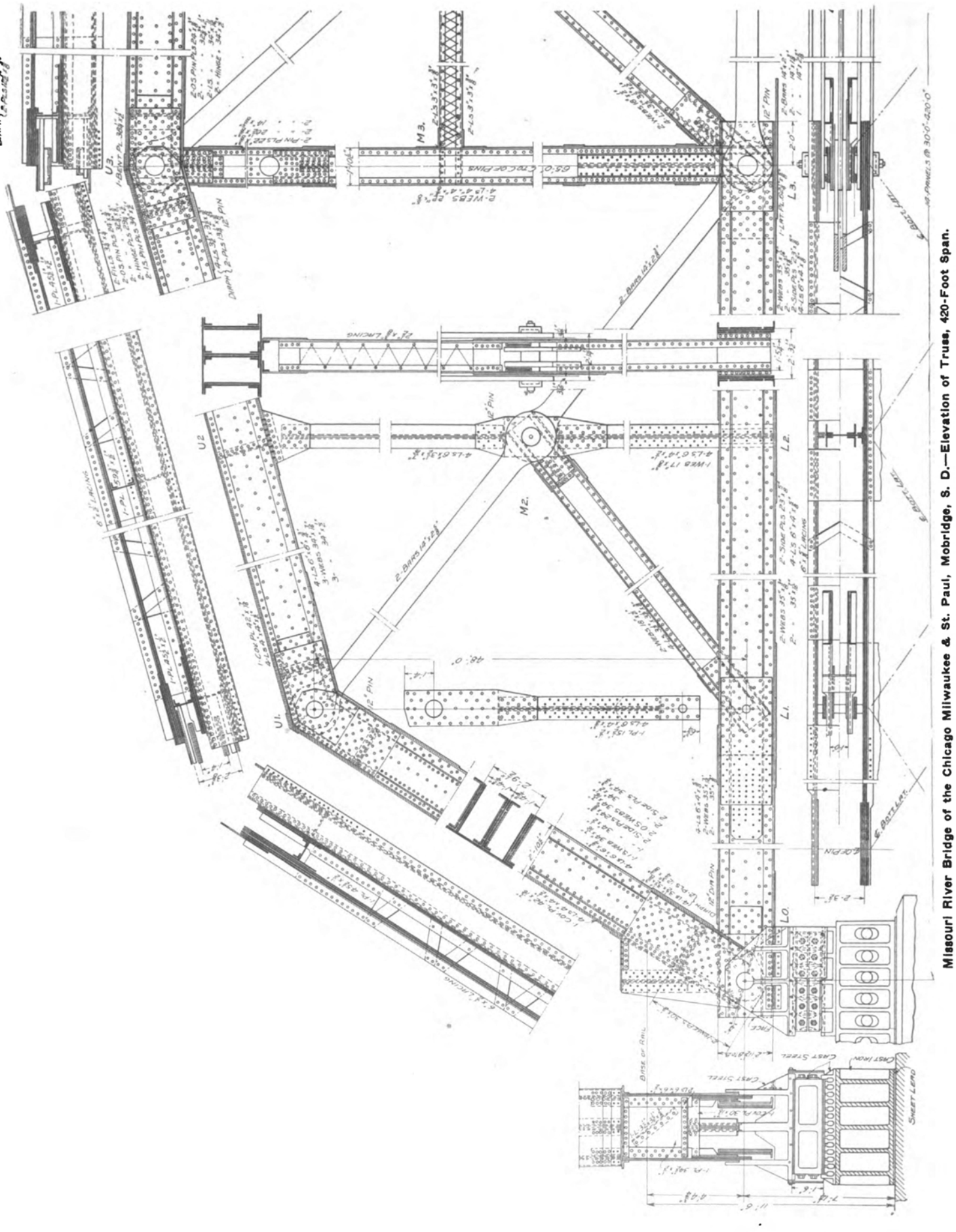
Missouri River Bridge of the Chicago Milwaukee & St. Paul—Stress Diagram.

The air pipe, water pipe and three discharge pipes are four inches in diameter. Electric light wires were carried down into the caisson through 2-inch pipe.

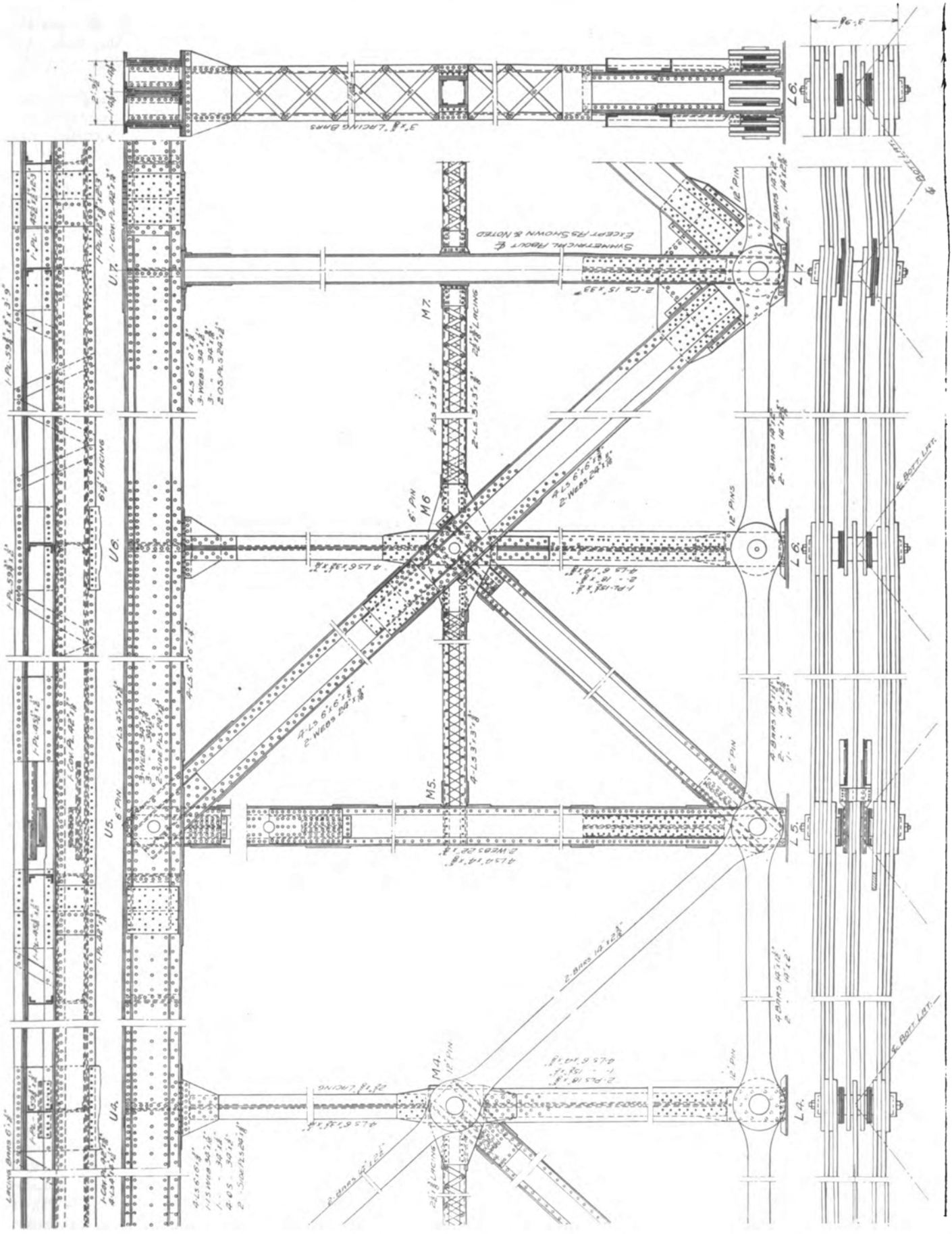
All of the work in connection with this structure is being done by the railway company forces, under the general direction of Mr. Loweth, engineer and superintendent of bridges and buildings.

It is expected that the substructure will be completed this fall and the superstructure erected during the coming winter. In the meantime, the material for the extension necessary to be carried across the river and to the front is being taken over on the temporary pile bridge.

One of the engravings shows a locus of the point of application of the resultant of all longitudinal forces which can come on the pier, combined with the vertical forces in such a way as to give the greatest possible overturning moment on the pier which can ever occur in a direction parallel with the center of track. This drawing shows that,



Missouri River Bridge of the Chicago Milwaukee & St. Paul, Mobridge, S. D.—Elevation of Truss, 420-Foot Span.



Missouri River Bridge of the Chicago Milwaukee & St. Paul, Mobridge, S. D.—Elevation of Truss, 420-Foot Span.

while the resultant at some sections falls outside of the middle third, the pier has a proper factor of safety against overturning or crushing.

Superstructure.

The general drawings of the 420-foot trusses show the design in detail. The top chord was made horizontal for a distance of eight panels. This does not present the graceful appearance of a top chord, which approximates the arc of a circle or a parabola, but has the advantage that at panel point U-5 it is not necessary to transmit the entire chord stress from chord U-3 U-5 through pin plates to chord U-5 U-7. Instead, the pin plates are built of only sufficient thickness to transmit the increment of chord stress at this point due to member U-5 M-6. The stress in chord U-3 U-5 is transmitted to chord U-5 U-6 through a bearing joint to the left of panel point U-5.

In order to keep the grip of rivets within a length which would permit of their being driven tight in any shop, and also to reduce the bending in the chord pins and in the rivets in the pin plates, it was necessary to make the top chord and end posts with three webs, as shown.

The form of the hangers M-6 L-6 and M-4 L-4 was determined by the bending due to the component of the bottom lateral stress parallel to the center line of the truss, acting through a lever arm equal to the distance from the center of the bottom chord pin to the plane of the bottom lateral plates at L-4 and L-6.

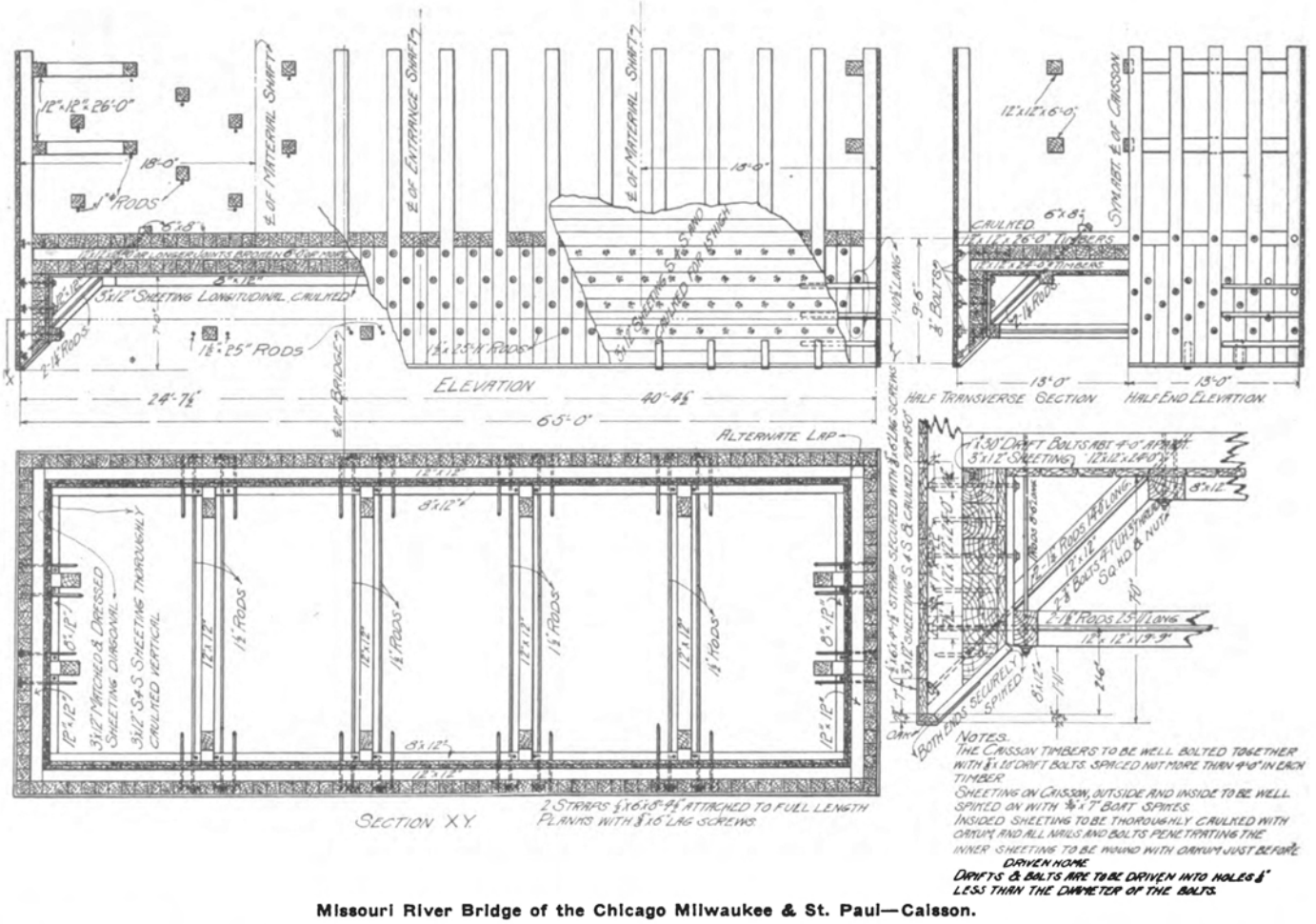
It was thought that it might be possible to design expansion rollers for this bridge with faces of some non-corrosive metal. However, as no satisfactory way was found for connecting such a metal to the face of the rollers, rollers were used made of cast steel throughout.

The roller bed is shown to be of a single steel casting instead of the usual construction of track rails riveted together. This permits of thickening the webs of the rails to whatever amount is made necessary by the compression in the rail web and the necessary lateral stability for each rail.

Diaphragms placed at right angles to the axis of the member are shown in the members having three webs. These diaphragms keep the pin holes straight and true by maintaining the webs of the main members parallel and at exact distances, center to center of webs, both while the member is being bored or faced and during the handling it receives before being placed in the structure. Diaphragms will also be found parallel to the axis of some compression members which keep the length of unsupported jaws to a proper minimum.

The distance between the first gauges on the outstanding leg or stringer connection is 10 inches. This permits of the slight increase in distance center to center of floor beams because of the elongation of the bottom chord under live load, by a sort of hinge action in the stringer connection.

The specifications of this structure conform to the general specifications for steel railway bridges, as approved by the American Railway Engineering and Maintenance of Way Association, March, 1906, except the additions and modifications in details made necessary by the unusual size of this structure. Connection angles for floor beams and stringers will be milled after riveting. All 12-inch pins to be bored with a 2-inch diameter hole through the center to permit inspection of the interior of the pin and relieve the internal stresses. Eye-bars are to be thickened at the head



Missouri River Bridge of the Chicago Milwaukee & St. Paul—Caisson.

by an amount equal to 16 per cent of the thickness of the body of the bar.

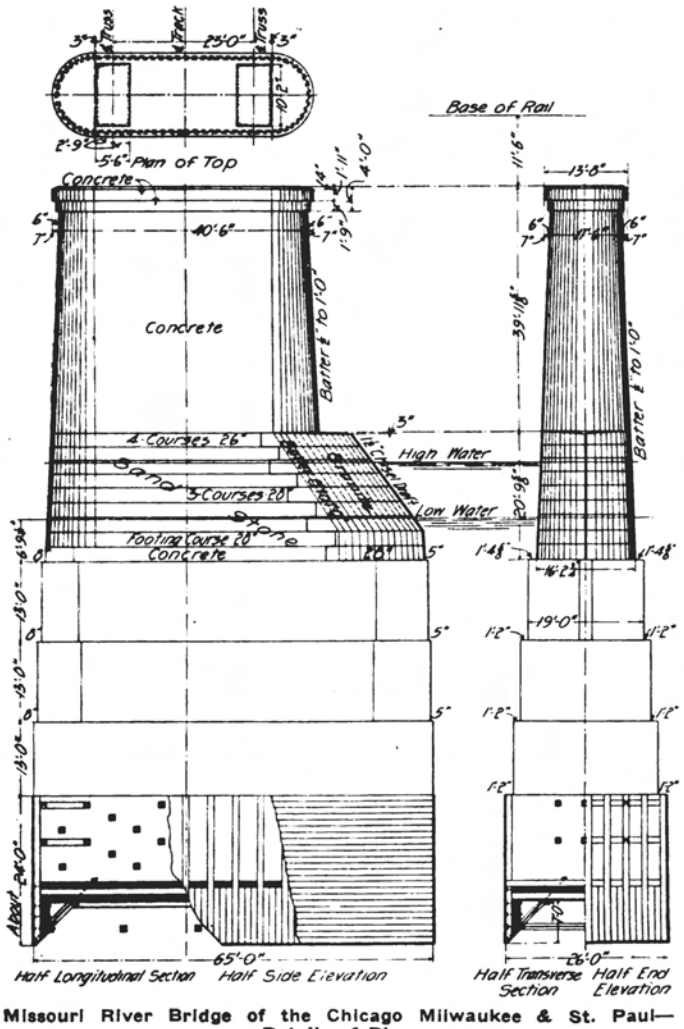
The other modifications are as follows, the paragraph numbers corresponding to those in the standard specifications (The Railway Age, March 23, 1906, page 486):

MATERIAL.

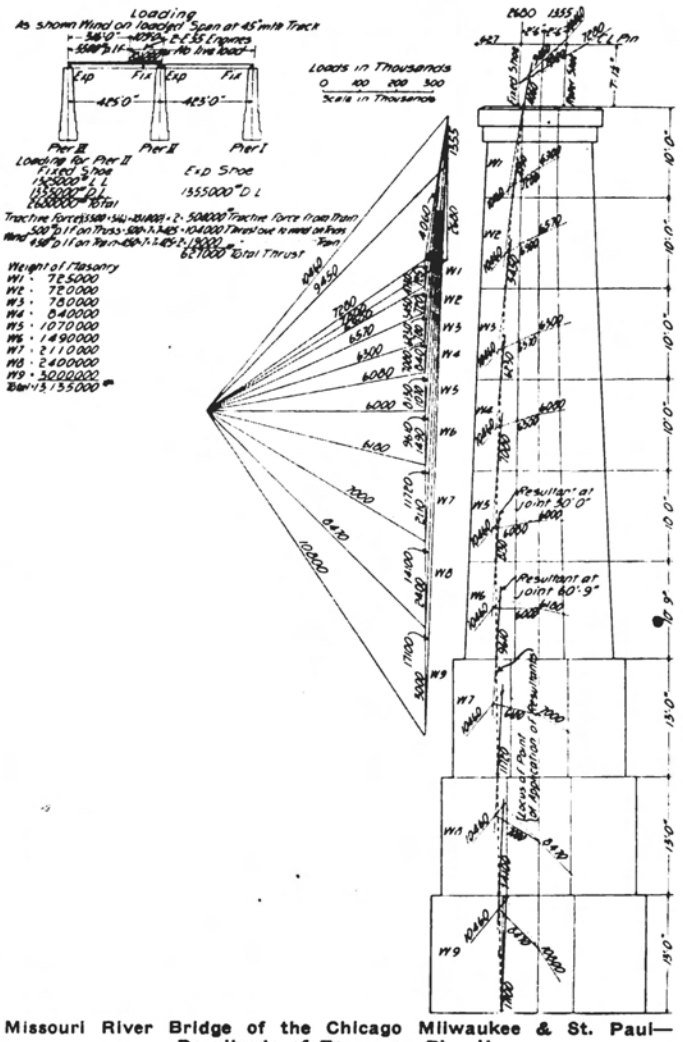
84. Maximum phosphorus, acid process, changed from 0.08 per cent to 0.06 per cent. Desired ultimate tensile strength for structural steel changed from 60,000 pounds to 63,000 pounds per square inch.

SHOP MANUFACTURE.

111. The workmanship and finish shall be equal to the best practice in modern bridge works. All material arriving from the mills shall be protected from rust by being stored under cover, or being oiled, and shall have clean surfaces,



Missouri River Bridge of the Chicago Milwaukee & St. Paul—Details of Pier.



Missouri River Bridge of the Chicago Milwaukee & St. Paul—Resultants of Forces on Pier II.

free from heavy scale or rust, before being worked on in the shops. (a).

112. Material shall be thoroughly straightened in the shop, by methods that will not injure it, before being laid off or worked in any way. Templets shall be laid flat without distortion while work is being laid out. (b).

113. Shearing and chipping shall be neatly and accurately done and all portions of the work exposed to view neatly finished. (d).

114. The size of rivets, called for on the plans, shall be understood to mean the actual size of the cold rivet before heating.

All parts of the structure shall have sub-punched and reamed rivet holes, except lateral, portal, sway and stringer bracing, batten plates and lacing of members having the lacing connected with one rivet. (c).

115. Where reaming is not required the diameter of the punch shall not be more than 1-16 inch greater than the diameter of the rivet; nor the diameter of the die more than ⅛ inch greater than the diameter of the punch. (d).

(a) Modified and enlarged. (b) Modified by additional clause. (c) New paragraph. (d) Modified. (e) Last sentence added.

116. All punching shall be accurately done. Drifting to enlarge unfair holes will not be allowed. If the holes must be enlarged to admit the rivet, they shall be reamed. Poor matching of holes will be cause for rejection. Sub-punching for reamed work shall be so accurately done that after reaming no punched surface shall appear in the periphery of the hole. (e).

117. Where reaming is required, the punch used shall have a diameter not less than 3-16 inch smaller than the nominal diameter of the rivet. Holes shall then be reamed to a diameter not more than 1-16 inch larger than the nominal diameter of the rivet. All reaming shall be done with twist drills, held at right angles to the surface. (See 132) (b).

118. When general reaming is required it shall be done after the pieces forming one built member are assembled and so firmly bolted together that the surface shall be in close contact. If necessary to take the pieces apart for shipping and handling, the respective pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No interchange of reamed parts will be allowed. (a).

119. Sheared edges or ends will generally not be required to be planed. (d).

120. The outside burrs on reamed holes shall be removed to the extent of making a 1-16-inch fillet. (d).

126. Connection angles for floor beams and stringers shall be flush with each other and correct as to position and length of girder. They shall be milled to exact lengths after being riveted up complete. The removal of more than 3-32 inch from thickness will be cause for rejection, and the cutting shall extend over the entire face of the connection. (d).

138. Screw threads shall make tight fits in the nuts and shall be United States standard, except for 1⅜-inch diameter and larger, when they shall be made with six threads per inch. Upset ends shall have an excess net section at root of threads of 15 per cent over that of body of bar. (d).

140. All steel castings shall be annealed. They shall be free from large or injurious blow holes. (e).

142. Expansion bed plates shall be planed true and smooth. Cast wall plates shall be planed top and bottom. The cut of the planing tool shall make a fine cut corresponding with the direction of expansion. All expansion bearings shall be assembled complete in the shop. (d).

SHOP PAINTING.

148. Steel work, before shipment, shall be thoroughly cleaned and given one good coating of pure linseed oil, well worked into all joints and open spaces. Any brand of paint may be substituted at the option of the purchaser at the net increase of cost of the paint over oil. (d).

157. The manufacturer will be furnished complete shop plans. (d).

158. Two complete copies of shipping invoices shall be furnished to the purchaser with each shipment. These shall show the scale weights of all individual pieces.

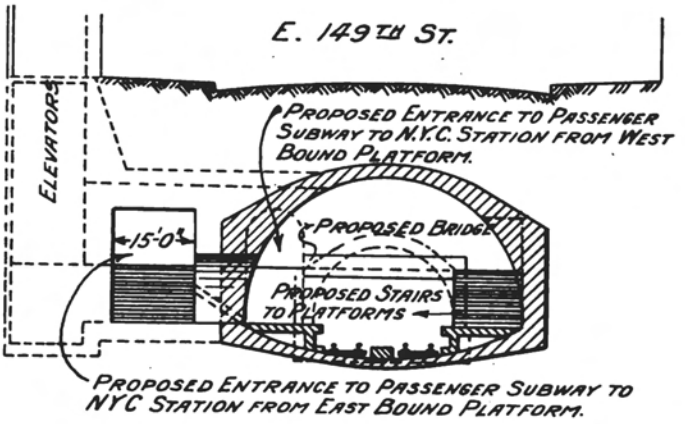
No material shall be loaded on cars for shipment until inspected and accepted by the inspector, and stamped with his individual stencil. The finishing of material on cars will not be permitted. (d).

BRONX IMPROVEMENT OF THE NEW YORK CENTRAL.

A comprehensive general account of the work which the New York Central is doing and proposes to do in the territory known as the electric zone was given in The Railway Age of January 26, 1906. The work has been progressing steadily in all parts and some of the more extensive alterations required by the change from steam to electric operation are fairly well advanced. Among the more interesting changes of which advantage is taken of the present opportunity to put into effect is that which is known as the Bronx improvement. This involves a complete rearrangement of the tracks and the building of a new station at Mott Haven, which is the junction point of the main line or Hudson River division and the Harlem division.

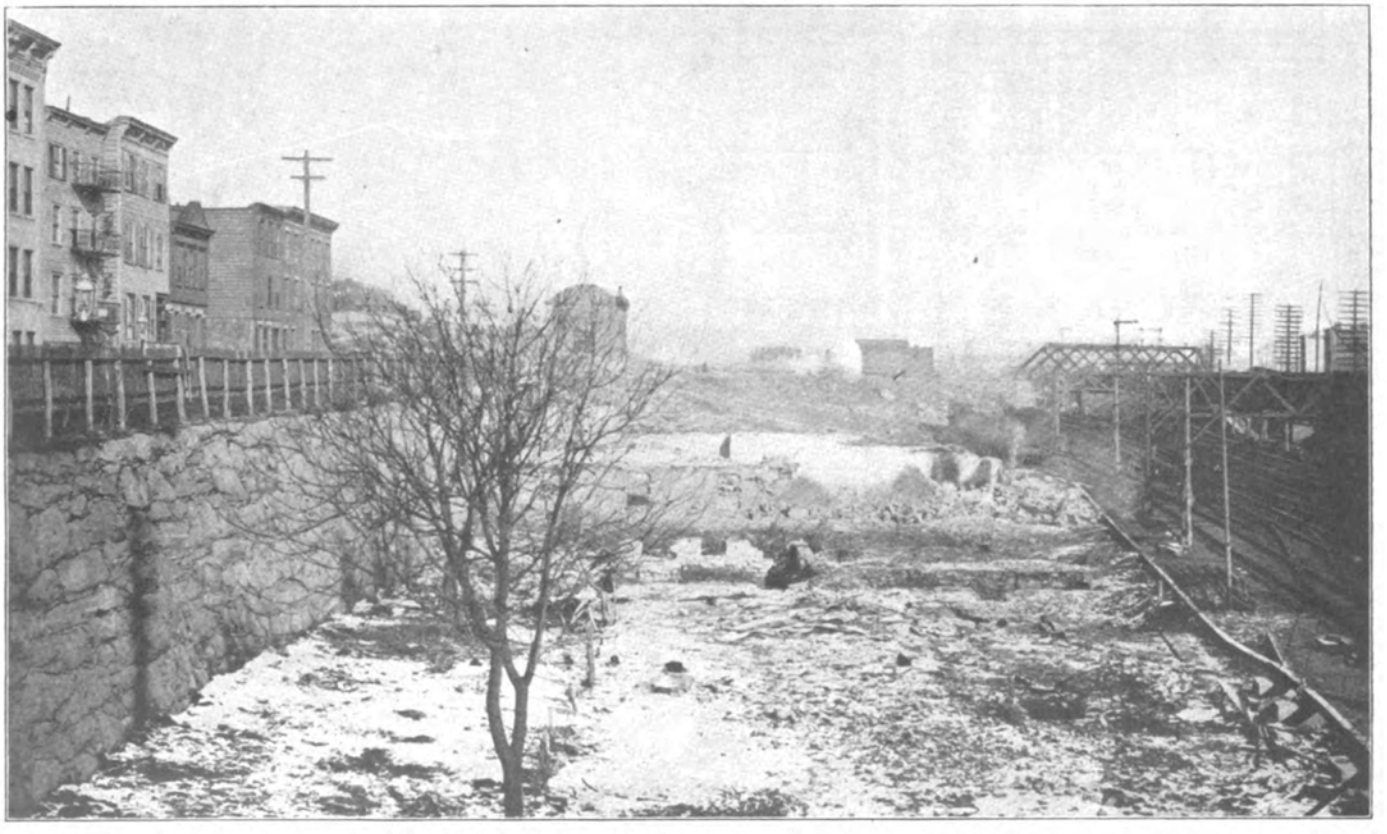
At present the Mott Haven station is at East One Hundred and Thirty-eighth street, between Park avenue and Mott avenue. The future station will be erected at One Hundred and Forty-ninth street, between Park avenue and Spencer place, and will be a much more commodious and imposing structure than the present. It will be the terminal for Bronx borough and the northern part of Manhattan, and it is estimated that this territory will have a population of 1,000,000 by 1910.

A feature, however, of special engineering interest is the arrangement of the tracks by which trains may pass from either division to the main line without the necessity of tracks crossing each other at grade. This arrangement will be understood by reference to the accompanying plan, profile and sections. At present the trains of the New York Central on the Harlem division are run to the left, but within a few weeks this practice will be reversed and trains will be run to the right. On both divisions, as well as on the main line, the two outer tracks are set apart for local traffic and the two inner tracks for express trains. In order, therefore, that southbound local trains from the



CROSS SECTION OF 149TH ST. AT AA.

Bronx Improvement—New York Central.



Bronx Improvement—New York Central—View from One Hundred and Forty-fourth Street.

(a) Modified and enlarged. (b) Modified by additional clause. (c) New paragraph. (d) Modified. (e) Last sentence added.