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## **The Memphis Bridge**

**Morison, George S.**

**New York, 1894**

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[Appendices.]

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APPENDIX C  
APPENDIX A.

ACT OF CONGRESS APPROVED APRIL 24, 1888.

LIST OF ENGINEERS, EMPLOYEES, AND CONTRACTORS.

ENGINEERS AND COMPANY'S EMPLOYEES.

NAME AND OCCUPATION.	TIME OF SERVICE.
<b>RESIDENT STAFF.</b>	
IRVING DICKINSON, Draughtsman.	
O. E. HOVEY, "	
E. H. CONNOR, Inspector of Superstructure,	Jan. 27, 1890, to Nov. 30, 1890.
W. S. MACDONALD, Inspector of Superstructure,	Oct. 1, 1891, " Dec. 24, 1891.
W. R. EDWARDS, { Rodman, . . . . .	May 27, 1889, " Apr. 14, 1890.
{ Asst. Insp. of Superstructure, . . . . .	Apr. 15, 1890, " Jan. 2, 1892.
R. KHUEN, { Rodman, . . . . .	July 16, 1890, " Sept. 4, 1890.
{ Asst. Insp. of Superstructure, . . . . .	Jan. 1, 1891, " Aug. 10, 1891.
W. A. HILL, Asst. Inspector of Superstructure, .	Mar. 9, 1891, " Dec. 28, 1891.
W. L. SMITH, Asst. Inspector of Superstructure, .	Aug. 10, 1891, " Dec. 9, 1891.
F. H. JOYNER, Inspector at Limestone Quarries, .	May 1, 1889, " Dec. 21, 1890.
N. JOYNER, Assistant Inspector at Limestone Quarries, . . . . .	May 19, 1889, " Mar. 31, 1890.
O. T. GEESE, Inspector at Granite Quarries, . .	May 13, 1889, " Aug. 31, 1891.
A. NOBLE, Resident Engineer, . . . . .	Oct. 1, 1888, to May 31, 1892.
M. A. WALDO, Assistant Engineer, . . . . .	Oct. 24, 1888, " Dec. 31, 1892.
J. M. HEISKELL, " . . . . .	Oct. 22, 1888, " Oct. 31, 1891.
W. E. ANGLIER, " . . . . .	Feb. 10, 1889, " May 14, 1892.
E. H. MAYNE, " . . . . .	Nov. 8, 1889, " June 5, 1890.
D. A. MOLITOR, " . . . . .	Sept. 8, 1890, " May 31, 1892.
C. VOGEL, Draughtsman, . . . . .	Nov. 30, 1891, " May 30, 1892.
E. K. BARRETT, Rodman, . . . . .	Jan. 5, 1890, " Apr. 17, 1893.
GEO. REYNOLDS, Inspector of Masonry, . . . . .	Aug. 15, 1889, " Oct. 14, 1889.
JOSHUA DIXON, " . . . . .	Sept. 15, 1889, " Apr. 30, 1891.
AUG. T. HOLMGREN, Inspector of Cement, . . . .	June 16, 1889, " Nov. 28, 1891.
D. A. KELSEY, Clerk, . . . . .	Feb. 8, 1889, " Dec. 31, 1892.
SANFORD MORISON, Clerk, . . . . .	Apr. 21, 1889, " June 5, 1892.
H. C. CHURCHILL, " . . . . .	Jan. 1, 1890, " Sept. 19, 1890.
R. F. THAYER, Time-keeper, . . . . .	May 20, 1889, " June 3, 1892.
JULIUS THOMPSON, " . . . . .	Nov. 11, 1888, " May 16, 1891.
L. S. STEWART, General Foreman, . . . . .	Oct. 26, 1888, " Apr. 25, 1892.
D. LEONARD, Foreman of Pressure Work, . . . .	Nov. 17, 1888, " Oct. 24, 1890.
D. BROPHY, Master Mechanic, . . . . .	Nov. 17, 1888, " Oct. 25, 1890.
C. H. WILSON, Foreman of Mattress Work, . . . .	July 17, 1889, " Jan. 23, 1891.
J. E. GRIFFIN, Foreman of Carpenters, . . . . .	Jan. 25, 1892, " Apr. 12, 1893.
GEO. W. FENTON, Master of Steamers BERTRAM and LINCOLN, . . . . .	Nov. 1, 1888, " July 7, 1890.
W. P. MCNEELY, Master of Tug WELCOME, . . . . .	Mar. 31, 1889, " Mar. 24, 1893.
<b>NON-RESIDENT STAFF.</b>	
E. GERBER, Office Engineer.	
R. MODJESKI, { Chief Draughtsman, . . . . .	Apr. 30, 1890.
{ Chief Inspector of Superstructure, . . . . .	Nov. 7, 1890, to Jan. 31, 1892.

CONTRACTORS.

LEWIS M. LOSS, . . . . .	Masonry.
UNION BRIDGE CO., . . . . .	Superstructure.
ELMIRA BRIDGE WORKS, . . . . .	Sub-contractor.
LASSIG BRIDGE AND IRON WORKS, . . . . .	" "
SCAFFE FOUNDRY AND MACHINE CO., . . . . .	" "
KEYSTONE BRIDGE CO., . . . . .	" "
PITTSBURG STEEL CASTING CO., . . . . .	" "
NEW JERSEY STEEL AND IRON CO., . . . . .	" "
A. & P. ROBERTS & CO., . . . . .	Superstructure.
PITTSBURG BRIDGE CO., . . . . .	" "
BAIRD BROTHERS, . . . . .	Erection.
PENNSYLVANIA STEEL CO., . . . . .	Viaduct Superstructure.
COFRODE & SAYLOR, . . . . .	Sub-contractor.
WILLIAM KELLEY, . . . . .	Earthwork, West Approach.
WILLIAM O'MARA, . . . . .	" " " "
JAMES SAGUIN, . . . . .	West Approach Trestle.
SPEERS & FREEMAN, . . . . .	Sloping and Paving, East Approach.

APPENDIX B.

ACT OF CONGRESS APPROVED FEBRUARY 26, 1885.

AN ACT TO AUTHORIZE THE CONSTRUCTION OF A BRIDGE ACROSS THE MISSISSIPPI RIVER AT MEMPHIS, TENNESSEE.

BE IT ENACTED BY THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA IN CONGRESS ASSEMBLED, That the Tennessee and Arkansas Bridge Company, a corporation organized and created under and by virtue of the laws of the State of Arkansas, and the Tennessee Construction and Contracting Company, a corporation organized and created under and by virtue of the laws of Tennessee, be, and the same are hereby, jointly authorized and empowered to erect, construct, and maintain a bridge over the Mississippi River from or near Memphis, in the State of Tennessee, to or near the town of Hopefield, in the State of Arkansas. Said bridge shall be constructed to provide for the passage of railway trains, and, at the option of the corporations by which it may be built, may be used for the passage of wagons and vehicles of all kinds, for the transit of animals, and for foot passengers, for such reasonable rates of toll as may be approved from time to time by the Secretary of War.

SEC. 2. That any bridge built under this act and subject to its limitations shall be a lawful structure, and shall be recognized and known as a post-route, upon which also no higher charge shall be made for the transmission over the same of the mails, the troops, and the munitions of war of the United States, or for passengers or freight passing over said bridge, than the rate per mile paid for the transportation over the railroad or public highways leading to the said bridge; and it shall enjoy the rights and privileges of other post roads in the United States.

SEC. 3. That said bridge shall be made with unbroken and continuous spans; two spans thereof shall not be less than five hundred and fifty feet in length in the clear, and no span shall be less than three hundred feet in the clear. The lowest part of the superstructure of said bridge shall be at least sixty-five feet above extreme high-water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with

the current of the river. No bridge shall be erected or maintained under the authority of this act which shall at any time substantially or materially obstruct the free navigation of said river; and if any bridge erected under such authority shall, in the opinion of the Secretary of War, obstruct such navigation, he is hereby authorized to cause such change or alteration of said bridge to be made as will effectually obviate such obstruction; and all such alterations shall be made and all such obstructions be removed at the expense of the owner or owners of said bridge. And in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river, caused or alleged to be caused by said bridge, the case may be brought in the circuit court of the United States in which any portion of said obstruction or bridge may be located. Provided further, That nothing in this act shall be so construed as to repeal or modify any of the provisions of law now existing in reference to the protection of the navigation of rivers, or to exempt this bridge from the operation of the same.

SEC. 4. That all railroad companies desiring the use of said bridge shall have and be entitled to equal rights and privileges relative to the passage of railway trains or cars over the same, and over the approaches thereto, upon payment of a reasonable compensation for such use; and in case the owner or owners of said bridge and the several railroad companies, or any one of them, desiring such use, shall fail to agree upon the sum or sums to be paid, and upon rules and conditions to which each shall conform in using said bridge, all matters at issue between them shall be decided by the Secretary of War, upon a hearing of the allegations and proofs of the parties. Provided, That the provisions of section two in regard to charges for passengers and freight across said bridge shall not govern the Secretary of War in determining any question arising as to the sum or sums to be paid to the owners of said bridge by said railroad companies for the use of said bridge.

SEC. 5. That any bridge authorized to be constructed under this act shall be built and located under and subject to such regulations for the security of navigation of said river as the Secretary of War shall prescribe; and to secure

that object the said companies or corporations shall submit to the Secretary of War, for his examination and approval, a design and drawings of the bridge and a map of the location, giving, for the space of two miles above and two miles below the proposed location, the topography of the banks of the river, the shore-line at extreme high and low-water, the direction and strength of the currents at all stages, and the soundings, accurately showing the bed of the stream, the location of any other bridge or bridges, and shall furnish such other information as may be required for a full and satisfactory understanding of the subject; and until the said plan and location of the bridge are approved by the Secretary of War the bridge shall not be built; and should any change be made in the plan of said bridge during the progress of construction, such change shall be subject to the approval of the Secretary of War.

SEC. 6. That the right to alter, amend, or repeal this act is hereby expressly reserved; and the right to require any changes in said structure, or its entire removal, at the expense of the owners thereof, whenever Congress shall decide that the public interests require it, is also expressly reserved.

SEC. 7. That it shall be the duty of the Secretary of War, on satisfactory proof that a necessity exists therefor, to require the companies or persons owning said bridge to cause such aids to the passage of said bridge to be constructed, placed, and maintained at their own cost and expense, in the form of booms, dikes, piers, or other suitable and proper structures for the guiding of rafts, steamboats, and other water-craft safely through the passage-way, as shall be specified in his order in that behalf; and on failure of the company or persons aforesaid to make and establish such additional structures within a reasonable time, the said Secretary shall proceed to cause the same to be built or made at the expense of the United States, and shall refer the matter without delay to the Attorney-General of the United States, whose duty it shall be to institute, in the name of the United States, proceedings in any circuit court of the United States in which such bridge or any part thereof is located for the recovery of the costs thereof; and all moneys accruing from such proceedings shall be covered into the Treasury of the United States.

Engineering	.....	.....	.....
Tools and Machinery	.....	.....	.....
Earthwork, West Approach	.....	.....	.....
Earthwork, East Approach	.....	.....	.....
West Approach Trestle	.....	.....	.....
Sloping and Paving East Approach	.....	.....	.....

PERMANENT STAFF	.....	.....	.....
NON-RESIDENT STAFF	.....	.....	.....
E. GERBER, Office Engineer	.....	.....	.....
R. MODRARI, Chief Draughtsman	.....	.....	.....
R. MODRARI, Chief Inspector of Superstructure	.....	.....	.....

Apr. 30, 1890  
Nov. 1, 1890, to Jan. 31, 1892

## APPENDIX C.

## ACT OF CONGRESS APPROVED APRIL 24, 1888.

AN ACT TO AUTHORIZE THE CONSTRUCTION OF A BRIDGE  
ACROSS THE MISSISSIPPI RIVER AT MEMPHIS, TENNESSEE.

BE IT ENACTED BY THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA IN CONGRESS ASSEMBLED, That the Kansas City and Memphis Railway and Bridge Company, a corporation created and organized under and by virtue of the laws of the State of Arkansas, its successors and assigns, be and the same are hereby authorized and empowered to erect, construct, and maintain a bridge over the Mississippi River, from or near the town of Hopefield in the State of Arkansas, to or near the taxing district of Shelby County, commonly known as the city of Memphis, in the State of Tennessee. Said bridge shall be constructed to provide for the passage of railway trains and wagons and vehicles of all kinds, for the transit of animals, and, at the option of the corporation by which it may be built, for foot-passengers, for such reasonable rates of toll as may be approved from time to time by the Secretary of War.

SEC. 2. That any bridge built under this act and subject to its limitations shall be a lawful structure, and shall be recognized and known as a post-route, upon which also no higher charge shall be made for the transmission over the same of the mails, the troops, and munitions of war of the United States, than the rate per mile paid for the transportation over the railroad or public highways leading to the said bridge, and it shall enjoy the rights and privileges of other post-roads in the United States.

SEC. 3. That the said bridge shall be made with unbroken and continuous spans. Before approving the plans for said bridge the Secretary of War shall order three engineer officers from the Engineer Bureau to be detailed to the duty of examining, by actual inspection, the locality where said bridge is to be built, and to report what shall be the length of the main channel span and of the other spans. *Provided*, That the main channel span shall in no event be less than seven hundred feet in length, or the other spans less than six hundred feet each in length; and if the report of said officers shall be approved by the Secretary of War, the spans of said bridge shall be of the length so required. The lowest part of the superstructure of said bridge shall be at least seventy-five feet above extreme high-water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with the current of the river. No bridge shall be erected or maintained under the

West Approach must descend 85 feet. I should propose to make  
with a 1.25 grade (63 feet per mile) which will require a distance of 345 feet  
all of which would be on a straight line. Of this, I have estimated on building

authority of this act which shall at any time substantially or materially obstruct the free navigation of said river; and if any bridge erected under such authority shall, in the opinion of the Secretary of War, obstruct such navigation, he is hereby authorized to cause such change or alteration of said bridge to be made as will effectually obviate such obstruction; and all such alterations shall be made and all such obstructions be removed at the expense of the owner or owners of said bridge; and in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river caused or alleged to be caused by said bridge, the case may be brought in the circuit court of the United States within whose jurisdiction any portion of said obstruction or bridge may be located. *Provided further*, That nothing in this act shall be so construed as to repeal or modify any of the provisions of law now existing in reference to the protection of the navigation of rivers, or to exempt this bridge from the operation of the same.

SEC. 4. That all railroad companies desiring the use of said bridge shall have and be entitled to equal rights and privileges relative to the passage of railway trains or cars over the same, and over the approaches thereto, upon payment of a reasonable compensation for such use; and in case the owner or owners of said bridge and the several railroad companies, or any one of them, desiring such use shall fail to agree upon the sum or sums to be paid, and upon rules and conditions to which each shall conform in using said bridge, all matters at issue between them shall be decided by the Secretary of War, upon reasonable notice to the parties in interest and upon consideration of such allegations and proofs as may be submitted to him. But the last foregoing provision shall not be held to exclude the ordinary jurisdiction of the courts of the United States in such cases.

SEC. 5. That any bridge authorized to be constructed under this act shall be built and located under and subject to such regulations for the security of navigation of said river, as the Secretary of War shall prescribe; and to secure that object, the said companies or corporations shall submit to the Secretary of War, for his examination and approval, a design and drawings of the bridge and a map of the location, giving, for the space of two miles above and two miles below the proposed location, the topography of the banks of the river, the shore-lines at extreme high and low water, the direction and strength of the currents at all stages, and the soundings, accurately showing the bed of the stream, the location of any other bridge or bridges, and shall furnish such

and the brown clay at -101, the material being identical with that  
found on the west side. The next boring was made 100 feet farther east, or a

other information as may be required for a full and satisfactory understanding of the subject; and until the said plan and location of the bridge are approved by the Secretary of War, the bridge shall not be built or commenced; and should any change be made in the plans of said bridge during the progress of construction, such change shall be subject to approval of the Secretary of War, and shall not be made or commenced until the same is so approved.

SEC. 6. That it shall be the duty of the Secretary of War, on satisfactory proof that a necessity exists therefor, to require the company or persons owning said bridge to cause such aids to the passage of said bridge to be constructed, placed, and maintained at their own cost and expense, in the form of booms, dikes, piers, or other suitable and proper structures for the guiding of rafts, steamboats, and other water-craft safely through the passage-way, as shall be specified in his order in that behalf; and on failure of the company or persons aforesaid to make and establish and maintain such additional structures within a reasonable time, the said Secretary may cause the said bridge to be removed at the expense of the owners thereof, or may proceed to cause the same to be built or made at the expense of the owners of said bridge, and in that case shall refer the matter without delay to the Attorney-General of the United States, whose duty it shall be to institute, in the name of the United States, proceedings in any circuit court of the United States within whose jurisdiction such bridge or any part thereof is located, for the recovery of the amount so expended by the Government and all costs of such proceedings; and all moneys accruing from such proceedings shall be covered into the Treasury of the United States.

SEC. 7. That if the construction of the bridge hereby authorized shall not be commenced within one year from the time this act takes effect, and be completed within four years after the same date, then this act shall be void, and all rights hereby conferred shall cease and determine.

SEC. 8. That an act entitled "An act to authorize the construction of a bridge across the Mississippi River at Memphis, Tennessee" approved February twenty-sixth, eighteen hundred and eighty-five, be, and the same is, hereby repealed.

SEC. 9. That the right to alter, amend, or repeal this act is hereby expressly reserved, and the right to require any changes in said structure, or its entire removal, at the expense of the owners, whenever the Secretary of War shall decide that the public interests require it, is also expressly reserved.

part of the river.  
These two plans have been considered separately and estimates made.

APPENDIX C.  
APPENDIX D.

ACT OF CONGRESS APPROVED APRIL 24 1888

CONTRACT WITH WAR DEPARTMENT.

other information as may be required for a full and satisfactory understanding

Whereas, By an act of Congress, approved April 24, 1888, entitled "An act to authorize the construction of a bridge across the Mississippi River at Memphis, Tennessee," it was enacted that the Kansas City & Memphis Railway and Bridge Company, a corporation created and organized under and by virtue of the laws of the State of Arkansas, its successors and assigns, be, and the same are hereby authorized and empowered to erect, construct, and maintain a bridge over the Mississippi River from or near the town of Hopefield, in the State of Arkansas, to or near the taxing district of Shelby County, commonly known as the city of Memphis, in the State of Tennessee; and,

Whereas, It is provided by section 5 of the act of Congress aforesaid, That any bridge authorized to be constructed under this act shall be built and located under and subject to such regulations for the security of navigation of said river as the Secretary of War shall prescribe; and to secure that object, the said companies or corporations shall submit to the Secretary of War, for his examination and approval, a design and drawings of the bridge, and a map of the location, giving, for the space of two miles above and two miles below the proposed location, the topography of the banks of the river, the shore lines at extreme high and low water, the direction and strength of the currents at all stages, and the soundings, accurately showing the bed of the stream, the location of any other bridge or bridges, and shall furnish such other information as may be required for a full and satisfactory understanding of the subject; and until the said plan and location of the bridge are approved by the Secretary of War, the bridge shall not be built or commenced; and should any change be made in the plans of said bridge during the progress of construction, such change shall be subject to approval of the Secretary of War, and shall not be made or commenced until the same is so approved; and

Whereas, The original plans were submitted to a board of Engineer Officers

for examination and report, as provided in section 3 of the act of Congress aforesaid; and,

Whereas, The report submitted by said board was not approved by the Secretary of War; and,

Whereas, The Kansas City & Memphis Railway and Bridge Company aforesaid has accepted the provisions of the act of Congress aforesaid, and in compliance therewith has submitted to the Secretary of War for his examination and approval a design and drawing of a proposed bridge across the Mississippi River, the main channel span of which is not less than seven hundred feet in length, and the other spans not less than six hundred feet in length, and the lowest part of the superstructure is seventy-five feet above extreme high-water mark, and has also submitted a map of the location thereof;

Now, therefore, I, William C. Endicott, Secretary of War, having examined and considered the plans of said bridge, and the map of the location thereof, submitted by the Kansas City & Memphis Railway and Bridge Company aforesaid, and which are hereto attached, do hereby approve the same, subject, however, to the following conditions, viz.:

1. That the Kansas City & Memphis Railway and Bridge Company shall provide an independent roadway for wagons and animals on each approach of said bridge, and, for the entire length of the bridge proper, a roadway of sufficient width for wagons to pass each other without inconvenience, to be used by wagons and animals in common with the railroad.
2. That said bridge shall be open for the passage of wagons and animals at all times except when trains are actually crossing.
3. That reasonable signals shall be given when trains are approaching the bridge, and no train shall be permitted to enter the common roadway until the wagons which are on the roadway when the signal is given have passed off of said common roadway.

AN ACT TO AUTHORIZE THE CONSTRUCTION OF A BRIDGE

ACROSS THE MISSISSIPPI RIVER AT MEMPHIS, TENNESSEE.  
4. That whenever in the opinion of the Secretary of War the roadway above provided for does not afford ample means for the passage of wagons and vehicles of all kinds, and the transit of animals, the Secretary of War may require the Railway and Bridge Company aforesaid to furnish a Ferry Train, consisting of such a number of large box cars with continuous floor, sides, and top, as he may deem necessary for the transportation of said wagons and vehicles, and the transit of animals across said bridge, and may require said company to receive and land said wagons, vehicles, and animals at such point as he may designate on each side of said river; and may prescribe the intervals at which said Ferry Train shall cross said bridge for the accommodation of said wagons, vehicles, and animals.

5. The right to require changes in said structure, if the public interest demands them, being reserved to the Secretary of War in section 9 of said act.

6. That the Engineer Officer of the United States Army in charge of the district within which the bridge is to be built may supervise its construction so far as may be necessary in order that the plans herein approved shall be complied with and the bridge built accordingly.

Witness my hand this twenty-third day of August, 1888.

WM. C. ENDICOTT,  
Secretary of War.

This instrument is also executed by the Kansas City & Memphis Railway and Bridge Company, by George H. Nettleton, its President, thereunto lawfully authorized, this twenty-third day of August 1888, in testimony of the acceptance by said company of the provisions of the act of Congress aforesaid, and of the conditions herein imposed.

KANSAS CITY & MEMPHIS RAILWAY AND BRIDGE COMPANY.  
In presence of ) By GEO. H. NETTLETON,  
F. H. DAMON. ) President.

The lowest part of the superstructure of said bridge shall be at least seventy-five feet above extreme high-water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with the current of the river. No bridge shall be erected or maintained under the



THREE SPAN BRIDGE.

The four piers of the Three Span Bridge would be numbered from east to west. Pier I would be located on the bench at the foot of the bluff where the elevation of the ground is about 8 and at station 104; Pier II would be at station 110 + 60, in the deepest water of the river; Pier III would be at station 117 + 25, or at the west edge of the strong current; Pier IV would be at station 123 + 85, close to the west bank and about at the low water shore line.

I have estimated on sinking the foundation of Pier IV to -55, or about three feet into the blue clay; on sinking the foundation of Pier III to -79, or about three feet into the light-colored clay; and on sinking the foundation of Pier II to -105, or through the light clay to the brown clay. The borings at the base of the bluff are not yet complete, but I have estimated on sinking this foundation to the same depth as that of Pier IV.

The foundation of Pier IV offers no special difficulties, it being in very shallow water and the depth being materially less than foundations I have lately put in on the Missouri River. The same may be said of the foundation of Pier I. The depth to which the foundation of Pier III must be sunk is no greater than that of our deep foundations at Omaha, but the foundation and the pier would be very large. At Pier II the difficulties are undoubtedly great, especially if it is found necessary to go as deep as I have estimated, namely, to -105, which is deeper than any foundation I know of which has been carried to any hard material, though by carefully choosing the time of year it might not be necessary to work in any deeper water than was done at the east abutment of the St. Louis Bridge.

For the present I have thought it best to estimate on putting in all four foundations by the pneumatic process, as I feel certain that this can be done. It is possible, however, that after we have put in the foundations of Piers III and IV and thereby learned more than we now know of the character of the clays, a better and cheaper method of handling Pier II may be devised.

The great length of span which it is proposed to use will require large masonry piers, and these piers will require foundations of correspondingly large size, especially as they are to rest on clay and not rock. I have estimated on making Piers II and III 14 feet thick and Piers I and IV 12 feet thick under the coping; the piers to be of limestone and of the form which experience has shown presents the least obstruction to the current and catches the least amount of driftwood, the caissons for Piers I and IV to be of rectangular form 36 feet by 82 feet; the caissons for Piers II and III to be octagonal, the area of base being 3936 feet in Pier II and 3357 feet in Pier III. In pneumatic foundations of ordinary size it is usually desirable to get all the weight possible to facilitate sinking. In foundations of the size we are now considering the reverse will be the case, and it will be desirable to reduce the weight as much as possible. I should propose to build the caisson entirely of oak, to surmount this caisson with a cribwork structure which should terminate at

-31, on which the masonry should rest. The cribwork would be built of timber and concrete, with three large wells, which wells would extend up into the masonry; these wells to be filled with concrete after the foundation is completed. In this way the weight on the roof of the caisson and the weight to be handled while sinking would be reduced to very comfortable limits.

Both Piers II and III should have protection mats around them, which mats should be subsequently ripped. The only protection required at Piers I and IV would be the protection which must at any rate be given to the shores. In my estimates I have provided for all these protections in one item and at a liberal figure.

The superstructure of this bridge would consist of three spans of 656 feet each (200 metres) between end pins, the trusses to be 77 feet deep and 33 feet between centers, and to be built entirely of steel. While these dimensions are greater than those of any trusses yet built, they are entirely within practicable limits and not so great an undertaking now as 400-foot spans were, twenty years ago. I have estimated on simple trusses with straight chords, though it is probable it would be expedient to use a curved upper chord. The details of one of these spans have been studied and a careful estimate made of the weights, showing that the weight of such a span will not exceed 3 600 000 pounds, or a little more than 5000 pounds per foot. To connect the east end of the bridge with the top of the bluff will require a short iron viaduct 240 feet long, the details of which will be similar to that of the longer viaduct on the west side.

The estimated cost of this bridge complete will be as follows:

Pier I.			
3 000 c. y. Masonry at \$20.....	\$60 000		
70 000 c. ft. Cribwork " 40 cts.....	28 000		
60 000 " " Caisson " 80 cts.....	48 000		
Sinking.....	15 000		
		\$151 000	
Pier II.			
4 200 c. y. Masonry at \$20.....	\$84 000		
163 000 c. ft. Cribwork " 40 cts.....	65 200		
70 000 " " Caisson " 80 cts.....	56 000		
Sinking.....	40 000		
		245 200	
Pier III.			
4 200 c. y. Masonry at \$20.....	\$84 000		
80 000 c. ft. Cribwork " 40 cts.....	32 000		
57 000 " " Caisson " 80 cts.....	45 600		
Sinking.....	35 000		
		186 600	
Pier IV.			
3 000 c. y. Masonry at \$20.....	\$60 000		
70 000 c. ft. Cribwork " 40 cts.....	28 000		
60 000 " " Caisson " 80 cts.....	48 000		
Sinking.....	15 000		
		151 000	
Outfit for Foundation Work.....		50 000	
Protection Work, including Mats and Riprap of Piers II and III, and Shore Protection at Piers I and IV.....		100 000	
TOTAL SUPERSTRUCTURE.....			\$888 800

Three 656 ft. Spans, 10 800 000 lbs. at 6 cts.....	\$648 000	
Floor and Painting.....	15 000	
TOTAL SUPERSTRUCTURE.....		663 000
TOTAL BRIDGE PROPER.....		\$1 546 800
East Approach.		
240 ft. Iron Viaduct.....	\$12 000	
West Approach.		
2 400 000 lbs. Iron at 5 cts.....	\$120 000	
3 000 c. y. Masonry at \$10.....	30 000	
Floor and Painting.....	20 000	
3 200 ft. Iron Viaduct.....	170 000	
Wooden Trestle.....	25 000	
TOTAL APPROACHES.....	195 000	207 000
TOTAL BRIDGE AND APPROACHES.....		\$1 753 800
Add 10% for Contingencies.....		175 380
		\$1 929 180
Engineering, etc.....		50 000
		\$1 979 180

This is the entire estimated cost of the bridge ready for rails from the edge of the bluff at Memphis to the foot of the grade on the west side of the river. It includes nothing for real estate damages, and I do not think these ought to amount to anything. It is perhaps entitled to a credit for tracks, as the amount of track which will be required is very much less than that now used in the connections with the transfer landings.

The prices used for caissons and cribwork are those for which experience has shown me this work can be done on the Missouri River. I think there should be a large reduction in these prices at Memphis. The same may be said of the cost of the masonry, but I have not yet examined any stone quarries.

The price for the superstructure (six cents per pound erected) is at least 20 per cent higher than this work could have been contracted for a year ago.

I should hope that the item of contingencies could be saved, and the actual cash cost of the bridge could be kept within \$1 800 000.

If your company should decide to build on this plan the matter of time is an important one. The foundations for Piers III and IV should be put in during the low water season of the present year. These piers should be finished during the Spring of 1888.

The foundation for Pier II should be put in in the Fall, during the low water season of 1888. Pier I can be put in at almost any time. The masonry of Piers I and II should be finished in the Spring of 1889.

The west long span should be raised in the Fall of 1888 and the other two spans in the Fall of 1889.

The approaches should be built in the Spring of 1889.

The bridge could be opened for traffic before the end of 1889. It might be possible to save one season in the construction of this bridge, but in view of the time required to make preparations for a work of this magnitude which would be a straight line, I have estimated on building

nitude I do not think it would be wise to attempt to do so. It must be remembered that the season which can be depended on for working in the river at Memphis is only five months long.

CANTILEVER BRIDGE.

The main span of the Cantilever Bridge would occupy the portion of the river spanned by the two easterly spans of the Three Span Bridge, the length of this span being 1300 feet. This is one half greater than the span of any railroad bridge now in existence, but 300 feet less than the East River Suspension Bridge and 400 feet less than each of the two main spans of the Forth Bridge now building in Scotland.

I have estimated on making the cantilevers 150 feet deep at the ends and building them with curved upper and lower chords, the masonry to finish ten feet above high water. This arrangement is not strictly in accordance with the requirements of the charter hitherto granted; it gives the required height (65 feet) for a distance of about 400 feet at the center, but this height is reduced at either side. It would, however, accommodate the navigation interests of the river perfectly, as there is abundant room in the center for the upper works of large boats and abundant width for tows which are never high. There can be little doubt that if this design should be decided on there would be no difficulty in getting the authority to build it.

To secure lateral stability I have proposed to put the cantilever trusses 75 feet apart at the base and to build them in inclined planes, these planes to be put 15 feet apart at the highest point. To avoid concentrating too much weight on one point I should put the support of the anchorage span 75 feet from the support of the main span. The result of this arrangement would be that the cantilever structure would be supported on each side of the main span by a group of four piers, these piers to occupy the corners of a 75 feet square. This arrangement is similar to that adopted for the Forth Bridge in Scotland.

In the structure I have estimated on, the center of the easterly group of piers is placed at station 104 + 12.5, and the center of the westerly group of piers at station 117 + 87.5, the length of the span, measured from centers of piers next to the channel being 1300 feet, the distance between centers of towers 1375 feet and the distance between centers of piers including towers 1450 feet. The design provides for shore or anchorage arms 375 feet long, which places the east anchorage 240 feet back of the edge of the bluff and places the west anchorage at station 122, or about 150 feet from the low water shore line. It would probably be economical to shorten the east shore arm and to lengthen the west shore arm. With the arrangement as it is now designed, a 225 foot span will be required to reach from the west anchorage to the end of the iron viaduct.

The substructure of this Cantilever Bridge will consist of (1) the east anchorage pier, (2) the group of piers under the east tower, (3) the group of

piers under the west tower, (4) the west anchorage piers and (5) a small pier under the west end of the approach span.

The east anchorage pier will be of the simplest kind, being merely a piece of masonry built in the bluff and of sufficient size to give the weight required for the anchorage. I have estimated on 1200 yards of masonry, but of less expensive character than that of the piers in the river.

The group of piers under the east tower would consist of four piers, each 16 feet in diameter under the coping, resting on caissons 36 feet square and founded at the same depth (+55) as Pier I of the Three Span Bridge.

The group of piers under the west tower would be similar to those under the east tower, except that the caissons would be 40 feet square and the foundations sunk to -79.

The west anchorage pier would be founded on a caisson 35 feet by 75 feet at a depth of -55, and though of considerable dimensions would offer no special difficulties in construction.

A small pier would be required back of the shore line to support the heavy bent at the end of the trestle, which would sustain the shore end of the 225 feet span.

The same shore protection would be required for the east tower as for Pier I of the Three Span Bridge, the same protection around the west tower as around Pier III and the same amount of protection on the west shore as with the other design, the total cost of protection being perhaps two thirds of that required in the Three Span Bridge.

A general plan and strain sheet have been made for this structure, and an approximate estimate of weights. This design, however, has not been worked out with the same degree of detail as the design for the Three Span Bridge, and the estimates, though probably ample, are not as accurate.

The estimated cost of this bridge complete would be as follows:

East Anchorage Pier.....		\$20 000	
East Tower:			
750 c. y. Masonry at \$20.....	\$15 000		
16 000 c. ft. Cribwork " 40 cts.....	6 400		
26 000 " " Caisson " 80 cts.....	20 800		
Sinking.....	7 500		
	\$49 700		
Group of 4 Piers.....		198 800	
West Tower:			
910 c. y. Masonry at \$20.....	18 200		
32 000 c. ft. Cribwork " 40 cts.....	12 800		
32 000 " " Caisson " 80 cts.....	25 600		
Sinking.....	10 000		
	\$66 600		
Group of 4 Piers.....		266 400	
West Anchorage Pier:			
3 300 c. y. Masonry at \$20.....	66 000		
27 000 c. ft. Cribwork " 40 cts.....	10 800		
52 000 " " Caisson " 80 cts.....	41 600		
Sinking.....	12 000		
		130 400	

West Approach Pier.....	5 000	
Outfit for Foundation Work.....	80 000	
Protection Work.....	70 000	
TOTAL SUBSTRUCTURE.....		\$720 600
Cantilever Superstructure.....	14 000 000 lbs.	
One 225 ft. Span.....	400 000 "	
	14 400 000 lbs. at 6 cts.	\$864 000
Floor and Painting.....		15 000
TOTAL SUPERSTRUCTURE.....		879 000
TOTAL BRIDGE PROPER.....		\$1 599 600
West Approach as for Three Span Bridge.....		195 000
TOTAL BRIDGE AND APPROACHES.....		\$1 794 600
Add 10 per cent for Contingencies.....		179 460
		\$1 974 060
Engineering, etc.....		50 000
		\$2 024 060

This is the entire estimated cost of the bridge ready for the rails from the bluff at Memphis to the foot of the grade on the west side of the river. Comparing it with the estimate of the Three Span Bridge, there is but a slight difference in the cost. The main cost of this bridge is the great cantilever superstructure, the accurate weight of which can only be determined after working out a careful design in detail. While I fully believe that the estimate now made is ample, I think the chances of saving the 10 per cent contingency allowance are much less in this last plan than in the former, and that it is probable that the Cantilever bridge would cost \$200 000 more than the Three Span Bridge.

In the matter of time the cantilever structure could probably be built a little quicker than the Three Span Bridge. The foundations for the east tower and anchorage could easily be put in this year and the east half of the structure erected during the Spring of 1888. The foundations for the west tower and anchorage could be put in in the low water season of 1888, the west half of the superstructure erected immediately thereafter and the bridge opened for traffic in the early Summer of 1889.

CONCLUSION.

Comparing the two structures when once completed, I think the Three Span Bridge would be the better one for the railroads. It would be a perfectly simple structure, the expense for maintaining which would be a minimum. It would involve no complicated details, and as it consists simply of straight trusses resting on masonry piers, would be subject to a minimum degree of disturbance should any slight settlement occur in the foundations. In brief, it would fulfill the universal requirement that the simplest structure is the best.



## APPENDIX F.

## REPORT OF AUGUST 2, 1888.

At first it appeared to me that the wiser method would be to build a 730 feet span and the "proper guards" on the Memphis side of the river. This would require a span of 750 feet between centers of piers on the east side of the river and two spans of 620 feet between centers further west. The arrangement of superstructure which then seemed most advisable was a fixed span between the two central piers, with cantilever arms projecting eastward from Pier II and westward from Pier III, the space between the west end of the west cantilever arm and Pier IV (the west pier) to be occupied by a span of about 400 feet. A similar span would extend eastward from the east end of the cantilever arm east of Pier II; but the east end of this span, instead of resting on Pier I, would be carried on the west end of a cantilever arm projecting from Pier I, this cantilever arm being balanced by an arm east of Pier I held down by an anchorage on the shore.

After laying out the plan, I found that this would involve either the construction of an unnecessarily long shore arm for the East cantilever, or the placing of the anchorage pier on the slope of the bluff, where its construction would be expensive and its security imperfect. It appeared, therefore, that the second alternative provided by the Secretary of War, namely, the 770 feet span, would not only relieve your Company of the necessity of building the guiding pier and guards, but would make the construction of both Pier I and the anchorage pier much less expensive than they would be if the 730 feet span were used.

I have, therefore, prepared a design of a bridge of this character, the east anchorage pier being located at the top of the bluff and a safe distance back from its face. The east pier (Pier I) is located so as to stand in nine feet of water at the maximum stage; that is, at station 103+30 (stations being the same as those used in my report of February, 1887). Pier II would be 790 feet west of Pier I, or at station 111+20, Pier III 620 feet farther west or at station 117+40, and Pier IV 620 feet farther on, at station 123+60, which is practically the west edge of the river. This arrangement places Pier I 70 feet farther east than Pier I of the three span bridge covered in report of February, 1887, which will somewhat reduce the cost of the pier. Pier II will be 60 feet farther west than Pier II of the former plan, which gives very slight advantage in construction. Piers III and IV are virtually unchanged.

Piers I, II and III will carry the equivalent of over 700 feet of superstructure each; but the weight of this superstructure would be concentrated on the axes of the piers, so that the piers may be made of minimum thickness. Pier IV will simply carry one end of a 450 feet span, or 225 feet of superstructure, and may be made thinner than the other piers. I have therefore estimated on making Piers I, II and III 12 feet thick, 36 feet between shoulders and 48 feet long over all under the coping, and building them with a half inch batter

to provide can be settled most economically by putting it on the same floor with the railroad; making this floor wide enough for two teams to pass, providing a substantial railing on each side and excluding carriages, teams and animals when trains are crossing. This arrangement is recommended only on the score of economy, but as the highway travel will be exceedingly light it is throughout; Pier IV to be 10 feet thick, 38 feet between shoulders, 48 feet long over all and built with the same batter. It has seemed to me best to start the masonry of Piers II and III below the ordinary bed of the river, the model form of pier having a minimum scouring effect. The result of this change of plan is to increase somewhat the amount of masonry in Piers II and III and to reduce the amount of masonry in Piers I and IV. After our experience at Cairo it has seemed best to build caissons with vertical sides, surmounted by cribwork of the same dimensions and similar construction. The foundations of Piers I and IV present no special difficulties. I have estimated on making the caisson for Pier I 30 feet by 70 feet and 60 feet high, including cribwork; this caisson to be sunk to elevation -45 (the zero being the U. S. Engineer's Gauge), stopping in a substantial clay. The caisson for Pier IV would be 26 feet by 70 feet and 70 feet high, including cribwork, and would be sunk to an elevation of -55. Piers II and III require larger caissons and much deeper sinking. The caisson for Pier II would be 45 feet by 90 feet and 55 feet high, including cribwork, and would be sunk to an elevation of -100, and that of Pier III, 40 feet by 90 feet, 50 feet high, including cribwork, and sunk to an elevation of -83. In the estimate given hereafter the same prices have been used for this work as in my report of February, 1887.

Pier I would contain 2650 yards of masonry; Pier II, 5400 yards; Pier III, 4800 yards, and Pier IV, 2100 yards, besides which there would be about 750 yards in the Anchorage Pier, making the total amount of masonry 15 600 yards, which has been carried into the estimates at \$20 per yard, though I think we could undoubtedly save one dollar and probably two dollars on this price.

It will be observed that the changes in the plans have somewhat increased the cost of Piers II and III, while diminishing that of Piers I and IV.

Approximate estimates have been made of the weight of the superstructure. In these estimates no provision is made for the weight of highway traffic crossing the bridge, as it is assumed that the bridge will be closed to highway traffic while trains are crossing, but the weight of the floor will be 300 pounds more per lineal foot than that of a plain railroad floor. The approximate estimates show that the weight of the entire structure from the anchorage to Pier IV will not exceed 11 000 000 pounds. This is but little more than the weight of the three independent spans of 656 feet each; but being of a more complicated character, the cost of the shopwork would be perhaps a little higher. On the other hand, erection becomes more simple, as no falsework will be required in the channel span. At present prices the cost erected could be safely estimated at 5 $\frac{1}{10}$  cents per pound, but I have carried it out at the same price as before; namely, 6 cents.

The matter of the arrangement of the highway which you are now required

with Street to a Connection with the same railroad on the west side of the river, the present estimate including the following items which were not in former estimate:

East Approach ..... \$100 000  
Four miles of Earthwork ..... 15 000  
Four miles of Track ..... 15 000  
New York, Aug. 2, 1888.

GEO. H. NETTLETON, Esq.,  
President Kansas City & Memphis Railway & Bridge Co.

DEAR SIR: On February 15th, 1887, I made to you a report on the proposed bridge to be built by your Company across the Mississippi River at Memphis, Tenn.

In this report it was assumed that a bridge might be built according to the requirements of the charter then in existence, which allowed the construction of spans of a less length than appeared economical and provided for a head room of 65 feet in the clear above high water.

The Act of Congress approved April 24th, 1888, repeals the charter above referred to and authorizes your Company to build a bridge at Memphis on somewhat different conditions, there being three important changes in the requirements.

FIRST. The minimum length of the channel span is fixed at 700 feet, subject to a report to be made by three officers from the Engineer Bureau, such report to be approved by the Secretary of War.

SECOND. The height in the clear above high water is fixed at 75 feet instead of 65 feet; and

THIRD. The bridge must be constructed to provide for the passage of wagons and vehicles of all kinds and the transit of animals.

The three engineer officers detailed for this purpose failed to agree, the senior officer recommending a clear span of 700 feet and the two junior officers of 1000 feet. All three agreed that the channel span should be next to the Tennessee shore, that the height should be 75 feet above high water and that the location described in my report of Feb. 15th, 1887, was a satisfactory location. The Secretary of War has added a long indorsement to the report of these engineers, the substance of which is covered by the last paragraph but two, which is as follows:

"Plans may be submitted by the RAILWAY AND BRIDGE COMPANY, giving a main channel span on the Memphis side of the river 730 feet long in the clear at low water, and two other spans 600 feet long in the clear at low water; the end piers to be placed at low water on either shore so that the three spans will cover the entire width of the river at low water. All the necessary aids to navigation in passing under the bridge cannot now be determined; but the RAILWAY AND BRIDGE COMPANY may consider the question of a guiding pier with proper guards to the bridge pier on the Memphis side for protection to navigation, or that of placing the pier on the Memphis side in 9 feet of water at the highest stage, making the long span 770 feet."

For the present, therefore, we will assume that the conditions thus prescribed by the Secretary of War are those under which the bridge will be built.

GEO. S. MORSON.

to provide can be settled most economically by putting it on the same floor with the railroad; making this floor wide enough for two teams to pass, providing a substantial railing on each side and excluding carriages, teams and animals when trains are crossing. This arrangement is recommended only on the score of economy, but as the highway travel will be exceedingly light it is not thought that it will give you any serious trouble. I am not at all clear but what the requirements would be met by running a ferry train, but have not thought best to estimate on this. The total estimate shows that the cost of a timber floor adapted to highway traffic, with railings, etc., will be \$10 per foot, or just double the cost of a roadway floor, besides which there will be the additional 300 pounds per foot added to the dead weight of the bridge.

In the matter of approaches, the East Approach, which was formerly very simple, being on the surface of the ground, is rendered much more troublesome and expensive by raising the grade ten feet. The difficulties, however, will principally relate to street crossings and the purchase of the property, the grade being generally about eight feet above the surface of the ground. As I am unable to estimate the value of the real estate required for this approach, the entire cost has been placed, as you suggested, at \$100 000.

The West Approach has, as before, been supposed to be built on a grade of 1½ per cent (66 feet per mile). The elevation of the top of the stringer at Pier IV is 114, or 80 feet above extreme high water at the bridge site. I have estimated on using an iron viaduct 4 800 feet long, the grade at the west end of it being 54, or 17 feet higher than the grade of your level track across the bottom land. West of this trestle the approach can be made in the form of an earth embankment and would connect with the present line of the Kansas City, Ft. Scott & Memphis Railroad about two miles from the end of the viaduct. At present I should advise building this viaduct in spans of 30 feet, the construction being of the simplest possible kind. For foundations I have estimated on using small masonry piers four feet square at the smallest place, the top of the masonry to be at the elevation of 39, resting on blocks of concrete nine feet square, the bottom of the concrete being at elevation 24 and being farther supported by nine piles under each pier. The estimated cost of each of these little piers, including iron anchor rods passing from concrete to top, is \$285. When the piers are finished I should propose to fill around them to a uniform elevation of 37, or two feet above high water, so as to protect the foundations, piles, etc., from the action of frost and water. This would amount to building an embankment 40 feet wide and averaging perhaps eight feet high under the whole of the trestle.

The roadway approach on the east side would amount to little. On the west side, however, it will be necessary to rise from the level of the bottom land. It seems wise to do this in the cheapest possible way. This would be on a timber trestle, which, if built with a grade of six per cent, need not be more than 1200 feet long, and its cost would not exceed \$10 000.

On this basis the following estimate has been prepared of the cost of the bridge as now proposed, this estimate being as nearly as possible in the same form as the estimate accompanying the report of February, 1887:

Pier I.			
2 650 c. y. Masonry at \$20.....	\$53 000		
42 000 c. ft. Caisson " 80 cts.....	33 600		
84 000 " Cribwork " 40 cts.....	33 600		
Sinking.....	15 000		
		\$135 200	
Pier II.			
5 400 c. y. Masonry at \$20.....	\$108 000		
81 000 c. ft. Caisson " 80 cts.....	64 800		
141 750 " Cribwork " 40 cts.....	56 700		
Sinking.....	40 000		
		269 500	
Pier III.			
4 800 c. y. Masonry at \$20.....	\$96 000		
72 000 c. ft. Caisson " 80 cts.....	57 600		
108 000 " Cribwork " 40 cts.....	43 200		
Sinking.....	25 000		
		221 800	
Pier IV.			
2 100 c. y. Masonry at \$20.....	\$42 000		
31 200 c. ft. Caisson " 80 cts.....	24 960		
78 000 " Cribwork " 40 cts.....	31 200		
Sinking.....	10 000		
		108 160	
Outfit for Foundation Work.....		50 000	
Protection Work, including Mats and Riprap of Piers II and III, and Shore Protection at Piers I and IV.....		100 000	
Anchorage.....		16 000	
Sloping and Finishing.....		2 000	
TOTAL SUBSTRUCTURE.....		\$902 660	
11 000 000 lbs. steel at 6 cts.....	\$660 000		
2 200 ft. floor " \$10.....	22 000		
Painting.....	6 000		
TOTAL SUPERSTRUCTURE.....		688 000	
TOTAL BRIDGE PROPER.....		\$1 590 660	
East Approach.....		\$100 000	
West Approach:			
3 400 000 lbs. of iron at 5 cts.....	\$170 000		
320 Piers " \$285.....	91 200		
4 800 ft. floor " \$5.....	24 000		
Painting.....	9 600		
75 000 c. y. Embankment at base.....	15 000		
Earthwork, 2 miles of road.....	15 000		
TOTAL APPROACHES.....		324 800	424 800
Highway Trestle on West side, 1200 ft. at \$8.....		9 600	
Four miles of Track.....		20 000	
TOTAL BRIDGES AND APPROACHES.....		\$2 045 060	
Add 10% for Contingencies.....		204 506	
Engineering.....		50 000	
		\$2 299 566	

This estimate is \$320 186 more than the estimate of February, 1887, or, without providing for contingencies, \$291 260 more.

Under the present plan the bridge proper reaches to the east anchorage, and its length includes the east approach viaduct of the former plan, so that the cost of the bridge proper as now estimated is \$31 860 more than the former estimate.

The former estimate was from the edge of the bluff at Memphis to the foot of the grade on the west side of the river. The present estimate is from a connection with the Kansas City, Fort Scott & Memphis Railroad track in

Fifth Street to a Connection with the same railroad on the west side of the river, the present estimate including the following items which were not in the former estimate:

East Approach.....	\$100 000
West Approach: Two miles of Earthwork.....	15 000
Four miles of Track.....	20 000
TOTAL.....	\$135 000
Add 10% Contingencies.....	13 500
TOTAL.....	\$148 500

So that the cost of the bridge as now designed, including all allowances, is \$171 686 more than the former estimate. This practically represents the additional cost of the requirements which Congress and the Secretary of War now insist upon.

I have prepared a revised plan of the bridge which I expect to submit personally to the Secretary of War on Friday the 3d inst. A copy of this plan accompanies this report. Of course you will not be ready to begin work until this plan has been formally approved, and it will then be too late to do much work in the river this season. If, however, you have determined on building the bridge, I would ask you to give us the authority to put in the foundation of Pier IV this year, and to purchase the steamer BERTRAM, now furnished with a complete pneumatic outfit, which has been used at Rulo and Nebraska City Bridges. The total amount which would be expended for this foundation and the steamer would be less than \$100 000. My idea would be to sink this foundation to the final depth and then sink a test pit within the caisson (as was done at Rulo) and thus determine the character of the lower clays on which the river piers are to be founded. The result of this examination might lead to a very material saving in the cost of the river foundations, as this proved to be the case at Rulo.

If this authority is given, I should propose to do no other work at Memphis until 1889, but to prepare the plans of the two river piers with the utmost possible care, and to put in these two foundations during the low water season in the latter part of 1889. The foundation of Pier I could then be put in at any time and the masonry completed by the summer of 1890. The central span (from Pier II to Pier III) should be erected during the low water season of 1890, and the remainder of the work would be independent of stages of water. I should hope to open the bridge in the early part of 1891.

As to the conduct of the work, my present judgment is that it would not be wise to put in any of the foundations by contract, as the contingencies (that is, in the matter of cost) are so great that any contractor would feel obliged to make his estimates on a basis which would leave him very large profits should everything work well. After the completion of the foundation for Pier IV, it may appear wise to do the work by contract, but my impression is otherwise.

All other parts of the work, including both masonry and superstructure, I should advise letting by contract.

Very respectfully yours,  
GEO. S. MORISON.

APPENDIX G.

ARGUMENT FOR AMENDMENT OF CHARTER.

AMENDATORY ACT.

An Act amendatory of an act to authorize the construction of a bridge across the Mississippi River at Memphis, Tenn., approved April twenty-fourth, eighteen hundred and eighty-eight.

BE IT ENACTED BY THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA IN CONGRESS ASSEMBLED, that Section 3 of the Act entitled "An Act to Authorize the Construction of a Bridge Across the Mississippi River at Memphis, Tenn.," approved April twenty-fourth, eighteen hundred and eighty-eight, be, and the same is hereby amended by striking out the words "seventy-five," and substituting the words "sixty-five," so as to make said section read as follows:

"Sec. 3. That the said bridge shall be made with unbroken and continuous spans. Before approving the plans for said bridge the Secretary of War shall order three engineer officers from the Engineer Bureau to be detailed to the duty of examining by actual inspection the locality where said bridge is to be built, and to report what shall be the length of the main channel span and of the other spans: Provided, That the main channel span shall in no event be less than seven hundred feet in length, or the other spans less than six hundred feet each in length; and, if the report of said officers shall be approved by the Secretary of War, the spans of said bridge shall be of the length so required. The lowest part of the superstructure of said bridge shall be at least sixty-five feet above extreme high water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with the current of the river. No bridge shall be erected or maintained under the authority of this act which shall at any time substantially or materially obstruct the free navigation of said river; and if any bridge erected under such authority shall, in the opinion of the Secretary of War, obstruct such navigation, he is hereby authorized to cause such change or alteration of said bridge to be made as will effectually obviate such obstruction; and all such alterations shall be made and all such obstructions be removed at the expense of the owner or owners of said bridge; and in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river caused or alleged to be caused by said bridge, the case may be brought in the circuit court of the United States within whose jurisdiction any portion of said obstruction or bridge may be located: Provided further, That nothing in this act shall be so construed as to repeal or modify any of the provisions of law now existing in reference to the protection

of the navigation of rivers, or to exempt this bridge from the operation of the same."

Sec. 2. The right to amend or repeal this act is hereby expressly reserved.

OBJECTIONS TO 75 FEET HEAD ROOM.

Besides the increased cost involved, there are two very serious objections to the requirement of 75 feet clear head room.

The first of these lies in the fact that it involves the lifting of the entire traffic which will cross the bridge ten feet higher than a head room of 65 feet would require, and that this represents so much increased expenditure for power and fuel, with a corresponding increase in cost, which must ultimately be borne by the shipper and producer.

The second objection, which is a more serious one, lies in the fact that this height will bring the eastern approach to the bridge about ten feet above the level of the bluff on which the city of Memphis is built, which will interfere with the existing arrangement of streets, and also require a grade on the approach up which it will be necessary to work engines in a manner which is objectionable and disagreeable within a city, and is a source of danger to frame buildings, of which there are many in this part of Memphis.

If the height of the bridge could be fixed at 65 feet instead of 75 feet, all these difficulties would be entirely avoided.

FIRST MEMPHIS BRIDGE CHARTER.

The first charter for a bridge across the Mississippi River at Memphis was granted by an act to authorize the construction of a bridge across the Mississippi River at Memphis, Tennessee, approved February 26th, 1885. This charter fixed the length of the channel spans at not less than five hundred and fifty feet and required the height of the lowest part of the superstructure to be at least sixty-five feet above extreme high water mark.

Section 3 of this act reads as follows:

"Sec. 3. That said bridge shall be made with unbroken and continuous spans; two spans thereof shall not be less than five hundred and fifty feet in length in the clear, and no span shall be less than three hundred feet in the clear. The lowest part of the superstructure of said bridge shall be at least sixty-five feet above extreme high water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with the current of the river. No bridge shall be erected or maintained under the

A list of the boats measured by this act is given in the Appendix, the boats being arranged in the order of the height of their pilot houses without including ornaments.

The Kansas City & Memphis Railway & Bridge Co. is now constructing a bridge across the Mississippi River at Memphis, Tenn. The construction of this bridge was authorized by an Act of Congress approved April 24, 1888, and the bridge is being built in accordance with plans which were approved by the Secretary of War in the same year.

The bridge crosses the Mississippi River with three spans, the span next to the Tennessee shore being 770 feet long in the clear and the other two spans 600 feet long. The actual length of the spans between centers of piers is 790 feet and 5 inches and 621 feet. These spans are without precedent for railroad bridges, except in the single case of the Forth Bridge in Scotland and the Suspension Bridge across the Niagara River, both bridges constructed under circumstances so unlike those of the Memphis Bridge that they cannot be considered as precedents. The long span of 770 feet in the clear is about 100 feet longer than the National Capitol at Washington.

The charter requires this bridge to be 75 feet above high water, which is 22 feet higher than has ever been required for any bridge previously built across any of the western rivers, the greatest height being the requirement for the Ohio River, which is 53 feet above high water.

The four piers of the bridge are now in process of construction. The shore pier on the Tennessee side is begun. The caisson for the first channel pier (the deepest foundation) has been sunk more than 84 feet below low water to the hard clay which underlies the alluvial deposit and is now within 12 feet of its final depth. The caisson for the second channel pier is completed and is now being sunk, being already 50 feet below low water. The foundation of the fourth pier near the Arkansas shore is finished and the masonry has been built above high water.

No objection is raised to the length of span required. The plans of the superstructure are nearly completed, and the work has been contracted for on the basis of the length of spans named above. In spite of the extraordinary length of these spans and the consequent additional cost, no attempt will be made to have the lengths reduced. The condition of the foundation work is conclusive evidence of this.

The height of 75 feet above high water seems, however, to be an unnecessary requirement, and it is earnestly desired to have this height reduced from 75 to 65 feet, which last height it is believed will accommodate the river traffic as well as the greater height now required.

The Kansas City & Memphis Railway & Bridge Co. therefore desires that the following amendatory act should be passed:

authority of this act which shall at any time substantially or materially obstruct the free navigation of said river; and if any bridge erected under such authority shall, in the opinion of the Secretary of War, obstruct such navigation, he is hereby authorized to cause such change or alteration of said bridge to be made as will effectually obviate such obstructions, and all such alterations shall be made and all such obstructions be removed at the expense of the owner or owners of said bridge. And in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river, caused or alleged to be caused by said bridge, the case may be brought in the circuit court of the United States in which any portion of said obstruction or bridge may be located: *Provided further*, That nothing in this act shall be so construed as to repeal or modify any of the provisions of law now existing in reference to the protection of the navigation of rivers, or to exempt this bridge from the operations of the same."

Had the Kansas City & Memphis Railway & Bridge Co. built its bridge under this charter, the longest span which it would be required to build would have been fifty feet shorter than the shortest span in the bridge it is now building, and the head room of the bridge would have been ten feet less than the height now required.

#### REPORT OF BOARD OF ENGINEERS UPON GENERAL BRIDGE LAW.

A bill was introduced in the Fiftieth Congress known as "Senate Bill 275," to authorize the construction of bridges across the Missouri between its mouth and the mouth of the Dakota or James River, and across the Mississippi River between St. Paul, Minn., and Natchez, Miss., and across the Illinois River between its mouth and La Salle, Ill. This bill was referred to a Board of Engineers who made their report on February 23d, 1888. This report is printed, being Senate Executive Document No. 120, 50th Congress, 1st Session. It is also printed in full in the Report of the Chief of Engineers, U. S. A., for 1888.

In this report (page 9) they say:

"The Board feel well assured that, by the use of well known appliances, the upper portions of steamboat chimneys can be lowered to the level of the pilot houses, and as the clear head room they have recommended will pass the pilot houses of the largest boats on the river, they consider that the slight delay which may accompany this operation of lowering the chimneys will be far less onerous to navigation than the great danger and difficulty which must of necessity attend an attempt to pass through a narrow draw opening at high stages of water."

In other words, the Board recognized the fact that smoke stacks can be so easily lowered that it is unwise to insist on bridges being built so as to give the height necessary for boats to pass without lowering their smoke stacks.

In the same report three lists of boats are given (pages 36, 40 and 41) in which the heights of pilot houses and of smoke stacks are noted.

The first is a list of Ohio River coal tow boats. In this list the greatest height of pilot house is 55 feet, the greatest height of chimney 88 feet. These boats pass through bridges 53 feet above high water, and though complaints have been made of the length of spans, no complaints are made of the height above water.

The second list is a list of the St. Louis and New Orleans Anchor Line boats, the largest passenger packets now running on the Mississippi River. The highest pilot house is 65 feet and the highest smoke stack 92 feet. As a matter of fact the height of the pilot house would be reduced to 60 feet by the removal of unnecessary ornamentation, and the smoke stacks are only four feet higher than the smoke stacks of boats on the Ohio River which pass under 53 feet bridges.

The third list is a list of the tow boats of the St. Louis & Mississippi Valley Transportation Co., the highest pilot house being 52 feet and the highest smoke stack 75 feet. These boats are among the most powerful boats which ever ran on the Mississippi River.

The Board of Engineers returned the proposed General Bridge Law with certain amendments, Section 18 of the bill as recommended by this Board reading as follows:

"Sec. 18. That all bridges authorized by this act over the Mississippi River between the mouth of the Ohio River and Natchez, Mississippi, shall be high bridges with unbroken and continuous spans, having at least one channel span of not less than six hundred and fifty feet clear channel way, all other spans over the water-way to have a clear channel way of not less than five hundred feet; and all said spans shall have a clear head room of not less than seventy feet above high water mark."

It appears to have been the conclusion of this Board that a height of five feet more than the height of the highest pilot house of which they had any record was ample for any portion of the Mississippi River. The Report of this Board of Engineers was based on a height of pilot house measured to the top of ornamentation instead of to the top without ornament, which is the correct measurement. This discrepancy probably occurred from the fact that the Board of Engineers, having a limited time at their command, took the heights as given by the steamboat owners instead of having them specially measured, and the character of the upper five or six feet was thus overlooked.

#### OBSERVATION OF HEIGHTS OF STEAMBOATS.

With the view of obtaining the most recent information, a special agent was sent down the Mississippi River from St. Louis to New Orleans and return with instructions to examine every boat on the river and report upon her principal dimensions. This trip was made in November and December, 1889.

While the report of this special agent only covers those boats which were in actual service at the time of his trip, it practically includes every boat now running on the Mississippi River except the Ohio River boats, all of which pass under bridges only 53 feet above high water.

A list of the boats measured by this agent with their principal dimensions is given in the Appendix, the boats being arranged in the order of the height of their pilot houses without including ornaments.

The pilot houses of the western river boats as now built are surmounted by a wooden ornament of absolutely no use, several feet higher than the flat roof of the pilot house. The smoke stacks are also ornamented on top, the ornamentation being often in the form of an open work resembling the feathered head dress of an Indian. In some instances this ornamentation is of solid form, and may be considered an extension of the smoke stack; generally it is only ornamental.

The results of this agent's examinations show that there are only about six steamboats on the Mississippi River whose pilot houses including ornamentation are more than 60 feet high, and that there is not a single boat on which the pilot house without ornamentation is 60 feet high, while there are only six boats in which the height of pilot houses without ornamentation is more than 55 feet.

#### COMPARISON WITH REQUIREMENTS ON TRIBUTARY RIVERS.

The laws under which the two bridges at St. Louis have been built require a head room of 50 feet in the clear above high water, which high water has been interpreted as the height of the St. Louis City Directrix, with an allowance in the case of the new Merchants' Bridge for the slope of the river. The St. Louis City Directrix is 7.6 feet below the extreme high water of 1844, thus making the actual requirement above extreme high water 42.4 feet.

The bridges on the lower Ohio River were built under the provisions of an Act supplementary to an act approved December seventeenth, eighteen hundred and seventy-two, entitled "An Act to authorize the construction of bridges across the Ohio River and to prescribe the dimensions of the same. Approved, February fourteenth, 1883." The closing part of Section 2 of this Act reads as follows:

"*Provided further*, That in lieu of the high draw prescribed above, bridges over the Ohio River below the Covington and Cincinnati Suspension Bridge may be built as continuous bridges with a clear height of fifty-three feet above local highest water, measured to the lowest part of the channel span."

The bridge across the Ohio River at Cairo within four miles of the mouth of the Ohio River, under which every boat passing from the Ohio River to the Mississippi must go, is built in accordance with this law. It is 53 feet above high water, and the range between high and low water at the site of the bridge as determined by the Chief of Engineers is 52.2 feet, making the total height of the bridge 105.2 feet above low water.

At Memphis the range between low and high water is 36 feet, and the requirement of 75 feet head room is not only 22 feet more than is required at Cairo above high water, but corresponds to 5.8 feet more than is required at Cairo above low water.

Geo. S. Monson.

CONCLUSIONS.

The general conclusions which may be drawn are:

First. It is an established fact that the lowering of smoke stacks is a small matter, which is so easily accomplished that it is unjust to require bridge companies to raise their bridges to a sufficient height to enable boats with high stacks to pass through without lowering.

Second. The boats on the Ohio River are now fitted with hinges for lowering their stacks, and the boats on the Mississippi River could easily adopt the same appliances.

Third. The greatest height of pilot houses is ten feet less than the height

required for the Memphis Bridge; and the greatest height of pilot houses without ornamentation, which is the only proper measurement, is fifteen feet less than the height now required.

Fourth. The Kansas City & Memphis Railway & Bridge Co. is building a bridge which from length of its spans and the other general features will form less of an obstruction to navigation than any bridge yet built on any western river.

Fifth. The plan of this bridge in the matter of spans meets the conditions of the General Bridge Law recommended by the Board of Engineers in their Report of February 23d, 1888. The requirements of the act under which the bridge is being built call for five feet more head room than was deemed neces-

sary by such Board of Engineers, and the Report of this Board of Engineers was based on a height of pilot house measured to the top of ornamentation instead of to the top without ornament.

Sixth. A height of SIXTY-FIVE feet would meet all reasonable requirements of navigation and remove from the bridge certain features which are very objectionable both to the bridge company and to the residents of the adjacent portion of the city of Memphis.

GEO. S. MORISON,

Ch. Engr. K. C. & M. R. & B. Co.

CHICAGO, Jan. 4th, 1890.

APPENDIX.

TABLE OF STEAMBOATS ON LOWER MISSISSIPPI RIVER DEC. 1889, ARRANGED ACCORDING TO HEIGHT OF PILOT HOUSE.

ALL HEIGHTS ON BASIS OF BOATS BEING LIGHT.

Name of Boat.	Port.	Line.	When Built.	Kind of Wheel.	Tonnage.	Length.	Height of Stack without Ornament.		Height of Stack with Ornament.		Height of Pilot House without Ornament.		Height of Pilot House with Ornament.	
							FEET.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.
Oliver Biene.....	New Orleans.....	Plan. & Mer. Pk. Co. ....	1886	Side.	1117.78	267.	78	10	88	10	59	9	64	9
City of St. Louis.....	St. Louis.....	Anchor.....	1883	"	1565.17	300.	84	2	91	2	59	7	62	7
City of New Orleans.....	"	"	1881	"	1586.28	290.	83	1	90	1	58	5	62	5
City of Baton Rouge.....	"	"	1881	"	1603.96	280.	83	3	90	3	57	2	62	2
Jesse K. Bell.....	New Orleans.....	Plan. & Mer. Pk. Co. ....	1879	"	921.60	219.4	82	6	86	6	56	6	65	6
City of Vicksburg.....	St. Louis.....	Anchor.....	1881	"	1356.52	273.7	79	2	86	2	55	10	60	10
Arkansas City.....	"	"	1882	"	1236.99	273.7	79	5	86	5	54	8	57	8
City of Providence.....	"	"	1880	"	1303.81	273.1	79	3	86	3	54	8	57	8
Pargoud.....	Louisville.....	Planters Pk. Co. ....	1884	Stern.	711.94	242.	70	11	77	11	54	4	59	3
Paul Tulauc.....	New Orleans.....	Plan. & Mer. Pk. Co. ....	1888	"	617.03	210.	68	4	73	4	54	3	58	3
Belle of Memphis.....	St. Louis.....	Anchor.....	1880	Side.	1222.80	267.	80	9	87	9	54	3	57	3
City of Monroe.....	"	"	1887	"	1038.25	275.	79	0	86	0	54	0	57	0
Guiding Star.....	Cincinnati.....	U. S. Trans. Co. ....	1878	Stern.	1121.97	304.	70	10	74	10	53	1	56	1
City of Cairo.....	St. Louis.....	Anchor.....	1887	Side.	1266.12	271.2	81	5	88	5	52	9	55	9
Crystal City.....	"	"	1887	"	787.43	234.	72	9	78	9	52	4	56	4
James Lee.....	Memphis.....	Lee Line.....	1879	"	747.94	237.	68	0	75	0	52	3	55	3
Kate Adams.....	"	The Mem. Pk. Co. ....	1889	"	665.93	247.5	72	1	87	1	50	7	59	7
Warren.....	New Orleans.....	Mo. & A. Pk. Co. ....	1882	Stern.	316.50	184.	67	1	72	1	50	6	56	6
New South.....	Evansville.....	"	1887	Side.	932.95	257.	66	5	71	5	49	7	54	7
Jay Gould.....	St. Louis.....	St. L. & Miss. V. T. Co. ....	1880	Stern.	466.25	186.8	65	7	67	7	49	2	51	2
Laura Lee.....	New Orleans.....	"	1878	"	377.90	209.	71	6	72	6	48	10	52	10
H. M. Hoxie.....	St. Louis.....	St. L. & Miss. V. T. Co. ....	1888	"	622.30	213.	63	1	65	1	48	9	51	9
T. P. Leathers.....	Cincinnati.....	The N. & N. O. Pk. Co. ....	1885	"	458.60	210.	67	2	74	2	48	7	51	7
Chickasaw.....	Memphis.....	Mem. & White R. Pk. Co. ....	1883	"	733.90	187.	65	7	70	7	48	1	56	1
Belle of the Coast.....	New Orleans.....	"	1880	"	480.17	187.4	64	11	67	11	48	1	56	1
La Fanche.....	"	"	1888	"	403.	165.	64	8	69	8	48	0	52	0
St. John.....	Shieldsboro.....	"	1878	"	382.33	176.	66	5	72	5	48	0	52	0
Rosa Lee.....	Memphis.....	Lee Line.....	1887	Side.	1059.71	210.	68	0	74	0	48	0	52	0
Future City.....	St. Louis.....	St. L. & Miss. V. T. Co. ....	1873	Stern.	589.80	187.4	72	9	74	9	47	7	52	7
De Soto.....	Cincinnati.....	Cinn. Pk. Co. ....	1881	"	881.27	261.	58	10	60	10	47	6	50	6
Lady Lee.....	Memphis.....	Lee Line.....	1889	"	289.31	165.	57	5	62	5	46	8	51	8
Golden Rule.....	Cincinnati.....	"	1877	"	881.27	261.	65	4	70	4	46	7	49	7
Mary Z. Comeaux.....	St. Louis.....	"	1883	"	420.06	177.6	64	4	66	4	46	6	49	6
Whisper.....	New Orleans.....	"	1878	"	362.	180.9	67	11	69	11	46	3	51	3
Danube.....	"	Red R. & Coast.....	1877	"	250.32	175.1	61	6	64	6	46	1	49	1
Coahoma.....	Memphis.....	Lee Line.....	1876	Side.	249.51	205.2	71	2	75	2	45	1	50	1
Bald Eagle.....	St. Louis.....	St. L. & C. Pk. Co. ....	1879	Stern.	454.	202.	50	7	55	7	44	10	47	10
Idlewild.....	"	St. L. & Miss. R. Pk. Co. ....	1879	"	520.36	207.6	58	2	61	2	44	7	51	7
Assumption.....	New Orleans.....	"	1875	"	238.41	150.	63	10	65	10	44	6	48	6
John Howard.....	Louisville.....	"	1871	"	329.69	180.	64	4	66	4	44	6	47	6
My Choice.....	St. Louis.....	St. L. & Miss. V. T. Co. ....	1872	"	462.23	183.	63	0	66	0	44	0	47	0
City of Florence.....	"	St. L. & Tenn. R. Pk. Co. ....	1882	"	358.31	165.	59	6	63	6	43	9	45	9
Cherokee.....	"	Cherokee Pk. Co. ....	1888	"	631.20	183.	57	4	62	4	43	6	45	6
John Gilmore.....	"	St. L. & Miss. V. T. Co. ....	1871	"	563.09	183.	63	1	68	1	43	4	45	4
Gus Fowler.....	Paducah.....	P. & C. Pk. Co. ....	1880	"	309.62	160.	54	1	58	1	43	3	46	3
Sella Wilds.....	Wheeling.....	"	1886	"	289.12	155.	52	4	57	4	43	2	47	2
Ruth.....	Memphis.....	Lee Line.....	1888	"	217.90	166.	53	7	58	7	42	11	45	11
Carnal Goldman.....	Natchez.....	N. & V. Pk. Co. ....	1883	"	172.19	100.	55	11	57	11	42	5	45	5
Teche.....	New Orleans.....	N. O. & B. T. Pk. Co. ....	1886	"	485.90	191.	63	0	67	0	42	4	47	4
Spread Eagle.....	St. Louis.....	Eagle Pk. Co. ....	1881	"	529.34	225.	50	4	55	4	42	1	45	1
E. W. Cole.....	Brashear.....	"	1880	"	487.91	202.	53	8	55	8	41	3	44	3
City of Savannah.....	St. Louis.....	St. L. & Tenn. R. Pk. Co. ....	1889	"	335.55	174.	59	10	65	10	41	2	44	2
E. M. Norton.....	"	St. L. & Miss. V. T. Co. ....	1875	"	549.	174.	57	6	61	6	41	0	43	0
Alto.....	New Orleans.....	"	1879	"	363.16	166.	60	6	62	6	40	7	44	7
Joe Peters.....	Memphis.....	Mem. & Ark. Pk. Co. ....	1883	"	525.	175.	57	6	58	6	40	0	45	0
Iron Duke.....	Pittsburgh.....	"	1880	"	421.25	177.	60	11	62	11	39	7	42	7
Chas. D. Shaw.....	Natchez.....	N. & V. Pk. Co. ....	1883	"	186.03	186.3	49	10	51	10	39	4	42	4
Mable Comeaux.....	St. Louis.....	"	1883	"	160.06	145.	49	6	51	6	38	2	42	2
H. J. Dickey.....	New Orleans.....	"	1881	"	208.54	167.	56	9	57	9	37	6	39	6
Alvin.....	"	N. O. & G. R. R. Co. ....	1877	"	201.55	143.	52	8	54	8	37	3	41	3
Halette.....	"	Red R. & Coast.....	1887	"	196.80	165.	53	5	55	5	36	1	39	1
John D. Scully.....	"	"	1878	"	285.70	218.	65	0	65	0	34	9	38	9
G. W. Sentell.....	St. Louis.....	F. A. Str. B. Co. ....	1882	"	306.76	180.	50	10	53	10	34	8	39	8
Alice Leblanc.....	New Orleans.....	"	1884	"	81.97	135.	46	1	49	1	34	2	38	2
Gen'l Newton.....	U. S. Steamer.....	"	1878	"	263.74	160.	48	11	48	11	35	7	36	7

ORDINANCE OF THE LEGISLATIVE COUNCIL OF THE TAXING DISTRICT OF SHELBY COUNTY, TENNESSEE, PASSED MARCH 23, 1891.

WHEREAS, the Kansas City and Memphis Railway and Bridge Company, a corporation created, organized and chartered under the laws of the State of Arkansas, has petitioned the Legislative Council of the Taxing District of Shelby County, Tennessee, for the right to construct and maintain its tracks and railroad and operate the same with its engines and cars thereon with steam or other motive power across certain streets and across, over and along certain alleys in the said Taxing District, as specified and described in a petition and map filed by the said Kansas City and Memphis Railway and Bridge Company, now on file in the office of the Taxing District of Shelby County, Tennessee; said railroad and tracks being for the purpose of furnishing an eastern approach to the bridge now being constructed by said Kansas City and Memphis Railway and Bridge Company, under an Act passed by the Congress of the United States and approved by the President of the United States, April 24, 1888, pages 92 and 93, Acts of Congress, 1888; and for the right to construct and maintain an incline for an entrance to the wagon way of said bridge, as set forth in said petition and map. Said railroad tracks and approaches are to be located across certain streets and across, over and along certain alleys, as shown by the petition and map aforesaid as follows:

"Beginning at Pier No. one (1) of said bridge near the east bank of the Mississippi River, the said east approach runs southeasterly through said Railway and Bridge Company's property to the north line of Virginia avenue, west of Delaware avenue; thence in the same direction at an angle across the extreme west end of said Virginia avenue into Block No. two (2); thence curving to the left it runs across the extreme northeast corner of said Block No. two (2) to the west line of said Delaware avenue; thence in like manner at an angle across said Delaware avenue into Block No. 3; thence across said Block No. three (3) to the west line of Indiana avenue; thence across Indiana avenue into Block No. five (5), the curve terminating about forty (40) feet east of the west line of said Block No. five (5); thence east to the west line of Arkansas avenue; thence across said Arkansas avenue, at right angles, into Block No. twelve (12); thence east through said Block No. twelve (12) to the west line of Louisiana avenue; thence east across Louisiana avenue, at right angles, into Block No. thirteen (13); thence east across said Block No. thirteen (13) to the west line of Pennsylvania avenue, upon which are located the tracks of the Citizens' Street Railway; thence east across said Pennsylvania avenue, at right angles, into Block twenty-two (22); thence across said Block No. twenty-two (22), and the alleys intersecting the same to the west line of Kansas avenue; thence across Kansas avenue to the west line of Block No. twenty-three (23); thence into and across said Block No. twenty-three (23).

The said approach from Block No. three (3) to Block No. twenty-three (23) inclusive to consist of four tracks. Also a connection line beginning in Pennsylvania avenue near the west line of Block No. twenty-two (22) and curving to the north through said Block No. twenty-two (22), and across the alleys intersecting the same, to the south side of Virginia avenue; thence across the said Virginia avenue to Block No. twenty-one (21); thence across the southeast corner of said block No. twenty-one (21) to the west side of Kansas avenue; then across and along said Kansas avenue to a connection with the tracks of the Kansas City, Fort Scott and Memphis Railroad in said Kansas avenue near the centre line of Broadway, the said connection line to consist of two tracks.

Also a second connection line, beginning in Block No. twenty-three (23) near the east line of Kansas avenue and curving to the north through said Block No. twenty-three (23) and across the alleys intersecting the same, to the west side of Kentucky avenue; thence across and along said Kentucky avenue to a connection with the tracks of the St. Louis, Iron Mountain and Southern Railway in said Kentucky avenue, the said second connection to consist of two tracks. Also a third connection line, connecting with the connection line first aforesaid in or near Virginia avenue and running thence northeastwardly across Kansas avenue to a connection with the tracks of the Kansas City, Fort Scott and Memphis Railroad, east of and near said Kansas avenue, the said third connection line to consist of two tracks." All situated, lying and being in the Tenth (10th) Ward of said Taxing District, commonly known as the City of Memphis.

Now, therefore, be it enacted and ordained by the Legislative Council of the Taxing District of Shelby County, Tennessee, as follows:

SECTION 1.—Be it enacted and ordained, That the Legislative Council of the Taxing District of Shelby County, so far as it has the legal power to do so, grants to the said Kansas City and Memphis Railway and Bridge Company the powers, rights and privileges above named and hereinafter set forth upon the express condition and agreement that the charges and tolls to be charged other railroad companies desiring to use said approaches, connections and bridge for their trains and cars may be fixed and established by the Secretary of War, under Section four (4) of the said Act of Congress, authorizing said Company to build and construct and maintain said bridge for the transportation of freight cars, passenger coaches or trains, foot passengers, etc., over said bridge and over all tracks or approaches thereto as shall be occupied by said Bridge Company, and that the right thereto shall be granted by it to every railroad company now or hereafter entering the Taxing District of Shelby County without discrimination in favor of or against any such railroad company. The

word "approaches" shall include all tracks used or owned by said Bridge Company in gaining access to the bridge proper, whether included in the territory covered by the above grant or otherwise.

That in the event the Secretary of War should decline, after a lawful and apt application has been made to him under said Act of Congress by any railroad now or hereafter running into said Taxing District, to fix the rates of tolls over the bridge for the reason that he has no jurisdiction over said approaches, or for any other reason declines to act, or in case the Circuit and District Courts of the United States for the Western District of Tennessee, or the Supreme Court of the United States, or the State Courts of record of competent jurisdiction in Tennessee and having jurisdiction in Shelby County, shall decide that said Act of Congress is inoperative as to the approaches, then this Legislative Council shall have and hereby retains the right to regulate tolls from time to time over all such approaches to said bridge upon a like application by any such railroad.

And for the further consideration of the materials to be furnished, labor performed, work done, and the considerations and obligations agreed to be performed on the part of the petitioner, the Kansas City and Memphis Railway and Bridge Company, as hereinafter set out and specified, and in consideration of the promotion of the public welfare, especially that of this Taxing District, resulting from the construction, maintenance, use and operation of said bridge and said approaches thereto, and the public welfare requiring it, the said Taxing District doth hereby grant, so far as it has the legal power to do so, to the Kansas City and Memphis Railway and Bridge Company, its successors and assigns, for the period of ninety-nine years, or so long as said bridge shall remain where it is now under the sanction of the United States Government, the right and privilege to construct, maintain and operate with steam or other motive power across the streets and across, over and along the alleys above named and shown by said map, and along the route or line above and thereon described, its said railroad tracks and connecting lines, and to operate the same for the purposes stated above and as designated in the petition and map of petitioner now on file in the said office of the Taxing District.

Sec. 2. Be it further enacted and ordained, That said Railroad and Bridge Company shall pave the incline approach to the wagon way of said bridge for vehicles and general traffic with stone placed upon Tishomingo gravel the whole length thereof, being about 150 feet long and to a width of 30 feet, and maintain the same. It shall pave all crossings of streets over which its said tracks pass, between tracks and 18 inches on each side thereof, with not less than three-inch white oak plank to be full width of each street and maintain

the same, and shall furnish to the Taxing District free of cost, Tishomingo gravel sufficient to cover from 10 to 12 inches deep, as the Taxing District Engineer may direct, the following four streets: Delaware, Arkansas, Indiana and Louisiana avenues for a width of 40 feet on each from the south line of Virginia avenue to the north side of Iowa avenue or Jackson street, all of which are crossed by said tracks, and also furnish all necessary wood curbing for said distances on said four avenues. All material necessary for the above shall be furnished by the said company at its own cost under the direction and supervision of the Taxing District Engineer, and all work to be done by it under this paragraph shall be under his supervision and direction.

Sec. 3. Be it further enacted and ordained, That the Taxing District is not to be chargeable or liable in any way for any of the expenditures necessary to the construction and operation of these lines of railroad, whether the same be for grading or changing of the street, drainage of the same or for other work or cause whatever in connection therewith. All expenditure, as well as damages, if any, resulting therefrom to property owners by changing, filling or cutting streets, failure to furnish and provide proper drainage or otherwise, shall as between said Taxing District and the Kansas City and Memphis Railway and Bridge Company be assumed by said Railway and Bridge Company, and the said Railway and Bridge Company agrees and hereby obligates itself to hold harmless and indemnify the Taxing District against all damages and expenditures whatever, if any shall accrue therefrom.

Sec. 4. Be it further enacted, That the Kansas City and Memphis Railway and Bridge Company in laying its tracks on and over streets shall so construct and maintain the same as to offer the least possible impediment or obstruction to the use of such streets by the general public.

Sec. 5. Be it further enacted and ordained, That it appearing that the entrance to the wagon way of said bridge is directly in front of Virginia avenue and near to the west end thereof, and that to construct a wagon road for an approach to such entrance, which will best accommodate the public, it is necessary to permanently close said Virginia avenue west of Delaware avenue; and said Railway and Bridge Company, which owns all the land on both sides of that portion of Virginia avenue, having asked that the same be closed, therefore, so far as this body can legally confer such authority, the permanent closing of said portion of Virginia avenue, for the construction therein of said approach and the occupation of said avenue thereby, is hereby authorized.

Sec. 6. Be it further enacted and ordained, That it appearing to be for the convenience of the public and of said Railway and Bridge Company in the construction, use and operation of said wagon road and other approaches, that they occupy a portion of Delaware avenue as now located at and just south of the crossing of Virginia avenue, and that the course of Delaware avenue be changed at that place by turning it northeasterly across the northwest corner of said block three (3) in the manner shown on said map and by said petition filed by said Company as aforesaid, therefore, said Railway and Bridge Com-

pany is hereby authorized, so far as this body can legally do so, to occupy said portion of Delaware avenue and to change the course thereof for said approaches, all as shown by said map and petition and as above set forth, upon its first having conveyed to said Taxing District in fee for the use of the public for a street that portion of said block three (3) to be covered by Delaware avenue when changed as aforesaid.

Sec. 7. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally do so, to construct and maintain a bridge or viaduct over said Delaware avenue as it now is and as hereby changed, where its railroad tracks cross said avenue, for the purpose of carrying said tracks, which bridge or viaduct shall be at least twelve (12) feet above the grade of said avenue as established by ordinance, and to which the surface of said street is to be depressed as hereinafter set forth.

Sec. 8. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to grade and depress the present surface of said Delaware avenue where said viaduct and tracks will cross it so as to conform to the grade of said avenue as heretofore established by ordinance.

Sec. 9. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body has the legal power to grant such authority, to construct and build an embankment of earth, eight (8) feet high at the highest point and forty (40) feet wide, where said bridge lines of railway cross Indiana avenue, sloping back north to the south line of Virginia avenue and south to the north line of Iowa avenue, so as to conform to the grade of said Indiana avenue, at the point of said crossing, heretofore adopted by said Taxing District; said embankment shall be of uniform width and constructed so as to give an easy incline from said highest point north to said Virginia avenue and south to said Iowa avenue.

Sec. 10. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to occupy the south alley (there being two) running east and west through said Block No. 5 with one of its four (4) lines of railway hereby authorized, and may build and construct an embankment or trestle therein so as to conform to the grade of said alley heretofore adopted by said Taxing District and so as to conform to the grade so adopted on Indiana and Arkansas avenues.

Sec. 11. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct and build an embankment of earth, four and one half (4½) feet high at the highest point and forty (40) feet wide, where said bridge lines of railway cross Arkansas avenue, sloping back north to the south line of Virginia avenue and south to the north line of Iowa avenue, so as to conform to the grade of said Arkansas avenue, at the point of

said crossing, heretofore adopted by said Taxing District, said embankment shall be of uniform width and constructed so as to give an easy incline from said highest point north to said Virginia avenue and south to said Iowa avenue.

Sec. 12. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to build and construct an embankment or trestle, not less than four and one half (4½) feet, nor to exceed six and one half (6½) feet high, across both of the alleys running north and south in said Block No. 12, so as to conform to the grade of said alleys heretofore adopted by the said Taxing District and so as to conform to the grade so adopted on said Arkansas and Louisiana avenues.

Sec. 13. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct and build an embankment of earth, six and one half (6½) feet high at the highest point and forty (40) feet wide, where said bridge lines of railway cross Louisiana avenue, sloping back north to south line of Virginia avenue and south to the north line of Iowa avenue, so as to conform to the grade of said Louisiana avenue, at the point of said crossing, heretofore adopted by said Taxing District. Said embankment shall be of uniform width and constructed so as to give an easy incline from said highest point north to said Virginia avenue and south to said Iowa avenue.

Sec. 14. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to build and construct an embankment or trestle not to exceed six and one half (6½) feet high across both alleys (there being two) running north and south through said Block 13 so as to conform to the grade of said alleys heretofore adopted by said Taxing District and so as to conform to the grade so adopted on Louisiana and Pennsylvania avenues.

Sec. 15. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to intersect and lay its said four (4) tracks across the Citizens' Street Railway, now laid along and over Pennsylvania avenue, and across said Pennsylvania avenue, and put down all necessary iron or wooden structures in said avenue to effect said crossing, which shall be made on the grade upon which said Citizens' Street Railway is laid and heretofore adopted by said Taxing District.

Sec. 16. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to lay its connection line, which curves northwardly out of the main line and consists of two (2) lines of railway in Bloc No. 22, across the alley running east and west through said Block No. 22, and across Virginia avenue just west of Kansas avenue, and into and across said Kansas avenue so as to intersect and connect with the Kansas City, Fort Scott and Memphis Railroad and to put down all necessary iron or wooden structures to effect said connection in said Kansas avenue: all of which shall be done so

as to conform to the grade of said alley and avenues heretofore adopted by said Taxing District and upon which grade said Kansas City, Fort Scott and Memphis Railroad is now laid and constructed upon said Kansas avenue:

Sec. 17. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct a second connection line curving northwardly out of the main line in said Block No. 23, which shall consist of two (2) tracks, across the alley running north and south in the eastern part of said Block No. 23 (there being two (2) such in said block), and across the alley running east and west therein, and across Virginia avenue where it intersects and crosses Kentucky avenue, into and across said Kentucky avenue so as to intersect and connect with the said St. Louis, Iron Mountain and Southern Railway laid in and along said Kentucky avenue, and to put down all necessary iron or wooden structures to effect said connection in said Kentucky avenue; all of which shall be done so as to conform with the grade of said alley and of Virginia and Kentucky avenues heretofore adopted by said Taxing District, and upon which grade said St. Louis, Iron Mountain and Southern Railway is now laid and constructed upon said Kentucky avenue:

Sec. 18. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct the third connection line, connecting with the first connection line herein authorized in or near Virginia avenue, and running thence northeasterly across Kansas avenue to a connection and intersection with the tracks of the Kansas City, Fort Scott and Memphis Railroad east of and near Kansas avenue, which third connection shall consist of two (2) lines of railway tracks, and to put down all necessary iron or wooden structures to effect said connection: all of which shall be done so as to conform with the said grade of Kansas avenue heretofore adopted by said Taxing District.

Sec. 19. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct all four (4) of its railway

Sec. 20. Be it further enacted and ordained, That said map filed by the said Kansas City and Memphis Railway and Bridge Company in said office of said Taxing District be and the same is hereby accepted as showing the true line of the tracks for permanent right of way, four (4) in number on the main line and the connection lines aforesaid each consisting of two tracks, for all which rights are hereby granted, and the same is hereby adopted and made part of this ordinance. And it is the true intent and meaning of this grant to give to said Railway and Bridge Company, but only as far as this body has the legal power to do so, and subject to the limitations and restrictions herein set forth, the right to construct, maintain and operate with steam or other motive power said lines of railroad and connections over and across the streets and over, across and along the alleys as shown on said map so referred to and made a part hereof.

tracks on its main line across both of the alleys running north and south through said Block No. 23, which shall be done so as to conform with the grade of said alleys heretofore adopted by said Taxing District, and upon which grade said Kansas City, Fort Scott and Memphis Railroad, and said St. Louis, Iron Mountain and Southern Railroad are constructed and built.

Sec. 20. Be it further enacted and ordained, That the said map filed by the said Kansas City and Memphis Railway and Bridge Company in said office of said Taxing District be and the same is hereby accepted as showing the true line of the tracks for permanent right of way, four (4) in number on the main line and the connection lines aforesaid each consisting of two tracks, for all which rights are hereby granted, and the same is hereby adopted and made part of this ordinance. And it is the true intent and meaning of this grant to give to said Railway and Bridge Company, but only as far as this body has the legal power to do so, and subject to the limitations and restrictions herein set forth, the right to construct, maintain and operate with steam or other motive power said lines of railroad and connections over and across the streets and over, across and along the alleys as shown on said map so referred to and made a part hereof.

Sec. 21. Be it further enacted and ordained, That no sufficient reason or objection having been found or made by any person for rescinding, repealing, amending or modifying the ordinance passed and approved by the Legislative Council on the 12th day of February, 1891, adopting the grade as established by the Taxing District Engineer on Virginia, Delaware, Indiana, Arkansas, Louisiana, Pennsylvania, Kansas and Kentucky avenues and alleys thereby shown at the points therein and thereby designated, and the plat or map or profile of said grades so established and adopted having been on file for more than thirty (30) days in the office of the Taxing District Engineer, and in the office of said Taxing District for the said period of time, all of which was published for more than 30 days in the "Evening Scimitar," a newspaper published daily in the said Taxing District and having a general circulation therein, said grades on said avenues and alleys are now finally adopted, approved, established and made binding.

Sec. 22. Be it further enacted and ordained, That the Taxing District makes the grant and confers the powers and privileges herein specified only so far as it has power to do, and no further, and the Kansas City and Memphis Railway and Bridge Company takes all the risk of the questions of power and agrees to be responsible therefor and to indemnify and hold harmless the Taxing District against all claims against it arising out of the privileges herein granted, if there should be any.

Sec. 23. It is further enacted that said Railway and Bridge Company shall at its own cost, whenever so directed by an ordinance of said Taxing District, put up at any one or all of the street crossings hereby contemplated, an electric light or railroad gate, or station a flagman, and maintain the same at its own cost, but said Taxing District shall not require any two of the above precautionary measures at any one of the said street crossings. This clause shall not, however, be construed as a release of any of the police powers of the said Taxing District now authorized by law, but said police power is by it retained expressly over the entire grant hereby made.

Sec. 24. Be it further enacted and ordained, That as evidence of the assent of said Railway and Bridge Company to the terms of this ordinance it shall execute a contract with said Taxing District embracing the provisions of this ordinance, which contract shall also be executed by the officers of said Taxing District in duplicate, one copy to be held by each of the parties thereto.

Sec. 25. Be it further enacted, That should the said Kansas City and Memphis Railway and Bridge Company fail to comply with all or any of the terms and conditions imposed upon it in this ordinance, then the rights, grants and privileges herein given may be at the option of the Legislative Council of the Taxing District declared cancelled and inoperative and thereafter cease to exist.

Passed March 23, 1891.

J. T. PETTIT,

Vice President.

Attest:

HENRY J. LYNN, Secretary.

APPENDIX I. TIME, COST AND MATERIALS USED IN FOUNDATIONS.

PIER I.

Table with columns for DATE, PRINCIPAL FOREMAN, NIGHT FOREMAN, SUB-FOREMEN, LOCK TENDERS, PRESSURE MEN, COFFEE HOUSE MEN, COFFEE, SUGAR, CANDLES, COAL FOR HEATING, SACKING OUT AND CLAY HOIST MEN, MASTER MECHANIC AND DAY ENGINEER, NIGHT ENGINEER, PUMP MEN, FIREMEN, COAL PASSERS, COAL FOR BOILERS, BLACK OIL, CYLINDER OIL, WASTE, TOTALS FOR EACH DAY, FEET SUNK EACH DAY, MATERIAL, WATER PUMP, and Remarks. The table contains detailed daily logs for Pier I from January 9 to March 25, 1890.

Carried forward 385.00 219.00 2115.90 182.85 14510.10 280.80 179.20 79.85 73.28 30.10 820.20 101.20 220.40 324.00 2602.28 8.15 4.44 16.12 2561.12

TIME, COST AND MATERIALS USED IN FOUNDATIONS.

PIER I.—CONTINUED.

DATE.	PRINCIPAL FOREMAN.		NIGHT FOREMAN.		SUB-FOREMAN.		LOCK TENDERS.		PRESSURE MEN.		COFFEE HOUSE MEN.		COFFEE.		SUGAR.		CANDLES.		COAL FOR HEATING.		SACKING OUT AND CLAY HOIST MEN.		MASTER MECHANIC AND DAY ENGINEER.		NIGHT ENGINEER.		PUMP MEN.		FIREMEN.		COAL PASSERS.		COAL FOR BOILERS.		BLACK OIL.		CYLINDER OIL.		WASTE.		TOTALS FOR EACH DAY.		FEET SUNK EACH DAY.		MATERIAL.		WATER PUMP.		REMARKS.	
	Days	Amt.	Days	Amt.	Days	Amount.	Days	Amt.	Hrs.	Amount.	Days	Amt.	Lbs.	Amt.	Lbs.	Amt.	No.	Amt.	300lb. boxes.	Amt.	Hrs.	Amount.	Hrs.	Amt.	Hrs.	Amt.	Hrs.	Amt.	Hrs.	Amt.	Tons.	Amount.	Gals.	Amt.	Gals.	Amt.	Lbs.	Amt.	Rev.	of Air	Hours	Rev.	Pres.	of Air						
" 26	1	5.00	1	4.00	5	15.75	2	4.80	411	164.40	3	4.50	10	2.50	7	0.44	2	0.05	2	0.56	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	11.03	31.31	2	0.22	3	0.18	283.50	0.56	Hard clay	24.00	45	78	31							
" 27	1	5.00	1	4.00	5	15.75	2	4.80	414	165.60	3	4.50	9	2.33	6	0.38	5	0.12	2	0.57	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	13.18	37.38	2	0.23	3	0.18	290.53	0.92	Silt	24.00	48	77	32							
" 28	1	5.00	1	4.00	5	15.75	2	4.80	410	164.00	3	4.50	10	2.50	8	0.50	8	0.19	2	0.56	192	33.70	17	5.40	24	7.20	12	2.40	36	5.40	36	5.40	19.22	54.44	2	0.20	3	0.18	316.41	2.03	"	32.50	42	75	40					
" 29	1	5.00	1	4.00	4	12.50	2	4.80	393	157.20	3	4.50	9	2.33	6	0.33	2	0.05	2	0.57	190	21.00	28	8.80	24	7.20	24	4.80	48	7.20	48	7.20	21.81	61.77	2	0.18	3	0.18	309.66	1.00	Fine sand	48.00	34	72	28					
" 30	1	5.00	1	4.00	4	15.75	2	4.80	417	167.80	3	4.50	11	2.85	6	0.28	1	0.03	2	0.56	196	36.80	29	9.20	24	7.20	24	4.80	48	7.20	48	7.20	18.22	51.62	2	0.18	3	0.18	309.05	2.38	Clay, 1/2 sand	48.00	35	76	27					
" 31	1	5.00	1	4.00	6	20.25	2	4.90	520	257.50	3	4.50	11	2.85	8	0.50	4	0.10	2	0.57	196	36.80	28	8.80	24	7.20	24	4.80	48	7.20	48	7.20	27.29	77.24	2	0.18	4	0.24	429.83	1.30	"	48.00	32	76	23					
April 1	1	5.00	1	4.00	6	21.00	2	5.00	420	268.00	3	4.50	13	3.37	9	0.57	3	0.07	2	0.56	184	23.45	28	8.80	12	3.60	24	3.60	24	3.60	12.90	36.59	2	0.18	4	0.24	390.73	1.01	Clay, hard and pure	5.08	31	64	27	Stopped water pump.						
" 2	1	5.00	1	4.00	6	21.00	2	5.00	410	256.75	3	4.50	14	3.63	9	0.57	8	0.19	2	0.57	172	30.20	22	6.60	24	7.20	24	3.60	24	3.60	10.59	30.06	2	0.18	4	0.24	377.10	0.75	"											
" 3	1	5.00	1	4.00	6	21.00	2	5.00	408	255.50	3	4.50	11	2.85	9	0.57	4	0.09	2	0.56	192	33.70	28	8.80	12	3.60	24	3.60	24	3.60	11.75	33.35	2	0.18	3	0.18	387.88	0.00	"											
" 4	1	5.00	1	4.00	6	21.00	2	5.00	392	245.50	3	4.50	11	2.85	8	0.50	7	0.17	2	0.57	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	9.30	26.42	2	0.18	3	0.18	365.57	0.00	"											
" 5	1	5.00	1	4.00	6	21.00	2	5.00	411	257.25	3	4.50	11	2.85	8	0.50	7	0.16	2	0.56	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	12.04	34.16	2	0.18	3	0.18	385.04	1.21	"											
" 6	1	5.00	1	4.00	5 1/2	19.25	2	5.00	392	245.50	3	4.50	10	2.50	6	0.38	2	0.04	2	0.57	184	32.50	16	5.20	12	3.60	24	3.60	24	3.60	12.61	35.77	2	0.18	3	0.18	371.46	0.00	"											
" 7	1	5.00	1	4.00	6	21.00	2	5.00	406	254.25	3	4.50	11	2.85	8	0.50	5	0.12	2	0.56	192	33.70	14	4.40	12	3.60	24	3.60	24	3.60	10.59	30.06	2	0.18	4	0.24	377.10	0.01	"											
" 8	1	5.00	1	4.00	6	21.00	2	5.00	384	240.50	3	4.50	9	2.33	8	0.50	6	0.14	3	0.84	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	16.63	47.13	2	0.18	3	0.18	381.00	0.00	"											
" 9	1	5.00	1	4.00	5	17.50	2	5.00	396	248.50	3	4.50	14	3.63	8	0.50	7	0.17	3	0.85	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	9.01	25.60	2	0.18	3	0.18	364.81	1.47	"											
" 10	1	5.00	1	4.00	6	21.00	2	5.00	392	245.50	3	4.50	11	2.85	8	0.50	2	0.05	3	0.85	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	5.99	17.07	2	0.18	3	0.18	356.38	0.01	"											
" 11	1	5.00	1	4.00	6	21.00	2	5.00	390	244.25	3	4.50	9	2.33	8	0.50	2	0.05	3	0.85	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	4.99	14.24	2	0.18	3	0.18	351.78	0.01	"											
" 12	1	5.00	1	4.00	6	21.00	2	5.00	390	244.25	3	4.50	11	2.85	8	0.50	7	0.16	3	0.84	144	25.30	16	5.20	12	3.60	24	3.60	24	3.60	9.44	26.81	2	0.18	3	0.18	356.57	1.34	"											
" 13	1	5.00	1	4.00	6	21.00	2	5.00	390	244.25	3	4.50	9	2.33	2	0.13	4	0.10	3	0.85	96	16.90	16	5.20	12	3.60	24	3.60	24	3.60	7.43	21.14	2	0.18	3	0.18	341.56	0.00	"											
" 14	1	5.00	1	4.00	5	17.50	2	5.00	366	232.25	3	4.50	10	2.50	6	0.38	1	0.02	3	0.85	96	16.90	16	5.20	12	3.60	24	3.60	24	3.60	9.01	25.60	2	0.18	3	0.18	324.70	1.78	Clay, harder and tougher	0.18										
" 15	1	5.00	1	4.00	5	17.50	2	5.00	396	245.50	3	4.50	11	2.85	7	0.44	3	0.07	3	0.85	144	25.30	16	5.20	12	3.60	24	3.60	24	3.60	9.01	25.60	2	0.18	3	0.18	332.03	0.87	"											
" 16	1	5.00	1	4.00	6	21.00	2	5.00	343	214.87	3	4.50	9	2.33	10	0.63	3	0.07	3	0.84	181	32.80	16	5.20	12	3.60	24	3.60	24	3.60	8.15	23.17	2	0.18	3	0.18	330.07	0.00	"											
" 17	1	5.00	1	4.00	6	21.00	2	5.00	358	224.33	3	4.50	6	1.56	6	0.38	3	0.07	2	0.57	192	33.70	16	5.20	12	3.60	24	3.60	24	3.60	8.81	25.04	2	0.18	3	0.18	341.43	0.01	"											
" 18	1	5.00	1	4.00	6	21.12	2	5.50	361	242.75	3	4.50	7	1.81	5	0.31	3	0.08	3	0.61	120	21.05	16	5.20	12	3.60	24	3.60	34	5.10	19.63	2	0.18	2	0.74	3	0.18	344.96	0.85	"										
" 19	1	5.00	1	4.00	6	22.50	2	6.00	358	238.50	3	4.50	7	1.81	5	0.32	3	0.09	3	0.61	8	1.60	16	5.20	12	3.60	24	3.60	24	3.60	9.29	18.96	2	0.18	3	0.18	350.24	0.00	"											
" 20	1	5.00	1	4.00	6	22.50	2	6.00	334	250.50	3	4.50	7	1.82	5	0.32	7	0.17	3	0.61	42	7.20	16	5.20	12	3.60	24	3.60	24	3.60	9.07	18.51	2	0.18	3	0.18	337.49	0.00	"											
" 21	1	5.00	1	4.00	6	22.50	2	6.00	278	208.50	3	4.50	6	1.56	4	0.25	6	0.15	3	0.61	.....	.....	16	5.20	12	3.60	24	3.60	24	3.60	4.55	9.29	1	0.09	2	0.12	278.57	0.00	"											
" 22	1	5.00	1	4.00	4	15.00	2	6.00	98	73.50	3	4.50	5	1.30	4	0.25	10	0.23	3	0.62	.....	.....	16	5.20	12	3.60	24	3.60	24	3.60	0.0																			







APPENDIX I-CONTINUED. TIME, COST AND MATERIAL USED IN FOUNDATIONS. PIER III-CONTINUED.

Main data table with columns for DATE, PRINCIPAL FOREMAN, NIGHT FOREMAN, SUB-FOREMEN, LOCK TENDERS, PRESSURE MEN, COFFEE HOUSE MEN, COFFEE, SUGAR, CANDLES, COAL FOR HOUSE BOAT, SACKING OUT, CLAY HOIST AND ELEVATOR MEN, MASTER MECHANIC AND DAY ENGINEERS, NIGHT ENGINEERS, PUMP MEN, FRAMMEN, COAL PASSERS, COAL FOR BOILERS, BLACK OIL, CYLINDER OIL, WASTE, TOTALS FOR EACH DAY, FEET SUNK EACH DAY, MATERIAL, WATER PUMP, Rev. of Air, and REMARKS. Includes a summary table at the bottom for Medical attendance, Maintenance of plant, Hire of tug and derrick, Labor, and Total.









APPENDIX J.-CONTINUED.  
RECORD OF SINKING CAISSONS.  
PIER I.-CONTINUED.

APPENDIX J.-CONTINUED.  
RECORD OF SINKING CAISSONS.  
PIER I.-CONTINUED.

Table with columns: DATE, ELEVATIONS OF CUTTING EDGE ABOVE MEAN SEA LEVEL (N.E., N.W., S.E., S.W., Average), SUNK IN 24 HOURS, TOTAL SINKAGE, ELEVATIONS OF SAND ORIGINAL ELEVATION = 199.4 (N.E., N.W., S.E., S.W., Average), AVERAGE PERCENTAGE OF CAISSON, WATER GAUGE, DEPTH DIMERSED, WEIGHTS (Caisson, Masonry, Sand, Water, Total), AIR PRESSURE (Indicated, Calculated), REACTION DUE TO AIR PRESSURE (Tons, Sq. Ft.), NET WEIGHT, SURFACE IN CONTACT, AVERAGE WEIGHT PER SQ. FT. OF SURFACE EXPOSED TO FRICTION, MATERIAL, REMARKS.

APPENDIX J.—CONTINUED.  
RECORD OF SINKING CAISSONS.  
PIER II.

Table with columns: DATE, ELEVATIONS OF CUTTING EDGE ABOVE MEAN SEA LEVEL (N.E., N.W., S.E., S.W., Average), SUNK IN 24 HOURS, TOTAL SINKAGE, ELEVATIONS OF SAND ORIGINAL ELEVATION = 151.6 (N.E., N.W., S.E., S.W., Average), AVERAGE PENETRATION OF CAISSON, WATER GAUGE, DEPTH IMMERS., WEIGHTS (Caisson, Masonry, Sand, Water, Total), AIR PRESSURE (Indicated, Calculated), REACTION DUE TO AIR PRESSURE, NET WEIGHT, SURFACE IN CONTACT, AVERAGE WEIGHT PER SQ. FT. OF SURFACE EXPOSED TO FRICTION, MATERIAL, REMARKS.

APPENDIX J.—CONTINUED.  
RECORD OF SINKING CAISSONS.  
PIER II.—CONTINUED.

Table with columns: DATE, ELEVATIONS OF CUTTING EDGE ABOVE MEAN SEA LEVEL, SUNK IN 24 HOURS, TOTAL SINKAGE, ELEVATIONS OF SAND ORIGINAL ELEVATION = 151.6, AVERAGE PENETRATION OF CAISSON, WATER GAUGE, DEPTH IMMERSSED, WEIGHTS (Caisson, Masonry, Sand, Water, Total), AIR PRESSURE (Indicated, Calculated), REACTION DUE TO AIR PRESSURE, NET WEIGHT, SURFACE IN CONTACT, AVERAGE WEIGHT PER SQ. FT. OF SURFACE EXPOSED TO FRICTION, MATERIAL, REMARKS.

APPENDIX J.—CONTINUED

RECORD OF SINKING CAISSONS. PIER III.

Table with columns: DATE, ELEVATIONS OF CUTTING EDGE ABOVE MEAN SEA LEVEL, SUNK IN 24 HOURS, TOTAL SINKAGE, ELEVATIONS OF SAND ORIGINAL ELEVATION = 156.3, AVERAGE PENETRATION OF CAISSON, WATER GAUGE, DEPTH IMMERSED, WEIGHTS (Caisson, Masonry, Sand, Water, Total), AIR PRESSURE (Indicated, Calculated), REACTION DUE TO AIR PRESSURE, NET WEIGHT, SURFACE IN CONTACT, AVERAGE WEIGHT PER SQ. FT. OF SURFACE EXPOSED TO FRICTION, MATERIAL, REMARKS.



APPENDIX J.—CONTINUED.  
RECORD OF SINKING CAISSONS.  
PIER III.—CONTINUED.

Table with columns: DATE, ELEVATIONS OF CUTTING EDGE ABOVE MEAN SEA LEVEL (N.E., N.W., S.E., S.W., Average), SUNK IN 24 HOURS, TOTAL SINKAGE, ELEVATIONS OF SAND ORIGINAL ELEVATION = 156.3 (N.E., N.W., S.E., S.W., Average), AVERAGE PENETRATION OF CAISSON, WATER GAUGE, DEPTH IMMERSED, WEIGHTS (Caisson, Masonry, Sand, Water, Total), AIR PRESSURE (Indicated, Calculated), REACTION DUE TO AIR PRESSURE (Tons, Lbs.), NET WEIGHT, SURFACE IN CONTACT (Sq. Ft.), AVERAGE WEIGHT PER SQ. FT. OF SURFACE EXPOSED TO FRICTION, MATERIAL, REMARKS.



APPENDIX J.—CONTINUED.  
RECORD OF SINKING CAISSONS.  
APPENDIX J.—CONTINUED.  
RECORD OF SINKING CAISSONS.  
PIER V.

Table with columns: DATE, ELEVATIONS OF CUTTING EDGE ABOVE MEAN SEA LEVELS, SUNKEN IN HOURS, TOTAL SINKAGE, ELEVATIONS OF SAND, ORIGINAL ELEVATION = 211.3, AVERAGE PENETRATION OF CAISSON, WATER GAUGE, DEPTH IMMERSSED, WEIGHTS (Caisson, Sand, Water, Total), AIR PRESSURE (Indicated, Calculated), REACTION DUE TO AIR PRESSURE, NET WEIGHT, SURFACE IN CONTACT, AVERAGE WEIGHT PER SQ. FT. OF SURFACE EXPOSED TO FRICTION, MATERIAL, REMARKS.

## APPENDIX K.

## SPECIFICATIONS FOR MASONRY.

## STONE.

The masonry below elevation 180 and the footing courses of Pier I may be of limestone. The masonry of Pier I above the footing courses, and of Piers II, III and IV above 180 and in each case below elevation 229 shall be of granite with limestone backing. The masonry above elevation 229 shall be of limestone or of granite with limestone backing, as may be directed by the Engineer.

The limestone used shall be that known as Bedford limestone from the quarries near Bedford, Indiana, unless some other limestone is expressly accepted by the Chief Engineer. The granite shall be a granite specially accepted by the Chief Engineer. All stone of each class shall be subject to the approval of the Engineer.

## MASONRY.

The masonry shall be first class work, laid in regular courses.

Copings, starting copings included, shall have the upper beds, wash, face and a width of six inches from face on lower beds six cut with true lines and surfaces. Belting shall have a like proportion of the lower bed bush hammered and shall have a face margin draft of four inches along the lower edge. The face of the upstream starting of Piers II and III shall be fine pointed with no projection exceeding one half inch. There shall be a draft of four inches on each side of the point of the pier on both the upstream and downstream ends of all piers below the starting coping. All other parts of the work shall have a rock face with no projections exceeding three inches from the pitch line of the joint and no hollows back of that pitch line.

The interior faces of the walls in the hollow portion of Piers II and III shall have no projections exceeding six inches and no hollows exceeding two inches from the true dimensions of the plans.

The stones shall be cut and coursed out at the quarries, every dimension stone being marked for its place, and full course plans shall be furnished to the Resident Engineer before shipment.

No course shall be less than 20 inches thick nor more than 36 inches thick, and no course, except the main belting and coping, shall be thicker than the course below it. The backing shall be of the same thickness as the dimension work and with beds of precisely the same character.

The bottom beds of the face stones shall never be less than 36 inches in either direction. Headers shall be at least six feet deep measuring from pitch line of the face, and stretchers shall measure at least five feet long in the wall.

## PIERS.

There will be four piers numbered from east to west and an Anchorage Pier.

The Anchorage pier will stand on the east bluff and back of the present face of that bluff. It will contain approximately 700 cubic yards.

Pier I will be on the East side of the river, standing in nine feet of water at high water. It will contain approximately 2300 cubic yards.

Piers II and III will be in the river. They will each contain approximately 4400 cubic yards.

Pier IV will be near the west bank. It will contain approximately 2800 cubic yards.

Piers I, II and III will finish 12 feet thick, 35 feet long between shoulders and 47 feet long over all under the belting course.

Pier IV will finish 10 feet thick, 37 feet long between shoulders and 47 feet long over all under the belting course.

The lower portions of Piers II and III will not be solid, but will contain three hollow spaces extending from the bottom of the masonry to high water.

The piers shall be built in all respects to conform to the plans which will be furnished by the Engineer.

The Anchorage Pier must be built around the anchor rods, which will extend from the bottom to the top of the masonry.

## FOUNDATIONS.

The foundations will be put in by the company.

The foundation for Pier I will finish at elevation 201, or 20 feet above low water, and the masonry will be started after the foundation is completed.

The foundation for Piers II and III will finish at elevation 141, or 40 feet below low water.

The contractor will be required to lay the masonry for these piers while the pneumatic foundations are being sunk, and to keep up with the rate of sinking, and must be prepared to lay four feet of vertical masonry per day.

The foundation of Pier IV is now finished at elevation 173, or eight feet below low water mark.

It is surmounted by a water-tight curb, and the contractor will begin laying masonry on the completed foundation.

The four courses under the coping shall have the joints bonded with cramps of one inch round iron twenty inches long between shoulders, the ends being sunk four inches into each stone.

MORTAR.

The cement used in masonry will be furnished by the Bridge Company, but the contractor will be required to take care of the cement and will be held responsible for any waste. The mixture of mortar and the selection of the cement shall be directed by the Resident Engineer.

The contractor will be required to furnish his own sand, which shall be subject to the approval of the Resident Engineer.

CONDITIONS.

The contractor will be required to furnish all necessary tools and materials of every description whatsoever excepting only cement.

Table with columns for dates (Apr. 26, May 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 1 June) and numerical values.

No material shall be measured or paid for which does not form a part of the permanent structure.

No free transportation will be furnished on the lines belonging to the Kansas City, Ft. Scott and Memphis R. R. system. The freight rates for this work will be at the rate of four mills per ton per mile. On other railroads contractors will make their own arrangements for freight.

Approximate estimates will be made monthly as the work proceeds. In these approximate estimates the cost of the freight will be deducted from the contract price on all material not yet delivered at the bridge site.

Stone quarried but not cut shall be estimated at one third the price of finished masonry. Stone quarried and cut shall be estimated at two thirds the price of finished masonry. Payment shall be made on these approximate monthly estimates deducting ten per cent as security for the completion of the work.

TIME.

The contractor must be prepared to begin laying the masonry on Piers II and III by August 1st, 1889, and to lay up at least 5000 yards of the lower portion of these two piers as fast as the foundation work proceeds.

MASONRY.

The masonry shall be first class work, laid in regular courses. Copings, starting copings included, shall have the upper beds, wash face and a width of six inches from face on lower beds six out with two lines and surfaces. Bedding shall have a like proportion of the lower bed wash face.

The face of the upstream starting of Piers II and III shall be finished with no projection exceeding one half inch. There shall be a draft of four inches on each side of the point of the pier on both the upstream and downstream ends of all piers below the starting coping. All other parts of the work shall have a rock face with no projections exceeding three inches from the pitch line of the joint and no hollows back of that pitch line.

The interior faces of the walls in the hollow portion of Piers II and III shall have no projections exceeding six inches and no hollows exceeding two inches from the true dimensions of the plans. The stones shall be cut and courses laid out at the piers, every dimension stone being marked for its place, and full course plans shall be furnished to the Resident Engineer before shipment.

No course shall be less than 20 inches thick nor more than 36 inches thick and no course, except the main bedding and coping, shall be thicker than the course below it. The bedding shall be of the same thickness as the dimension work and with beds of precisely the same character.

The bottom beds of the face stones shall never be less than 36 inches in either direction. Headers shall be at least six feet deep measuring from pitch line of the face, and stretchers shall measure at least five feet long in the wall.

and III by August 1st, 1889, and to lay up at least 5000 yards of the lower portion of these two piers as fast as the foundation work proceeds. He will be held responsible for any delays in sinking these foundations which may be due to his failure to lay four vertical feet of masonry per day whenever required.

The remainder of the masonry shall be completed during the winter and spring of 1890, and the entire masonry shall be finished by July 1st, 1890, unless otherwise ordered.

The right is reserved to suspend the work, and no stone shall be prepared for any portion of the masonry above elevation 229 until special orders to this effect are given by the Chief Engineer.

(Signed) Lewis M. Loss, President.

(Signed) KANSAS CITY AND MEMPHIS RAILWAY AND BRIDGE COMPANY.

By GEO. H. NETTLETON, President.

Piers I, II and III will finish 12 feet thick 35 feet long between shoulders and 17 feet long over all under the bedding course.

Pier IV will finish 10 feet thick 37 feet long between shoulders and 47 feet long over all under the bedding course.

The lower portions of Piers II and III will not be solid, but will contain three hollow spaces extending from the bottom of the masonry to high water.

The piers shall be built in all respects to conform to the plans which will be furnished by the Engineer.

The Anchorages Pier must be built around the anchor rods, which will extend from the bottom to the top of the masonry.

FOUNDATIONS.

The foundations will be put in by the company. The foundation for Pier I will finish at elevation 201, or 20 feet above low water, and the masonry will be started after the foundation is completed.

The foundation for Piers II and III will finish at elevation 141, or 40 feet below low water.

The contractor will be required to lay the masonry for these piers while the pneumatic foundations are being sunk and to keep up with the rate of sinking and must be prepared to lay four feet of vertical masonry per day.

The foundation of Pier IV is now finished at elevation 173, or eight feet below low water mark.

It is surrounded by a water-tight curb, and the contractor will begin laying masonry on the completed foundation.

APPENDIX I.

SPECIFICATIONS FOR SUPERSTRUCTURE.

by errors in these plans, without extra charge, where such errors could be discovered by an inspection of the plans.

II. MATERIAL.

8. All parts, except nuts, swivels, clevises and wall-pedestal plates, will be of steel. The nuts, swivels and clevises may be of wrought iron, but shall have sufficient strength to break the bodies of the members to which they are attached. The pedestal plates will be of cast iron.

9. All material shall be subject to inspection at all times during its manufacture, and the engineer and his inspectors shall be allowed free access to any works in which any portion of the material is made. Timely notice shall be given to the engineer so that inspectors may be on hand.

STEEL.

10. Steel will be divided into three classes: first, High Grade Steel, which shall be used in all the principal truss members; second, Medium Steel, which shall be used in the floor system, laterals, portals, transverse bracing and the lacing of the truss members; third, Soft Steel, which shall be used only for rivets and at the option of the contractor where wrought iron is permitted.

11. The bolsters which carry the large pin bearings on Piers I, II and III shall be of cast steel.

12. In any case where it seems doubtful what quality of steel is required, High Grade Steel shall be used.

13. Steel may be made by the open hearth or by the Bessemer process, but no steel shall be made at works which have not been in successful operation for at least one year.

14. All steel shall be made from uniform stock low in phosphorus, and the manufacturer shall furnish reports of the analysis of every melt certified by a chemist satisfactory to the Chief Engineer.

15. In the finished product of open hearth steel the amount of phosphorus shall not average more than 1/100 of one per cent and never exceed 1/50 of one per cent.

16. In the finished product of Bessemer steel, the amount of phosphorus shall not average more than 1/100 of one per cent and never exceed 1/50 of one per cent.

17. A sample bar three quarters of an inch in diameter shall be rolled from every melt, the method of obtaining the piece from which this bar is

I. GENERAL DESCRIPTION.

1. The superstructure is divided into two parts: First, the Continuous Superstructure of the main bridge; Second, the Deck Span at the west end.

2. The Continuous Superstructure will consist of a central span (resting on Piers II and III), 621 feet 0 1/2 inches long, from each end of which will project a cantilever arm, 169 feet 4 1/2 inches long; of an anchorage span (from the Anchorage Pier on the Tennessee shore to Pier I), 225 feet 10 inches long, from which will project a cantilever arm precisely like those projecting from the central span; of two intermediate spans 451 feet 8 inches long (one of which will be suspended from the cantilever arms projecting from Piers I and II, and the other will be suspended at the east end from the cantilever arm projecting from Pier III and will rest at the west end on Pier IV), the entire continuous superstructure being 2258 feet 4 inches long, divided into one span of 225 feet 10 inches, one of 790 feet 5 inches and two of 621 feet 0 1/2 inches.

3. This Continuous Superstructure will be rigidly fastened to Piers I, III and IV, but will rest on expansion rollers on Pier II. Slip joints will be provided for expansion at the suspended ends of the independent spans.

4. The trusses will be placed 30 feet between centers and will be divided into panels 28 feet 2 1/2 inches long, the right being reserved to shorten the panels by an amount not exceeding one half inch at any time before the work is actually manufactured.

5. The Deck Span at the west end will be 338 feet 9 inches long from the center of Pier IV to the center of the pin on Pier V, divided into twelve panels of 28 feet 2 1/2 inches each, the trusses being placed 22 feet between centers. The east end of the span will be carried in niches on the west side of Pier IV; the west end will have roller bearings over the center of Pier V. This span will include a vertical bent which will carry the west end of the west pair of stringers.

6. The estimated approximate weight of the Continuous Superstructure is 13 000 000 pounds; that of the Deck Span 1 000 000 pounds, making the total estimated weight of the superstructure of the bridge proper 14 000 000 pounds.

PLANS.

7. Full detail plans showing all dimensions will be furnished by the engineer. The work shall be built in all respects according to these plans. The contractor, however, will be expected to verify the correctness of the plans and will be required to make any changes in the work which are necessitated

28. Analyses shall be made by the manufacturer of every melt showing amount of phosphorus, silicon and manganese, and certified copies of these analyses shall be furnished to the mill inspector, who will forward them to the Chief Engineer.

29. Weekly reports in full detail, including reports of chemical analyses, shall be sent to the Chief Engineer at his Chicago office, not later than the day rolled to be the same in all cases, and the amount of work on this sample bar to be as nearly as practicable the same as on the finished product. The first laboratory test shall be made on this sample bar in its natural state without annealing.

18. A second sample bar having a cross section of one square inch shall be cut from the finished product of every melt. The second laboratory test shall be made on this sample bar in its natural state without annealing.

19. In the laboratory tests all observations as to elastic limit, ultimate strength, elongation and reduction shall be made on a length of eight inches.

20. A piece of each sample bar shall be bent 180 degrees and closed up against itself without showing any crack or flaw on the outside of the bent portion.

21. The first laboratory test shall meet the following requirements:

Table with 4 columns: Property, High Grade Steel, Medium Steel, Soft Steel. Rows include Maximum Ultimate Strength, Minimum Ultimate Strength, Elastic Limit, Percentage of Elongation in 8 inches, and Reduction at Fracture.

22. The second laboratory test shall meet the following requirements:

Table with 4 columns: Property, High Grade Steel, Medium Steel, Soft Steel. Rows include Maximum Ultimate Strength, Minimum Ultimate Strength, Elastic Limit, Percentage of Elongation in 8 inches, and Reduction at Fracture.

23. If the ultimate strength comes within five hundred pounds of the maximum or minimum limit, a second test will be made, and both tests will be required to come within the limits.

24. Every melt which does not conform with these requirements shall be rejected.

25. A full report of the laboratory tests shall be furnished certified by an inspector accepted by the Chief Engineer.

26. The broken and bent specimens shall be preserved subject to the orders of the Chief Engineer.

27. Three notices of the acceptance of each melt shall be mailed on the day of such acceptance, stating the number of the accepted melt and quality of steel. Two of these notices shall be sent to the Chief Engineer at his Chicago and New York offices respectively and one to the shop inspector at the works.

The four courses under the coping shall have the joints bonded with  
 28. Analyses shall be made by the manufacturer of every melt, showing amount of phosphorus, carbon, silicon and manganese, and certified copies of these analyses shall be furnished to the mill inspector, who will forward them to the Chief Engineer.

29. Weekly reports in full detail, including reports of chemical analyses, shall be sent to the Chief Engineer at his Chicago office not later than the end of the week succeeding the week in which such tests are made.

30. Three notices of the shipment of manufactured material identifying the melts and dimensions shall be mailed on the day after such shipments are made, in the same manner as the notices of acceptance of material.

31. Every finished piece of steel shall be stamped on one side near the middle of the bar and also on both ends of the bar with a number identifying the melt.

32. The finished product shall be perfect in all parts and free from irregularities and surface imperfections of all kinds.

33. The cross sections shall never differ more than two per cent from the ordered cross sections as shown by the dimensions on the plans.

34. All sheared edges shall be planed off so that no rough or sheared surface shall ever be left on the metal.

35. Steel for pins shall be sound and entirely free from piping. All pins in the main trusses shall be drilled through the axis.

#### CAST STEEL

36. A sample bar  $1\frac{1}{2}$  inches in diameter and 16 inches long shall be cast from every melt. This sample bar shall then be turned down to three quarters of an inch in diameter and the laboratory tests made upon it.

37. These laboratory tests shall show an ultimate strength of at least 70 000 pounds, an elastic limit of at least 40 000 lbs., an elongation of at least 15 per cent in 8 inches and a reduction of 18 per cent at point of fracture.

38. Steel castings shall be sound and as free as possible from blow holes.

39. If on the finished surface the blow holes cover more than  $\frac{1}{100}$  part of the entire surface, and if any blow hole exceeds one eighth of an inch in diameter, the casting shall be rejected.

#### CAST IRON.

40. Cast iron shall be the best quality of dark gray charcoal iron of a quality suitable for car wheels, the castings to be entirely sound and free from blow holes.

#### III. MANUFACTURE.

41. The work shall be done in all respects according to the detail plans furnished by the Chief Engineer.

42. Where there is room for doubt as to the quality of work required by the plans or specifications, the doubt shall be decided by using the best class of work which any interpretation would admit of.

43. All workmanship, whether particularly specified or not, must be of the best kind now in use. Past work done for the same chief engineer will never be recognized as a precedent for the use of other than the best kind of work.

44. Ragged edges or any kind of irregularities or unnecessary roughness will be sufficient ground for rejection.

45. All surfaces in contact shall be cleaned and painted before they are put together.

46. All work shall be finished in the shop and ample time given for inspection.

47. No material shall be loaded on cars until accepted by the inspector.

48. The finishing of work after loading will not be permitted.

#### SOLID DRILLED WORK.

49. All riveted members which are made of High Grade Steel and all other pieces connecting with such members shall be solid drilled, no punching whatever being allowed, excepting lacing bars which may be punched and reamed.

50. All plates, angles and shapes shall be carefully straightened at the shops before they are put together. Mill straightening will not be considered to meet this requirement.

51. The pieces shall be then assembled and held in position by clamps and bolts.

52. Where bolts passing through the metal are used, the holes shall be drilled in all metal more than three quarters of an inch thick, the diameter of the drilled hole to be at least one eighth of an inch less than the diameter of the finished hole.

53. In metal not more than three quarters of an inch thick punched holes may be used for fitting up, the diameter of the punched hole not to be more than three quarters the diameter of the finished hole, and the number of punched holes never to exceed eight in any one plate or four in one flange of any one angle.

54. After assembling, the work shall be drilled, the rivet holes being carefully spaced in truly straight lines and at the exact distances shown on the plans.

55. After the drilling is completed a special reamer shall be run over both edges of every hole, so as to remove the sharp edges and make a fillet of at least  $\frac{1}{16}$  of an inch under each rivet head.

56. The assembled parts shall then be riveted up without taking apart, unless specially directed by the Chief Engineer.

57. In general, all holes which are to pass through several thicknesses of metal shall be drilled with all those pieces of metal assembled in the exact relative position they are to hold in the bridge.

58. In the case of connections between members having four webs, one member may be finished complete with the splice plates riveted on. The two inside webs of the adjoining member, one end being already faced, may then be fitted up separately in their true position and the rivet holes in the splices drilled. These inside webs may then be removed; the member to which they belong shall be assembled, riveted up complete and the ends faced, the facing to agree exactly with the two ends already faced. (See § 67.) The member shall then be fitted to the adjoining member and the rivet holes in the splices connecting the outside webs shall be drilled.

59. The size of rivets shown on the plans is the size of the cold rivet before heating.

60. The diameter of the finished hole shall not be more than  $\frac{1}{16}$  of an inch greater than the diameter of the cold rivet. It is intended that the heated rivet shall not drop into the hole, but require a blow from a hammer to force it in. If it is found that rivets will drop easily into the holes, the inspector will condemn those rivets and order a larger size.

61. In all cases where riveting is to be done in the field, the parts so to be riveted shall be fitted together in the shops and the rivet holes drilled while they are so assembled.

62. The riveted connections of the portals, cross frames and floor beams with the posts and chords shall be drilled with the several parts fitted together, excepting in the case of interchangeable floor beams.

63. An iron templet not less than two inches thick may be used instead of the floor beams when drilling the holes in the chords, and the same templet instead of the chords when drilling the holes in the floor beams; a templet may be used in the same manner in drilling the connections between the floor beam and the supported upright at panel points where two inclined members come together; but the connection between the floor beam and the vertical suspenders at panels point  $L_1$  and  $L_2$  of the intermediate spans shall be drilled with the parts actually assembled and marked. With this arrangement two floor beams at each end of the intermediate spans, making eight in all, become special; the other floor beams are classed as interchangeable.

64. All rivets shall be driven by power wherever this is possible.

65. All rivets shall be regular in shape, with hemispherical heads concentric with the axis and absolutely tight. Tightening by calking or recapping will not be allowed. This applies to both power driven and hand driven rivets.

66. All pin holes and holes for turned bolts passing through the whole width of a riveted member shall be bored or drilled after all other work is completed.

67. All surfaces in contact shall be carefully faced, the facing to be done after the entire member is assembled and riveted up, except that in the case of chord sections with four webs, the inside webs may have one end faced before they are assembled, these two faced ends to be carefully held against a plane surface when assembled and the corresponding ends of the other two webs to be faced after riveting and to agree with the ends already faced.

68. When two chord pieces are fitted together complete in the shop there shall be no perceptible wind in the length of the two sections. The chords are generally made in two panel lengths, or 56 feet 5½ inches long. In the case of shorter lengths a sufficient number of pieces shall be put together to make a continuous length equal to two of the long sections.

69. All chord sections shall be stamped at each end on the outside with letters and numbers designating the joints in accordance with the diagram plan furnished by the Chief Engineer.

70. The posts shall be fitted together for their entire length and bolted up and when so fitted shall be perfectly straight and free from wind.

71. The same rule shall apply to the marking of the posts as to the marking of the chords.

72. Pin holes shall be bored truly and at exact distances, parallel with one another and at exactly right angles to the axis of the member.

73. Pin holes in the posts shall be truly parallel with one another and shall be at right angles to the axis of the post.

74. Pin holes shall be bored with a sharp tool which will make a clean, smooth cut. Two cuts shall always be taken, the finishing cut never to be more than ¼ inch. Roughness in pin holes will be sufficient reason for rejecting a whole member.

75. Measurements shall be made from an iron standard of the same temperature as the member measured.

#### PUNCHED AND REAMED WORK.

76. All riveted members which are composed entirely of Medium Steel may be punched and reamed, but this does not apply to the connections between such members and High Grade Steel members, which connections shall be solid drilled throughout.

77. All plates, angles and shapes shall be carefully straightened at the shops before they are laid out. Mill straightening will not be held to meet this requirement.

78. The rivet holes shall be marked from templates and these templates shall lie flat without distortion when the marking is made.

79. The angles of stringers must be square and straight. The web plate must not project above the angles and the top surfaces of the top angles must be such that the outside edges are never above a true plane and never more than one-sixteenth of an inch below a true plane coincident with the roots of the angles.

80. The outside angle at the root of the angles connecting the stringers with the floor beams or the floor beams with the posts, chords or other members, shall never be less than a right angle, and the excess over a right angle shall never be greater than ½ of an inch in the longer leg of the angle; the angle shall be perfectly straight.

81. In fitting these angles to stringers or floor beams they shall be so

fitted that the exact length is measured to the root of the angle, the two roots being in exactly the same plane; the entire end of the assembled member shall then be faced. The effect of these requirements will be to prevent any reduction of area of the angle at the root by facing and to secure a true surface of the whole width of the connection which will require no strain in the rivets to draw the parts together.

82. After laying out with templates, the rivet holes may be punched with a punch at least ⅜ of an inch smaller than the diameter of the rivets as given on the plans and working in a die only ¼ of an inch larger than the punch.

83. The several parts of the member shall then be assembled and the holes reamed so that at least ⅙ of an inch of metal is everywhere taken out.

84. After the reaming is completed a special reamer shall be run over both edges of every hole so as to remove the sharp edges and make a fillet of at least ⅙ of an inch under each rivet head.

85. The pieces shall be riveted together without taking apart.

86. All requirements as to size and quality of rivets and manner of riveting and measuring shall be the same as the requirements for Solid Drilled riveted work.

87. All bearing surfaces shall be truly faced.

88. All sheared edges shall be planed off and all punched holes shall be drilled out so that none of the rough surfaces is ever left upon the work.

#### FORGED WORK.

89. The heads of eye bars shall be formed by upsetting and forging into shape by a process acceptable to the Chief Engineer. No welds will be allowed.

90. After the working is completed the bars shall be annealed in a suitable annealing furnace by heating them to a uniform dark red heat and allowing them to cool slowly.

91. The form of the heads of the steel eye bars may be modified by the contractors to suit the process in use at their works, but the thickness of the head shall not be more than 1/16 inch greater than that of the body of the bar, and the heads shall be of sufficient strength to break the body of the bar.

92. The heads and the enlarged ends for screws in laterals, suspenders and counters shall be formed by upsetting and shall be of sufficient strength to break the body of the bar.

93. Nuts, swivels and clevises, if made of steel, shall be forged without welds; whether made of steel or wrought iron, one of each size shall be tested and be of sufficient strength to break the bars to which they are attached.

94. Eye bars shall be bored truly and at exact distances, the pin holes to be exactly on the axis of the bar, and at exactly right angles to the plane of the flat surfaces.

95. When six bars of the same billed length are piled together the two pins shall pass through both pin holes at the same time without driving. Every bar shall be tested for this requirement.

96. Pin holes shall be bored with a sharp tool that will make a clean smooth cut. Two cuts shall always be taken, the finishing cut never to be more than ¼ inch. Roughness in pin holes will be sufficient reason for rejecting bars.

97. Twenty full-sized steel eye bars shall be selected from time to time from the bars made for the bridge, by the inspector for testing.

98. No bars known to be defective in any way shall be taken for test bars, but the bars shall be selected as fair average specimens of the good bars which would be accepted for the work.

#### MACHINE WORK.

99. All bearing surfaces shall be faced truly.

100. Chord sections and half-post sections shall be faced after they are riveted up complete, the facing to be perfectly true and square. In the case of four web chords, one end of the two inside webs only may be faced before riveting up.

101. The ends of the stringers and of floor beams shall be squared in a facer.

102. All surfaces so designated on the plans shall be planed.

103. All sheared edges shall be planed off, and all punched holes shall be drilled or reamed out.

104. All pins shall be accurately turned to a gauge, and shall be of full size throughout.

105. Pin holes shall be bored to fit the pins with a play not exceeding 1/16 of an inch. These requirements apply to lateral connections as well as to any other pins.

106. The plans show the distances between centers of pin holes. Shop measurements, however, shall be made between the bearing edges of the pin holes, that is, between the inside edges of compression members and the outside edges of tension members, with a proper allowance for the diameter of the pin. An iron standard of the same temperature as the piece measured shall always be used.

107. All screws shall have a truncated V thread, United States standard sizes.

108. Special pains shall be taken with the roller bearings on Pier II. The castings shall be accurately fitted together and when bolted up, the top surface shall be a perfectly true plane.

109. The rail plates shall be planed on the bottom after being riveted up, then planed on the top and the surface polished. Any roughness or irregularity which prevents a uniform opening between the rail heads shall be planed out.

110. The rollers shall have the hollow sides planed and the bearing surfaces turned to a perfectly true cylinder and polished.

111. The rods passing through the rollers shall fit the holes with a play not exceeding 1/16 of an inch.

112. The side bars connecting the rods shall be drilled to fit the rods with a play not exceeding  $\frac{1}{4}$  of an inch, and the upper and lower surfaces of these side bars shall be planed.

113. The lower side bar in each instance shall be fitted with a graduated bronze scale, so divided as to register inches of motion of the top bearing, and the upper bar shall be fitted with a German silver vernier, so divided as to read to sixteenths of inches as graduated on the scale.

114. The two bearings, including everything between the masonry and the fourteen inch pin, shall be set up complete in a level position at the Athens shops and shall not be shipped before they have been examined and approved by the Chief Engineer. They shall be ready for his inspection on or before January 1, 1891.

115. Special pains shall be taken with the slip joints at the suspended ends of the intermediate spans; the surface of the joints shall be polished and fitted exactly.

#### MISCELLANEOUS.

116. All material shall be cleaned, and, if necessary, scraped and given one heavy coat of Cleveland iron-clad paint, purple brand, put on with boiled linseed oil, before shipment. This applies to everything except machine finished surfaces.

117. The same paint shall be used wherever painting is required.

118. All machine surfaces shall be cleaned, oiled and given a heavy coat of white lead and tallow before shipment. The inspector must see that this is a substantial coat, such as is used on machinery, and not a merely nominal covering.

119. All small bolts, all pins less than six inches in diameter, the expansion rollers and everything with special work on it, shall be carefully boxed before shipment.

120. The contractor will be required to furnish the field rivets for erection, furnishing 20 per cent. in excess of each size over and above the number actually required, but this excess will not be estimated, but considered as taking the place of the work which is not done on these rivets.

#### IV. INSPECTION.

121. The mill inspection shall be performed at the expense of the contractor, by an inspector accepted by the Chief Engineer.

122. This inspector will be required to furnish the certificates and notices in the manner specified above.

123. The mill inspector shall from time to time check the manufacturers' analyses by analyses made by an independent chemist.

124. The acceptance of material by such inspector will not be considered final, but the right is reserved to reject material which may prove defective or objectionable at any time before the completion of the contract.

125. The inspection at the shops will be under the charge of an inspector appointed by the Chief Engineer, with such assistants as may be required.

126. Such inspector will be considered at all times the representative of the Chief Engineer, and his instructions shall be followed in the same manner as if given by the Chief Engineer.

#### TESTS OF FULL-SIZED BARS.

127. The tests of full-sized eye bars shall be made in the large testing machine at Athens.

128. These bars will be required to develop an average stretch of twelve per cent. and a minimum stretch of ten per cent. before breaking. The elongation shall be measured on a length of not less than twenty feet, including the fracture.

129. The bars will be required to break in the body.

130. They shall also show an elastic limit of not less than 32 000 lbs. and an ultimate strength of not less than 62 000 lbs., as indicated by the registering gauges of the testing machine at Athens.

131. In the case of bars too long for the machine, the bars shall be cut in two, each half reheated, and both halves tested in the machine, the two tests, however, to count as a single test bar.

132. If the capacity of the machine (estimated at 1 200 000 lbs.) is reached before the bar is broken, the bar shall be taken out of the machine and the edges shall be planed off for a length of 10 feet at the center until the section is reduced to the equivalent of 16 square inches of section of the original bar. The bar shall then be placed in the machine and broken; when this is done the elongation shall be measured on a length of eight feet and an ultimate strength of 60 000 lbs. computed on the 16 inches of original section will be considered satisfactory.

133. In these tests, a failure to meet the required elongation will be considered fatal and be a sufficient cause for condemning the bars represented by the bars so tested, but the Chief Engineer shall examine carefully into the cause of the breakage of any bar which does not meet the requirements and may order additional tests if he sees fit.

134. The failure of a bar to break in the body shall not be considered sufficient reason for rejection, provided the required elongation is obtained and not more than one quarter of the bars break in the head.

135. In all requirements and tests the qualities given are minimum or maximum requirements and not averages unless expressly so stated.

#### V. TERMS.

136. The work will be paid by the pound of finished work loaded on cars at Buffalo.

137. On riveted work and other material shipped from Athens, the difference between the freight rates from Athens to Memphis and from Buffalo to Memphis will be borne by the contractor.

138. No material will be paid for which does not form a part of the finished superstructure.

139. All expenses of testing shall be borne by the contractor.

140. All riveted work shall be manufactured at the Athens shop, unless by special permission of the Chief Engineer.

141. Prices will be per pound at separate rates for High Grade Steel and for Medium Steel.

142. To avoid complications, all members the principal parts of which are High Grade Steel shall be estimated as wholly of High Grade Steel, and all members the principal parts of which are of Medium Steel shall be estimated as wholly of Medium Steel.

143. Cast Steel shall be estimated as High Grade Steel.

144. Cast and wrought iron shall be estimated at the same price as Medium Steel.

145. The anchorage span, the east cantilever arm and one half the east intermediate span shall be completed and shipped on or before October 1st, 1890.

146. The Deck Span shall be completed and shipped on or before December 1st, 1890.

147. The central span and the two adjoining cantilever arms shall be shipped complete on or before June 1, 1891.

148. The west intermediate span and the second half of the east intermediate span shall be shipped complete on or before August 1st, 1891.

149. Approximate estimates shall be made at the end of each month of the material received and work performed up to that time.

150. In these estimates material received at the shops but not manufactured shall be estimated at 65 per cent of the contract price for finished material.

151. Material manufactured but not shipped shall be estimated at 85 per cent of the contract price.

152. Material completed and shipped shall be estimated at the full contract price.

153. Payments shall be made on these estimates on or about the middle of the following month, deducting therefrom 10 per cent, which shall be held as security until the completion of the entire contract.

154. In these monthly estimates no material will be estimated as received at the shop more than six months before the date set for the completion and shipment of such material.

155. In these monthly estimates no material will be estimated as manufactured more than four months before the date set for the completion and shipment of such material.

156. The contractors will be required to keep the material at their shops insured from injury by fire to the full amount of the payments made on such material by the Bridge Company.

VI. ERECTION.

157. The contractor will be expected to receive all material as it arrives on the cars, to unload this material and store it in a material yard until ready for erection.

158. He will be held responsible for the custody and care of all superstructure material after its arrival.

159. The material of the main Continuous Superstructure will be delivered on cars on the east side of the river.

160. When ready for erection, the Bridge Company will switch any cars on which this material has been loaded, to a point where it can be transferred to barges, no charge being made for such switching.

161. All material for the Deck Span at the west end will be delivered on cars on the west side of the river.

162. A track will be laid to a convenient position for unloading material, near Pier V, and no switching will be done after the material has once been unloaded.

163. The contractor will be required to keep all the material in good condition, and in case of its becoming dirty or rusty, will be expected to clean it before erecting.

164. The contractor will be required to paint all surfaces which will be inaccessible for painting after erection, the paint being furnished by the Bridge Company.

165. The contractor will be required to furnish all tools, barges and false work of every description, excepting power riveters.

166. The contractor will be required to remove all work which he may put in the river so that there will be nothing left either to interfere with navigation or to catch drift.

167. No holes shall be drilled or bolts placed in the piers without the express permission of the engineer.

168. All bolts so put in shall be removed and the holes carefully filled with Portland cement mortar, and any damages done shall be charged to the contractor.

169. The contractor will be required to erect the superstructure complete in every respect including riveting.

170. Everything is to be completed ready to receive the timber floor.

171. The erection shall include the placing and riveting of the iron hand rail.

172. The contractor will be expected to raise the ties for the central span and the adjoining cantilever arms and distribute them without charge. This does not include any framing, fitting or bolting. The ties will be delivered to the contractor loaded on barges.

173. The central span will be raised on false work.

174. The west intermediate span will be raised on false work.

175. The east intermediate span may be raised on false work, or without, at the option of the contractor.

176. The anchorage arm east of Pier I will be raised on false work.

177. The three projecting cantilever arms will be built out without false work.

178. It is expected that the anchorage arm and the cantilever arms projecting from Pier I can be raised in the fall of 1890. That the deck span at the west end can be raised in the following winter. That the false work for the central span can be put in in August and September of 1891, and the erection of this span completed in the following month. That the cantilevers can be built out and the entire bridge completed by January 1, 1892.

179. All erection shall be done under the direction of the Chief Engineer and in conformity with his requirements.

180. The wall-plate castings shall be set on Piers II and III before the bottom chord is placed.

181. The expansion rollers and the bolster complete shall be set on Pier III. The bottom chords shall then be put together and riveted up complete. The expansion end shall then be adjusted so that the axis of the rollers will be exactly vertical at a temperature of 70 degrees Fahrenheit. This adjustment shall be made at a time when there has been no sun on the steel work for ten continuous hours, and when there has been no sudden change of temperature. The span shall be erected complete and the end rollers shall be examined again, and if any error is found, shall be corrected, the correction being made under the same conditions as to sunshine and sudden changes of temperature

as the original adjustment. Special care shall be taken with the rollers while the span is being swung, and if by any accident they get out of place, the span shall be wedged again and the rollers be readjusted.

182. The eye bars in the end panel of the top chord shall be stiffened so as to resist compression by fitting planks between the bars and bolting the whole together.

183. When the erection of the central span is completed, the two cantilever arms shall be built out and the two intermediate spans erected, thus completing the bridge.

184. All rivets shall be regular in shape with hemispherical heads concentric with the axis and absolutely tight. Tightening by calking or recapping will not be allowed.

185. All riveted joints which have to resist tension, this including all joints in both chords of the central span and all joints in the bottom chord of the intermediate spans, shall be riveted by power, except in such special cases as the engineer may authorize hand-driven rivets. This authority will never be given for rivets in splices of web plates.

186. A power riveter, with air pump or with hydraulic pump and accumulator, will be furnished by the Bridge Company. The contractor will be required to keep the same in repair and will not be relieved from any responsibility in this connection, the Bridge Company only agreeing to bear the cost of the machine.

187. No extra bills are to be rendered by the contractor, except for new work not embraced in the contract. Charges for reaming holes, fitting bolts in place of rivets and other small work of this class will not be allowed.

188. The setting of the wall plate castings, including the drilling of holes in masonry for the anchor bolts, the packing of rust cement or lead under the castings and all other work connected therewith, is to be done by the contractor.

189. The contractor will be responsible for any damages which the Bridge Company may be held liable for in consequence of any of his work.

GEO. S. MORISON,

Chief Engineer.

January 4th, 1890.

APPENDIX M.

SUPPLEMENTARY SPECIFICATIONS, MAY 6, 1890.

MODIFICATIONS OF SPECIFICATIONS FOR SUPERSTRUCTURE OF BRIDGE ACROSS THE MISSISSIPPI RIVER, AT MEMPHIS, TENN. ACCEPTED APRIL 22d, 1890. STEEL.

10. Steel will be divided into three classes: first, High Grade Steel, which shall be used in all the principal truss members; second, Medium Steel, which shall be used in the floor system, laterals, portals, transverse bracing and the lacing of the truss members; third, Soft Steel, which shall be used only for rivets, and at the option of the contractor where wrought iron is permitted.

11. The bolsters which carry the large pin bearings on Piers I, II and III, shall be of cast steel.

12. In any case where it seems doubtful what quality of steel is required High Grade Steel shall be used.

13. Steel shall be made by the open hearth process, but no steel shall be made at works which have not been in successful operation for at least one year.

14. All steel shall be made from uniform stock low in phosphorus, and the manufacturer shall furnish reports of the analysis of every melt, certified by a chemist satisfactory to the Chief Engineer.

15. In the finished product of acid open hearth steel the amount of phosphorus shall not average more than 1/1000 of one per cent and never exceed 1/100 of one per cent.

16. In the finished product of basic open hearth steel the amount of phosphorus shall not average more than 6/1000 of one per cent and never exceed 1/100 of one per cent.

17. A sample bar three-quarters of an inch in diameter shall be rolled from a four-inch ingot cast from every melt. The first laboratory test shall be made on this sample bar in its natural state without annealing.

18. A second sample bar having a cross section of one square inch shall be cut from the finished product of every melt. The second laboratory test shall be made on this sample bar in its natural state without annealing.

19. In the laboratory tests all observations as to elastic limit, ultimate strength, elongation and reduction shall be made on a length of eight inches.

20. A piece of each sample bar shall be bent 180 degrees and closed up against itself without showing any crack or flaw on the outside of the bent portion. Two successful tests out of a total of three will be accepted as satisfactory.

21. The first laboratory test shall meet the following requirements:

Table with 3 columns: Property, High Grade and Medium Steel, Soft Steel. Rows include Minimum Ultimate Strength, Minimum Elastic Limit, Minimum Percentage of Elongation in 8 inches, and Minimum Percentage of Reduction at Fracture.

22. The second laboratory test shall meet the following requirements:

Table with 3 columns: Property, High Grade Steel, Medium Steel, Soft Steel. Rows include Maximum Ultimate Strength, Minimum Ultimate Strength, Minimum Elastic Limit, Minimum Percentage of Elongation in 8 inches, and Minimum Percentage of Reduction at Fracture.

23. If the ultimate strength comes within five hundred pounds of the maximum or minimum limit, a second test will be made, and both tests will be required to come within the limits.

24. Every melt which does not conform with these requirements shall be rejected. Cases in which the tests are thought not to give fair representations of the character of the material shall be referred to the Chief Engineer.

25. A full report of the laboratory tests shall be furnished, certified by an inspector accepted by the Chief Engineer.

26. The broken and bent specimens shall be preserved subject to the orders of the Chief Engineer.

27. Three notices of the acceptance of each melt shall be mailed on the day of such acceptance, stating the number of the accepted melt and quality of steel. Two of these notices shall be sent to the Chief Engineer at his Chicago and New York offices respectively and one to the Shop Inspector at the works.

V. TERMS.

123. The mill inspector shall from time to time check the manufacturers' analyses by analyses made by an independent chemist.

124. The acceptance of material by such inspector will not be considered final, but the right is reserved to reject material which may prove defective or objectionable at any time before the completion of the contract.

28. Analyses shall be made by the manufacturer of every melt, showing amount of phosphorus, carbon, silicon and manganese, and certified copies of these analyses shall be furnished to the Mill Inspector, who will forward them to the Chief Engineer. The phosphorus and carbon analyses shall always be made. Analyses for silicon and manganese shall be made whenever called for by the Inspector. Copies of all analyses, whether made by request of the Inspector or by the desire of the manufacturer, shall be furnished to the Chief Engineer.

29. Weekly reports in full detail, including reports of chemical analyses, shall be sent to the Chief Engineer at his Chicago office not later than the end of the week succeeding the week in which such tests are made.

30. Three notices of the shipment of manufactured material, identifying the melts and dimensions shall be mailed on the day after such shipments are made, in the same manner as the notices of acceptance of material.

31. Every finished piece of steel shall be stamped on one side near the middle of the bar and also on both ends of the bar, with a number identifying the melt. If it is found impossible to stamp any particular piece on the ends, the Inspector may authorize the two end stamps to be put on the surface, within one-half inch of each end, the fact of the stamping being done in this way to be specified distinctly on all notices and invoices; this may be done, however, by an agreed character.

32. The finished product shall be perfect in all parts and free from irregularities and surface imperfections of all kinds.

33. The cross sections shall never differ more than two per cent. from the ordered cross sections as shown by the dimensions on the plans.

34. All sheared edges shall be planed off so that no rough or sheared surface shall ever be left on the metal.

35. Steel for pins shall be sound and entirely free from piping. All pins in the main trusses shall be annealed before they are turned and shall be drilled through the axes.

GEO. S. MORISON, Chief Engineer.

May 6th, 1890.

APPENDIX N.  
APPENDIX O.

SUPPLEMENTARY SPECIFICATIONS, JANUARY 1, 1891.

MODIFICATIONS OF SPECIFICATIONS FOR SUPERSTRUCTURE OF BRIDGE ACROSS THE MISSISSIPPI RIVER AT MEMPHIS, TENN., ACCEPTED DECEMBER 29TH, 1890.

- 10. Steel will be divided into four classes: first, High Grade Steel, which shall be used in all the principal truss members except eye bars; second, Eye-bar Steel, which shall be used only in eye bars; third, Medium Steel, which shall be used in the floor system, laterals, portals, traverse bracing and the lacing of the truss members; fourth, Soft Steel, which shall be used only for rivets, and at the option of the contractor where wrought iron is permitted.
- 11. The bolsters which carry the large pin bearings on Piers I, II and III shall be of cast steel.
- 12. In any case where it seems doubtful what quality of steel is required, High Grade Steel shall be used.
- 13. Steel shall be made by the open-hearth process, but no steel shall be made at works which have not been in successful operation for at least one year.
- 14. All steel shall be made from uniform stock low in phosphorus, and the manufacturer shall furnish reports of the analysis of every melt, certified by a chemist satisfactory to the Chief Engineer.
- 15. In the finished product of acid open-hearth steel the amount of phosphorus shall not average more than  $\frac{1}{100}$  of one per cent, and never exceed  $\frac{1}{10}$  of one per cent.
- 16. In the finished product of basic open-hearth steel the amount of phosphorus shall not average more than  $\frac{1}{100}$  of one per cent, and never exceed  $\frac{1}{10}$  of one per cent.
- 17. A sample bar three-quarters of an inch in diameter shall be rolled from a four-inch ingot, cast from every melt. A laboratory test shall be made on this sample bar in its natural state without annealing, but this test may be made subsequent to the acceptance of the material and shall be for record only.
- 18. A second sample bar having a cross section of one square inch shall be cut from the finished product of every melt. The second laboratory test shall be made on this sample bar in its natural state without annealing.

- 19. In the laboratory tests all observations as to elastic limit, ultimate strength, elongation and reduction shall be made on a length of eight inches.
- 20. A piece of each sample bar shall be bent 180 degrees and closed up against itself without showing any crack or flaw on the outside of the bent portion. Two successful tests out of a total of three will be accepted as satisfactory.
- 21. The first laboratory test shall meet the following requirements:
 

Minimum Ultimate Strength, pounds per square inch.....	65 000	57 000
Minimum Elastic Limit, pounds per square inch.....	38 000	32 000
Minimum Percentage of Elongation in 8 inches.....	20	28
Minimum Percentage of Reduction at Fracture.....	40	50
- 22. The second laboratory test shall meet the following requirements:
 

Maximum Ultimate Strength, pounds per square inch.....	78 500	75 000	72 500	63 000
Minimum Ultimate Strength, pounds per square inch.....	69 000	66 000	64 000	55 000
Minimum Elastic Limit, pounds per square inch.....	40 000	38 000	37 000	30 000
Minimum Percentage of Elongation in 8 inches.....	18	20	22	28
Minimum Percentage of Reduction at Fracture.....	38	40	44	50
- 23. If the ultimate strength comes within five hundred pounds of the maximum or minimum limit, a second test will be made, and both tests will be required to come within the limits.
- 24. Every melt which does not conform with these requirements shall be rejected. Cases in which the tests are thought not to give fair representations of the character of the material shall be referred to the Chief Engineer.
- 25. A full report of the laboratory tests shall be furnished, certified by an inspector accepted by the Chief Engineer.
- 26. The broken and bent specimens shall be preserved subject to the orders of the Chief Engineer.
- 27. Notices shall be sent in duplicate to the Chief Engineer at his Chicago office and to the Shop Inspector at the works.
- 28. Analyses shall be made by the manufacturer of every melt, showing amount of phosphorus, carbon, silicon and manganese, and certified copies of these analyses shall be furnished to the Mill Inspector, who will forward them to the Chief Engineer. The phosphorus and carbon analyses shall always be made. Analyses for silicon and manganese shall be made whenever called for

- by the Inspector. Copies of all analyses, whether made by request of the Inspector or by the desire of the manufacturer, shall be furnished to the Chief Engineer.
- 29. Duplicate reports in full detail, including reports of chemical analyses, shall be sent to the Chief Engineer at his Chicago office, and also to the shop Inspector at the works, not later than the day on which the accepted material is shipped.
- 30. Two notices of shipment of manufactured material, identifying the melts and dimensions, shall be mailed on the day after such shipments are made, one to be sent to the Chief Engineer at his Chicago office, and one to the Shop Inspector at the works.
- 31. Every finished plate, bar or angle shall be stamped on one side near the middle with a number identifying the melt, and this stamp shall be surrounded by a heavy circle of white paint. Steel for pins shall have the melt numbers stamped on the ends. Rivet and lacing steel and small pieces for pin plates and stiffeners may be shipped in bundles securely wired together with the melt number on a metal tag attached.
- 32. The finished product shall be perfect in all parts and free from irregularities and surface imperfections of all kinds.
- 33. The cross sections shall never differ more than two per cent from the ordered cross sections as shown by the dimensions on the plans.
- 34. All sheared edges shall be planed off so that no rough or sheared surface shall ever be left on the metal.
- 35. Steel for pins more than four inches in diameter shall be hammered steel, and tests shall be made on this steel in accordance with the requirements of Section 22. In such tests an elongation of fifteen per cent, and a reduction of area of thirty per cent, given in each of two test bars tested separately, will be accepted as satisfactory, provided the character of the fracture is satisfactory. The bending test required in Section 20 shall be made on pin steel, but pin steel will not be rejected, provided the bar will bend around a circle of a diameter equal to twice the thickness of the bar without cracking. Steel for pins shall be sound and entirely free from piping. All pins in the main trusses shall be annealed before they are turned and shall be drilled through the axes.

GEO. S. MORISON,  
Chief Engineer.

January 1, 1891.

NO.	TEST	High Grade Steel	Eye-bar Steel	Medium Steel	Soft Steel
21	Minimum Ultimate Strength, pounds per square inch.....	65 000	57 000		
21	Minimum Elastic Limit, pounds per square inch.....	38 000	32 000		
21	Minimum Percentage of Elongation in 8 inches.....	20	28		
21	Minimum Percentage of Reduction at Fracture.....	40	50		
22	Maximum Ultimate Strength, pounds per square inch.....	78 500	75 000	72 500	63 000
22	Minimum Ultimate Strength, pounds per square inch.....	69 000	66 000	64 000	55 000
22	Minimum Elastic Limit, pounds per square inch.....	40 000	38 000	37 000	30 000
22	Minimum Percentage of Elongation in 8 inches.....	18	20	22	28
22	Minimum Percentage of Reduction at Fracture.....	38	40	44	50

APPENDIX O.

APPENDIX O.

SUPPLEMENTARY SPECIFICATIONS, JANUARY, 1931.

TESTS OF STEEL EYE BARS.

by the Inspector. Copies of all analyses whether made by request of the Inspector or by the manufacturer shall be furnished to the Chief Inspector.

30. A piece of each sample shall be made on a length of eight inches. Elongation and reduction shall be made on a length of eight inches.

31. Modifications of specifications for superstructure of bridge across the Mississippi River.

Table with columns: DIMENSIONS, INCHES; RESULTS OF MECHANICAL TESTS; TESTS ON FULL-SIZE EYE BARS; TESTS ON SAMPLE BARS FROM SAME MELTS. Includes sub-headers for NOMINAL, ACTUAL, AFTER TEST, REDUCTION OF AREA, ELONGATION, ELASTIC LIMIT, MAX. LOAD, PLACE OF FRACTURE, MELT NUMBER, AREAS, REDUCTION, ELONGATION, ELASTIC LIMIT, MAX. LOAD, PHOSPHORUS, KIND OF STEEL, MADE BY, FORGED BY.

APPENDIX B.

REPORT OF TESTING COMMITTEE.

APPENDIX O.—CONTINUED.

TESTS OF STEEL EYE BARS.

TABULATED STATEMENT OF RESULTS OF TESTS MADE ON THE MEMPHIS BRIDGE MAY 12, 1892.

Observations taken on the empty structure immediately after the test showed that no permanent deflections had taken place.

Chief Engineer, K. C. & M. Ry. & Bridge Co. Gen. S. Morrison, Esq.

REMARKS.	SPAN.	DIMENSIONS, INCHES.								RESULTS OF MECHANICAL TESTS.								MELT NUMBER.	KIND OF STEEL.	MADE BY.	FORGED BY.								
		ORIGINAL.				AFTER TEST.				REDUCTION OF AREA, Per cent.	ELONGATION.		ELASTIC LIMIT, Lbs. per sq. in.	MAX. LOAD, Lbs. per sq. in.	PLACE OF FRACTURE.	AREAS.						REDUCTION, Per cent.	ELONGATION, Per cent.	ELASTIC LIMIT, Lbs. per sq. in.	MAX. LOAD, Lbs. per sq. in.	PHOSPHORUS, Per cent.			
		NOMINAL.		ACTUAL.		Width.		Thick-ness.			Inches.	Per cent.				Inches.	Inches.										Inches.	Inches.	
		Width.	Thick-ness.	Length C. to C.	Gauged Length.	Width.	Thick-ness.	Width.	Thick-ness.																				
High steel. After test, bar cut in two, reheated, not reannealed, test completed as below. First half above. Broke in unannealed end near heat line of new head. Second half. Broke like above. Area between fracture and new head reduced 24.1 per cent. After test. Bar cut in two, reheated, not reannealed, retested as below. First part of above. Broke in unannealed part of bar on heat line of new head. Second part of above. Broke like above.	EAST INTERMEDIATE.	7	1 1/4	258.68	238	7.01	1.27	5.31	0.90	46.3	38.2	16.8	28 640	56 830	Body	11 072	1.0200	.5403	47.0	28.1	40 790	68 730	.030	Basic open-hearth	Carnegie, Phipps & Co.	Union Bridge Co.			
		8	1 1/4	478.88	432	8.03	1.75	.....	.....	.....	52.7	12.0	.....	32 220	61 260	Not broken	10 770	1.0020	.6013	40.0	28.1	40 920	76 150	.042	"	"	"		
		8	1 1/4	236.28	168	8.03	1.75	6.23	1.18	47.8	22.1	13.2	.....	54 720	.....	Body	10 770	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
		8	1 1/4	240.28	180	8.03	1.75	7.44	1.60	15.3	20.1	11.2	.....	57 190	.....	"	10 770	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
		8	1 1/4	478.88	432	8.00	1.26	.....	.....	.....	.....	.....	.....	32 380	69 930	Not broken	10 770	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		8	1 1/4	236.99	166	8.00	1.26	6.29	0.94	41.37	25.8	16.5	.....	68 590	.....	Body	10 770	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		8	1 1/4	238.18	168	8.00	1.26	6.41	0.85	45.9	18.2	10.8	.....	58 880	.....	"	10 770	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		8	1 1/4	254.63	216	7.98	1.20	6.14	0.92	41.0	33.2	15.4	31 930	63 870	"	10 828	1.0100	.4108	59.3	21.9	40 900	69 800	.024	"	"	"	.....	.....	
Soft steel suspender. Full capacity of machine reached. First part. Second part. Lower lateral. Broke at back end of upset for screw, disclosing piece of iron welded in. Lower lateral. First part. Second part.	WEST INTERMEDIATE.	7	1 1/2	258.68	216	7.00	1.18	5.27	0.85	45.8	36.8	17.0	27 870	53 520	Body	20 816	1.0560	.4995	52.7	31.9	33 480	58 050	.027	Basic open-hearth	Carnegie, Phipps & Co.	Pencoyd B. & C. Co.			
		9	2 1/2	338.58	300	9.00	2.31	.....	.....	10.5	35.3	11.8	27 730	54 400	Not broken	09 257	1.0900	.5416	50.3	29.5	39 900	66 780	.013	"	"	Keystone Bridge Co.			
		9	1 1/2	206.58	168	9.09	1.25	6.81	0.83	50.3	39.1	23.3	32 590	57 410	Body	09 405	.9734	.4488	53.8	28.7	38 110	60 920	.014	"	"	"			
		9	1 1/2	205.38	168	9.09	1.25	6.94	0.94	42.6	34.8	20.7	32 820	58 440	"	09 405	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
		6	1 1/2	409.08	348	6.07	1.18	.....	.....	.....	.....	.....	19.5	5.6	35 480	60 390	In upset for screw	3 055	.830	.435	47.6	23.0	39 760	74 340	.069	Acid	Pencoyd I. & S. Co.	Pencoyd B. & C. Co.	
First part. Second part. First part. Second part.	DECK SPAN.	8	1 1/2	279.98	240	8.11	1.79	6.26	1.34	42.2	37.1	15.5	28 940	58 010	Body	11 150	1.114	.5960	46.5	23.0	40 480	66 880	.030	Basic open-hearth	Carnegie, Phipps & Co.	Union Bridge Co.			
		8	1 1/2	279.88	240	8.11	1.79	6.13	1.24	47.7	38.8	16.2	28 660	58 290	"	11 150	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
		7	1	289.23	252	7.02	1.00	5.53	0.75	40.9	44.9	17.8	31 380	59 850	"	11 072	1.020	.5402	47.0	28.1	40 790	68 730	.030	"	"	"			
		7	1	249.48	252	7.00	1.00	5.51	0.67	47.3	42.7	16.9	31 470	59 730	"	11 072	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

The first four bars were entirely experimental and did not represent bars which it was intended to use in the structure. They were generally of rather too high a steel, and the result of these tests led to the adoption in the specifications of a special eye-bar steel, midway between the medium and high grade steel. Tests Nos. 5 and 6 were 6 inch bars which showed a weak steel below the requirements of the specifications, and led to the substitution of 7 inch bars for 6 inch bars for all floor-beam suspenders, the 7 inch bars being made of soft steel.

Tests 13 and 14 were both of the same bar. The first test was unsatisfactory and showed a flaw in the steel. The second test was a test of a stretched bar reheated after stretching, and not reannealed; as was to be expected, it broke in the new head. Test No. 16 showed a flaw. Test No. 17, of the same bar, when reheated and planed down to a reduced section, showed that the steel was excellent.

Test No. 18 was good. Tests Nos. 19 and 20 of the same bar broke in heads which had been forged but not reannealed, the last having been forged on a stretched bar. Test 26 falls a little below the requirements of the specifications, and this was explained by a slight flaw at the fracture, the fracture taking place in the head. Test 48 led to the rejection of the bars represented by it.

APPENDIX P.

REPORT OF TESTING COMMITTEE.

GEO. S. MORISON, Esq. Chief Engineer K. C. & M. Ry. & Bridge Co.

DEAR SIR: The committee appointed to report on the results of the testing of the Memphis Bridge on the 12th of May, 1892, submits the accompanying tabulated statement of deflections observed in the different spans of the bridge, under the several test loads applied:

The sign - indicates a downward deflection. The sign + indicates an upward deflection.

The statement gives the deflections for the north and south trusses of each span, and also movements eastward and westward of the north and south roller bearings on Pier II; the other bearings being all fixed.

The testing was done with 18 locomotives weighing in the aggregate 1405.7 tons.

Load I was applied to the cantilever arm east of Pier I. It consisted of four locomotives covering the entire length of cantilever and weighing 342 tons.

Load II was applied to the span between Piers I and II. It consisted of 15 locomotives covering the entire distance between piers and weighing 1190.3 tons.

Load III was applied to the span between Piers II and III and to the cantilever arm east of Pier I. It consisted of 12 locomotives covering the entire span (II-III) and weighing 944 tons; and of four locomotives covering the entire length of cantilever and weighing 320.3 tons.

Load IV was applied to the adjacent spans of span (II-III) and consisted of nine locomotives from Pier II eastward, weighing 690.2 tons; and of nine locomotives from Pier III westward, weighing 715.5 tons.

Load V was applied to the span between Piers III and IV, and consisted of 11 locomotives covering the entire length of span and weighing 825.2 tons.

Load VI consisted of 18 locomotives coupled together, weighing 1405.7 tons.

This train, moving at a speed of 30 miles per hour, entered the bridge at the west end and was stopped at the east end within a distance as short as

practicable. The deflections under the rapidly moving load did not exceed the maximum deflections under static load.

Observations taken on the empty structure immediately after the test showed that no permanent deflections had taken place.

The vibrations under the running test were as moderate as could be expected, even from such massive spans.

The behavior of the entire structure under the different tests made was altogether very satisfactory.

Respectfully submitted,

ROBERT MOORE, C. L. STROBEL, G. BOUSCAREN,

The Committee.

LOCOMOTIVES USED IN TESTS.

Table with columns: Position in Train, Railroad, Number, Kind, Weight in Tons. Lists 18 locomotives from various railroads including K. C. & M. B. R. R., K. C., Ft. S. & M. R. R., I. C. R. R., L. N. O. & T. R. R., N. N. & M. V. R. R., M. & C. R. R., T. M. Ry., St. L., I. M. & S. Ry., L. & M. R. R., L. & N. R. R., and a total weight of 1405.7 tons.

TABULATED STATEMENT OF RESULTS OF TESTS MADE ON THE MEMPHIS BRIDGE, MAY 12, 1892.

Table with columns: POINTS OBSERVED, 1st Load, 2d Load, 3d Load, 4th Load, 5th Load, 6th, Running Load. Shows deflection values in feet for various points like Centre of cantilever span, West end of 1st cantilever span, etc.

MOVEMENTS OF ROLLER BEARINGS, IN FEET.

Table with columns: POINTS OBSERVED, 1st Load, 2d Load, 3d Load, 4th Load, 5th Load. Shows movement values for North rollers on Pier II and South rollers.

Vertical text on the right side of the page, likely bleed-through from the reverse side, containing technical notes and test results.

