trified, *i.e.*, Stage III. This curve is based on average readings over short periods; that is to say, momentary variations, which are liable to be very severe on such a system, are not taken into account. The load factor, which is the relation between the actual output in units and the possible output if the maximum load were maintained throughout the 24 hours, is 33 per cent.

Under these conditions it is obvious that a type of prime mover should be adopted which can economically deal with such large variations of load; that is, a prime mover which has a large over-load capacity beyond its normal or economical load. The functions of such a prime mover are exactly fulfilled by the steam turbine, and this is recognised to be the most efficient machine for producing power for such a load. Compared with the reciprocating steam engine, its steam consumption is less, it requires considerably less attendance, and its use represents a substantial saving in oil consumption and repairs. I can, from actual experience of both types of plant, speak of the great economy, both in capital cost and in the above respects, which results from the use of the steam turbine.

The largest power stations erected, both in Europe and America, during the last five years have been equipped with steam turbines, and have shown a considerable economy compared with stations not so equipped. I, myself, have had considerable experience of the use of large steam turbines, as the Carville power station on the Tyne was the first power station in England to use them. This station to-day contains eight 7,000-h.p. turbines, and is producing electric power as economically as, if not more economically than, any other station in the world.

(To be continued.)

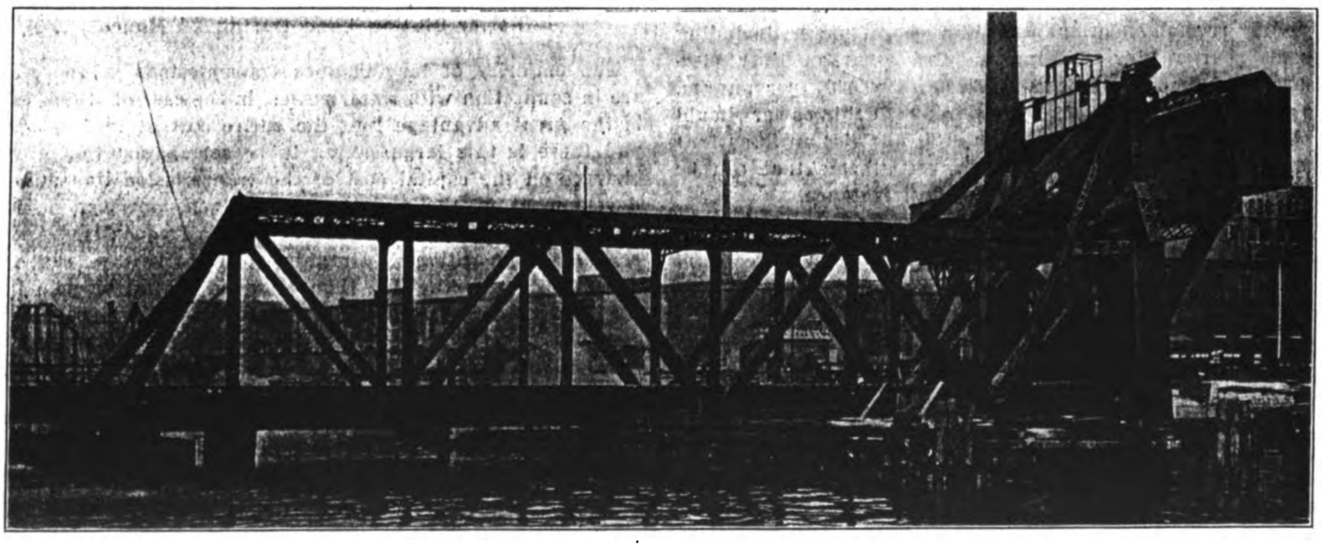
KINZIE STREET BASCULE BRIDGE OF THE CHICAGO & NORTH-WESTERN.

Wells street station, the Chicago passenger terminal of the Chicago & North-Western, is a short distance east of the north branch of the Chicago river. The entrance to this station for all trains of the North-Western has been over a riveted lattice double track, swing span, known as Kinzie street bridge. In order to provide a 100 ft. clear channel in the river it became necessary about a year ago to replace this bridge with one of longer span. As all of the suburban trains of the North-Western, as well as the through trains, use this station, about 260 trains a day cross this bridge, exclusive of switching movements; and in season the river traffic causes on an average 1,000 movements of the bridge each month. These conditions could be served best by a bascule bridge, and the Strauss design was adopted. This bridge, which is a double track, single leaf, trunnion type, was recently opened for service.

The new bridge was located on the south side of the old swing span with the trunnion pier on the east, or station, side of the river. To give space for building this pier a part of the east arm of the swing bridge had to be cut off to allow it to clear the new pier and bridge. The method of doing this, of counterweighting the shortened arm, and of putting in the necessary temporary trestle work, etc., in the shortest possible time while traffic over the bridge was suspended, was described in the *Railway Age* September 6, 1907, page 323.

Portal View of Kinzie Street Bridge.

The trunnion pier of the bridge was carried down 115 ft. to bed rock, and was built by the pneumatic caisson process. The rest pier is founded on piles. The bridge itself is extremely compact in design. The large concrete counterweight, which weighs 1,200 tons, and has been painted black to harmonize with the rest of the structure, is pivotally connected to the tail end of the truss and is guided by the usual links forming the characteristic parallel motion of the Strauss design. The trunnions are located at the top chord and are 28 in. in diameter. The counterweight pins are 12 in. and the link pins 7 in.



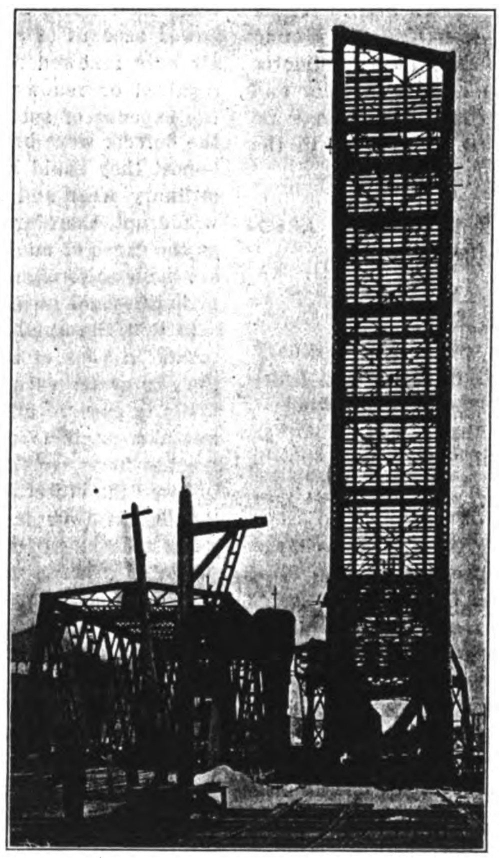
General View; Kinzie Street Bascule Bridge of the Chicago & North-Western.

The operating machinery is at the very top of the tower and is housed within a fireproof enclosure. The driving pinions operate two pin racks connected to the span at the first panel point ahead of the trunnions and a spur-gear equalizer synchronizes the movement of the two racks. The two motors are

50 h.p. each and have solenoid brakes. There is also a hand brake, and an automatic emergency brake which is both a hand and power brake. This brake is set automatically by the bridge itself when it reaches a certain limiting position.

The machinery is controlled from the operator's house, which is of reinforced concrete and is located at the level of the top chord of the leaf. The usual standard electrical equipment of controllers, switchboard, signals, etc., is provided. There are two independent sources of electric power, both 500 volt direct current, as well as a hand power and a pneumatic drive, these reserves being provided because of the great importance of keeping the bridge always in service. Despite the great size and weight of the leaf, it can be swung easily by the hand gear. The locking mechanism includes a front support for taking the live load off of the trunnions, and a truss lock at the rest pier end. These are driven by a 3-h.p. lock motor located at the center of the leaf, and the mechanism is such as to automatically cut out the motor when the parts reach their operative positions. The rail joints are mitred and are self locking.

Side View of Kinzie Street Bridge.



Kinzie Street Bridge During Construction, Old Swing Span on Left.

When the new bridge was ready and was lowered into service the old one was floated off to one side and dismantled. Except for the interruption to rail traffic mentioned at the outset, and a few hours interruption to river traffic during the flotation of the old bridge, traffic was maintained without hindrance on both railroad and river throughout the work. The bridge has been in service for several weeks and is giving entire satisfaction. It takes about 45 h.p. and one minute of time to operate it. The design provides for a duplicate structure to be built adjacent to the present bridge within five years.

The work was done under the direction of E. C. Carter, chief engineer of the Chicago & North-Western, W. H. Finley, assistant chief engineer, having general charge of the work in the office and field. The plans of the substructure were made under the direction of I. F. Stern, engineer of bridges. W. C. Curtis was resident engineer. The Great Lakes Dredging & Dock Co. built the substructure and the Toledo Massillon Bridge Co. was the general contractor for the superstructure, the erection being sublet to the Kelly-Atkinson Construction Co. The Strauss Bascule & Concrete Bridge Co. furnished the design and the general plans and specifications for the superstructure.

MR. HARRIMAN SUSTAINED IN REFUSAL TO ANSWER.

In the cases of Edward H. Harriman and Otto H. Kahn, the Supreme Court of the United States on Monday last held that the Interstate Commerce Commission is not entitled to press questions relative to private transactions, even though they involve dealings in the securities of interstate railways when the investigation of which such questions are a part has been begun upon the Commission's initiative. The opinion of the court was announced by Justice Holmes and dealt with the refusal of Messrs. Harriman and Kahn to make reply to questions put by the Commission in the course of an inquiry concerning the dealings of Mr. Harriman as president of the Union Pacific in the stocks of other railway companies, the inquiry being that on the "Alton deal" in 1906. Justice Holmes said that the Commission's inquiries should be confined to cases in which complaint had been made. He said that privacy should be properly regarded in proceedings begun by the Commission for its own purposes. The decision does not curtail the power of the Commission to compel the attendance and testimony of witnesses in cases where formal complaint of violation of law is concerned, but in the absence of such complaint the institution of such proceedings is held by the court to be without authority of law. The Federal Court at New York had ordered Harriman to answer the Commission's questions as to his ownership of 103,401 shares of preferred stock in the Chicago & Alton, purchased by the Union Pacific and deposited with Kuhn, Loeb & Co., under an agreement to sell at terms to be fixed by Messrs. Harriman, Stewart and Mitchell; also regarding his interest in other stocks. The opinion of the court, after setting forth the circumstances leading up to the controversy, goes on to say that while many broad questions were discussed in the argument, the court confined itself to comparatively narrow ground. The Interstate Commerce Commission contended that it might make any investigation that it deemed proper, not merely to discover any facts tending to defeat the purposes of the Interstate Commerce Act, but to aid it in recommending any additional legislation relating to the regulation of commerce that it might conceive to be within the power of Congress to enact; that in such an investigation it had power, with the aid of the courts, to require any witness to answer any question that might have a bearing upon any part of what it had in mind.

As to the power of Congress, Justice Holmes says that whatever it might be there was no attempt in the Interstate Commerce Act to do more than to regulate the interstate business of common carriers, and the primary purpose for which the commission was established was to enforce the regulations

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LXV.

REBUILDING OF THE KINZIE STREET DRAWBRIDGE OF THE CHICAGO & NORTHWESTERN RY.

By William H. Finley, Mem. W. S. E.

Read December 21st, 1898.

OLD BRIDGE.

Historical—Before beginning the description of the work involved in the placing of the new bridge, carrying the tracks of the C. & N. W. Railway over the North Branch of the Chicago River, near Kinzie St., I thought a short history of the old structure would be of interest to the Society.

Fig. 1 is from a photograph of the old bridge taken shortly before it was removed. It was a two-track pin connected span 175 ft. long c. to c. end bearings, and rested at the center on a

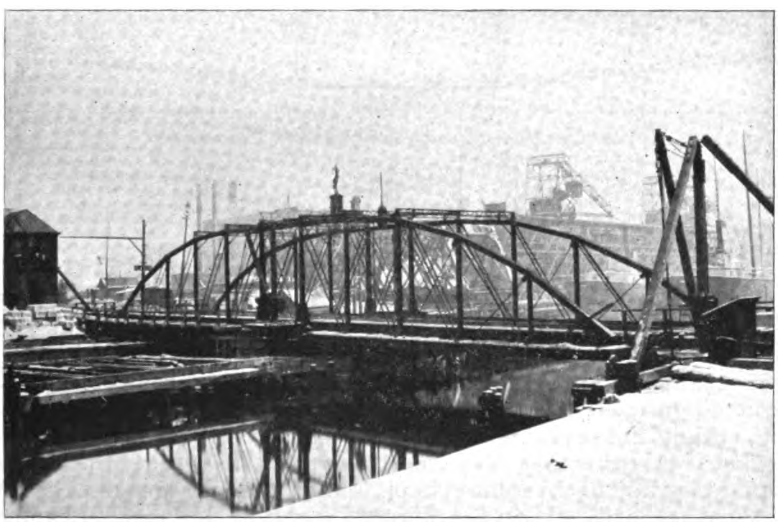
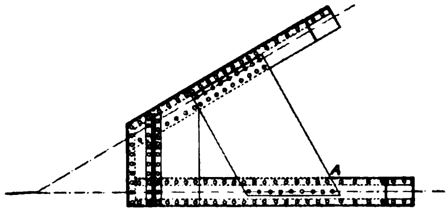


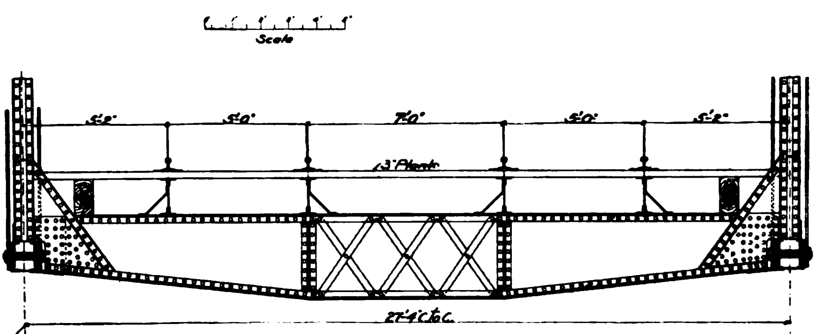
Fig. 1.

stone pier supported by piles and on pile piers at the ends. On the east there was a 16-ft. wooden stringer approach span and on the west two such approach spans.

The draw span was built in 1879 by the American Bridge Co., of Chicago, and possesses some historical interest from the fact



Detail of End of Truss



Cross Section showing Intermediate Floorbeam

Fig. 2.

that it was the first all steel bridge erected in this country, and also from the class of steel used in its construction. This material was known as "Hay steel," taking the name from its inventor, who claimed that by reducing certain ores in a specially constructed furnace, around which an electric current was kept flowing, adding the resultant slag or "sponge," as he called it, to the ordinary mixture in a Bessemer converter, it would produce a superior grade of Bessemer steel. This material was first tried in some railroad rails on the Chicago & Alton Railway, and gave such satisfactory results that it was decided to use it in the construction of bridges. The material for the Kinzie Street bridge was made by the Edgar Thompson Steel Works, of Pittsburg, Pa., Mr. Hay furnishing his specially prepared "sponge."

Not having been able to secure any record of the tests made on the steel when rolled, I had a physical and chemical analysis made of parts of the old bridge, which gave the following results:

	Elastic Limit lbs. per Sq. Inch.	Tensile Strength per Sq. Inch.	Elongation in 8 Inches.	Reduction in Area.
Cut from angle—				
No. 1	58,340 lbs.	73,430 lbs.	17.19 %	42.46 %
No. 2	54,540 "	70,960 "	16.41 "	46.35 "
No. 3	53,510 "	73,870 "	19.53 "	45.26 "
No. 4	56,810 "	77,480 "	17.97 "	43.08 "
No. 5	52,320 "	75,440 "	16.41 "	36.48 "
No. 6	53,320 "	75,930 "	15.63 "	39.37 "
No. 7	54,230 "	73,190 "	18.75 "	43.90 "
Average......	54,700 lbs.	74,500 lbs.	17.41 %	42.40 %
Cut from plate—				
No. 8.	57,940 lbs.	86,860 lbs.	17.97 %	32.52 %
No. 9.	59,200 "	88,330 "	14.84 "	36.38 "
No. 11.	59,460 "	89,780 "	14.84 "	28.41 "
Average.......	58,870 lbs.	88,300 lbs.	15.88 %	32.44 %

CHEMICAL ANALYSIS.

	Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
Angle.........	.24 %	.038 %	.47 %	106 %	.092 %
Plate..........	.42 "	.017 "	.44 "	109 "	.070 "

The particular bottom chord section from which these test pieces were cut was damaged by a boat striking it, and the four angles and two side plates forming the member were broken in two, square across, and several cracks occurred in the angles and plates at different points in the length of the member. The bridge men found it very difficult to make repairs to this struc-

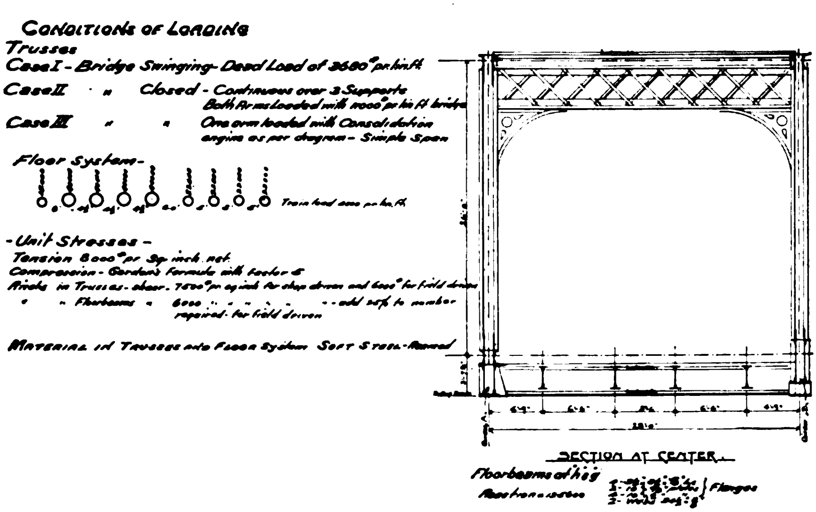


Fig. 5.

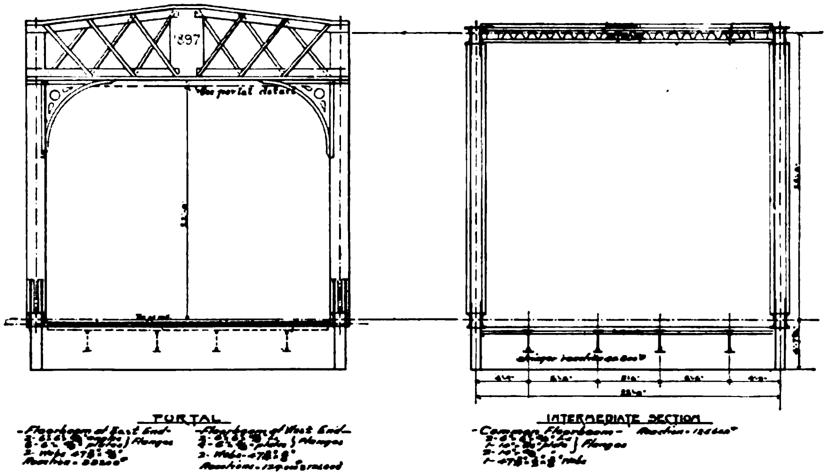


Fig. 6.

ture, owing to the brittle character of the material. I have seen angles break off piece by piece when backing out rivets and great care had to be taken in bursting off rivet heads, as it was a common occurrence to have the metal crack and break away from around the rivet. None but experienced bridge men were employed in making these repairs, yet, with all their care, they could not prevent considerable damage being done.

The old bridge was part center and part rim bearing, and Fig. 2 shows the details of construction ot the floor and the connection of the end post to the bottom chord. This latter connection is very faulty in design, and was the cause of the breaking of the bottom chord at point A when a locomotive happened to run on the span just as it was leaving its end bearings. The stress in the end post produces through the gusset plate transverse bending in the bottom chord at point A, which was sufficient in the instance cited to break the bottom chord in two.

NEW DRAW.

Superstructure—The new draw span differs from the usual design of swing bridges in having the center of rotation in the plane of one of the trusses instead of the longitudinal axis. The necessity for this departure from accepted practice will be better understood by an inspection of Fig. 3, which shows the relative position of the three bridges at this point. The bridge on the north is the double track draw span of the Chicago. Milwaukee & St. Paul, that on the south the old double track draw span of the Chicago & Northwestern Ry., while between them is the Kinzie street city bridge. This is the condition as it existed before the new draw of the Northwestern road was built, and it will be noticed that when the North-

western and the city draws were open their ends almost touched. When the question of putting in a new draw came up, the Federal government in granting a permit for its construction, stipulated that it should give a clear opening of 70 ft. in the west channel. Inasmuch as the old draw gave but 58 ft. opening in this channel, it was evident that if the new draw was swung from the same center as the old one it would over-lap the city bridge by about 12 feet. Two schemes to overcome this were discussed: One was to move the bridge south far enough to permit it to clear the city bridge in swinging; the other was to place the longitudinal axis of the new bridge coincident with that of the old

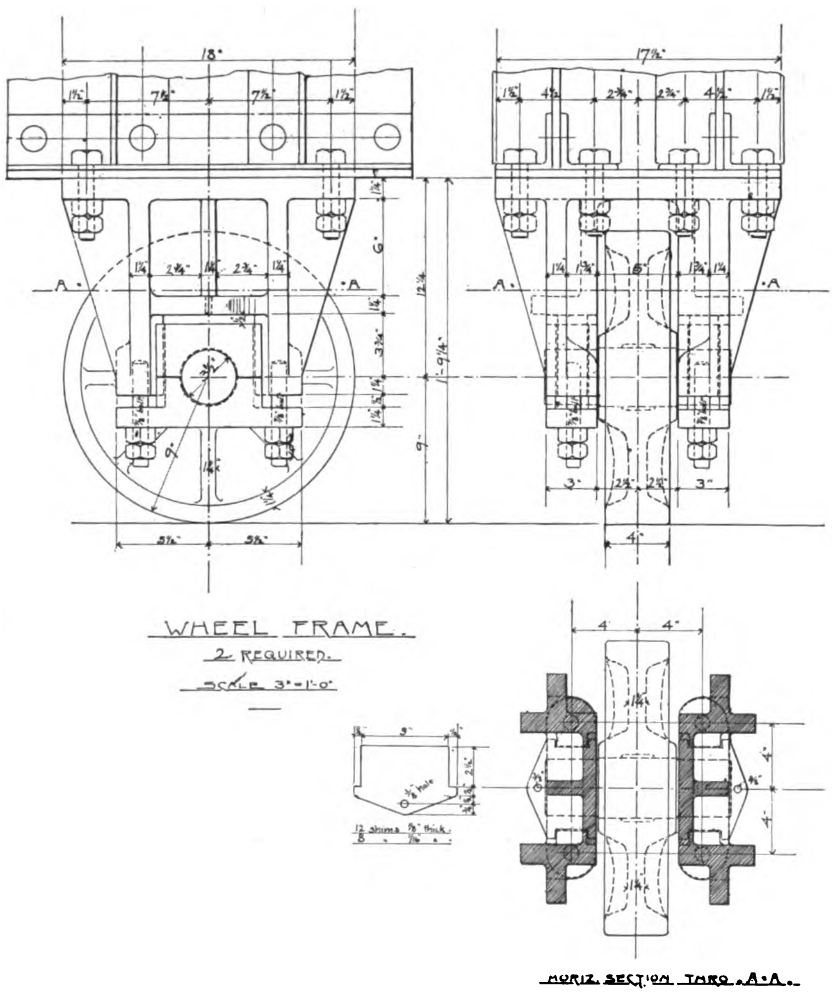


Fig. 8. Balance Wheels.

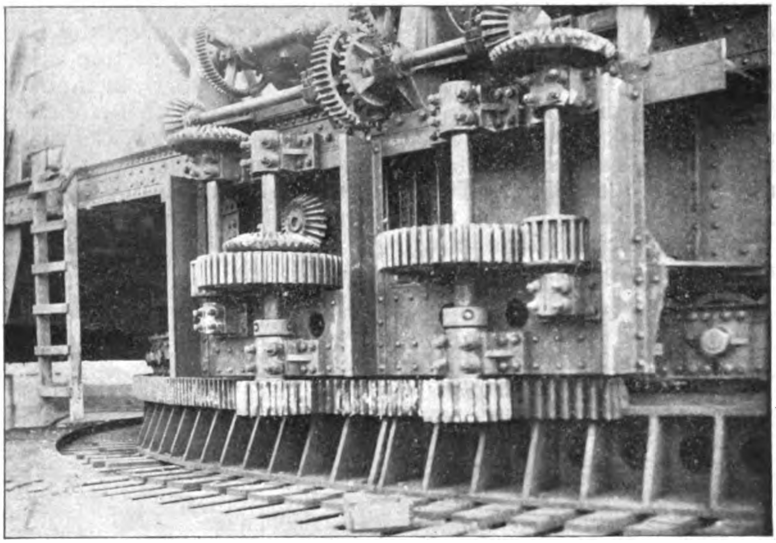
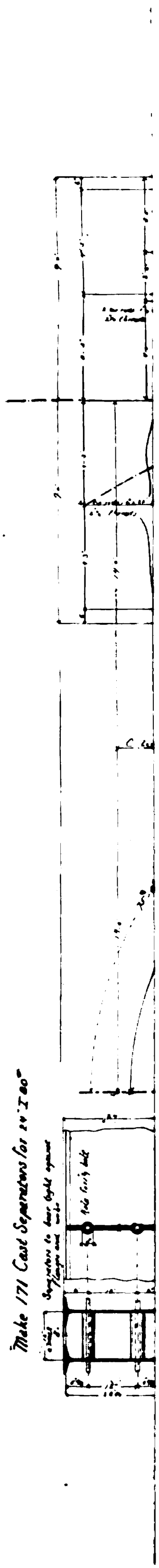
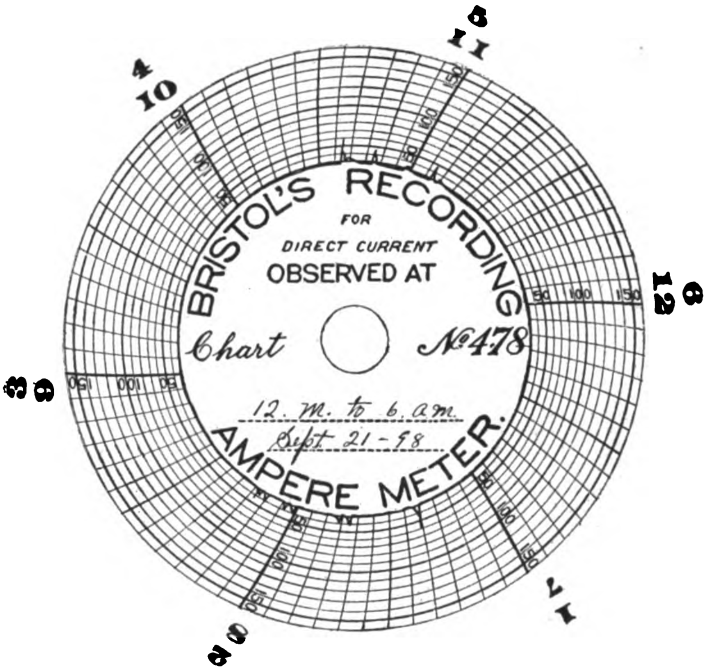


Fig. 10. View of Operating Gears.

bridge and locate the center of rotation under the south truss so that in swinging open it would move away from the city bridge, and when over the protection pier give the same clearance to the city bridge as did the old draw. The first scheme would necessitate the changing of all the tracks in the Wells Street Terminal Yard, as well as those on the west side of the river, to conform to the new position of the bridge. It would have been a very expensive piece of work and have seriously interfered with the operation of the terminal. While the second scheme would avoid this difficulty, yet it had the precedent of failure back of it. The draw of the Chicago, Milwaukee & St. Paul Ry., just north, was originally built with the point of rotation under one truss, but gave trouble from the start, and after a few years' service this method of swinging was abandoned and the turning arrangement remodeled, making an ordinary center swinging bridge of it. However, after due consideration of the merits of the two plans, it was decided to adopt that of the excentric swing. Figs. 4, 5 and 6 show the type of truss used and give the loading, resultant stresses and make-up of members. Fig. 7 shows the turning arrangement at the center. On the left is seen in section the pivot center, made up of two concentric rings of conical tool steel rollers, working in tool steel bearings. The outer ring consists of 23 rollers 4 inches long and 4 inches large diameter; the inner ring consists of 18 rollers 3 inches long and 3 inches large diameter.

This pivot carries 375,000 pounds while rotating, giving a pres-


Make 171 Cast Separators for 24" I 80"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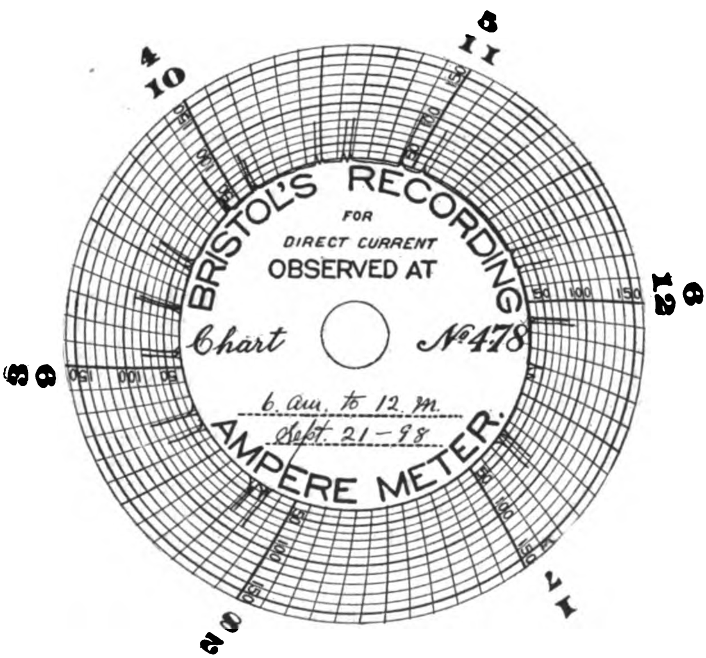
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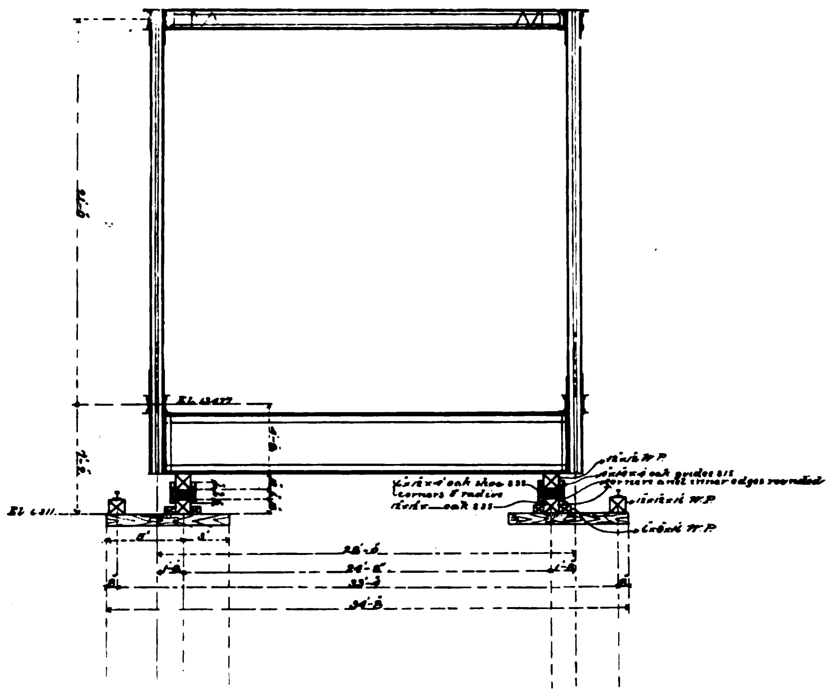

Fig. 13. Cross Section of Launching Ways.

sure of 2,568 lbs. per lineal inch of roller. The pivot is supported by a box girder which distributes the weight over a platform of seventeen 24-inch I-beams 18 ft. long. The wedges shown on each side of the pivot furnish reactions for the live load concentrations over these points. They are worked by compressed air and merely driven home to a tight bearing. The balance wheels shown on each side of the wedges steady the bridge while swinging.

On the right is shown in section the curved girder that supports the north truss at the center and distributes half the weight of the bridge on the partial ring of live rollers. This girder is about 18 ft. long and rests on ten cast steel wheels 20 in. diameter and 12-inch face, giving a pressure of 3,125 lbs. per lineal inch of roller when bridge is swinging. The bridge in opening swings through an angle of 75 degrees. The partial ring of live rollers makes an angular movement of 37½ degrees or half the movement of the bridge. To prevent slip and always insure the same relative movement of the bridge and wheels, they are connected by guide racks and pinions as shown. The curved girder has a rack its entire length, as has also the bottom track. To every sixth roller there is attached a pinion that meshes with the upper and lower racks. When the bridge is opening or closing, the up-

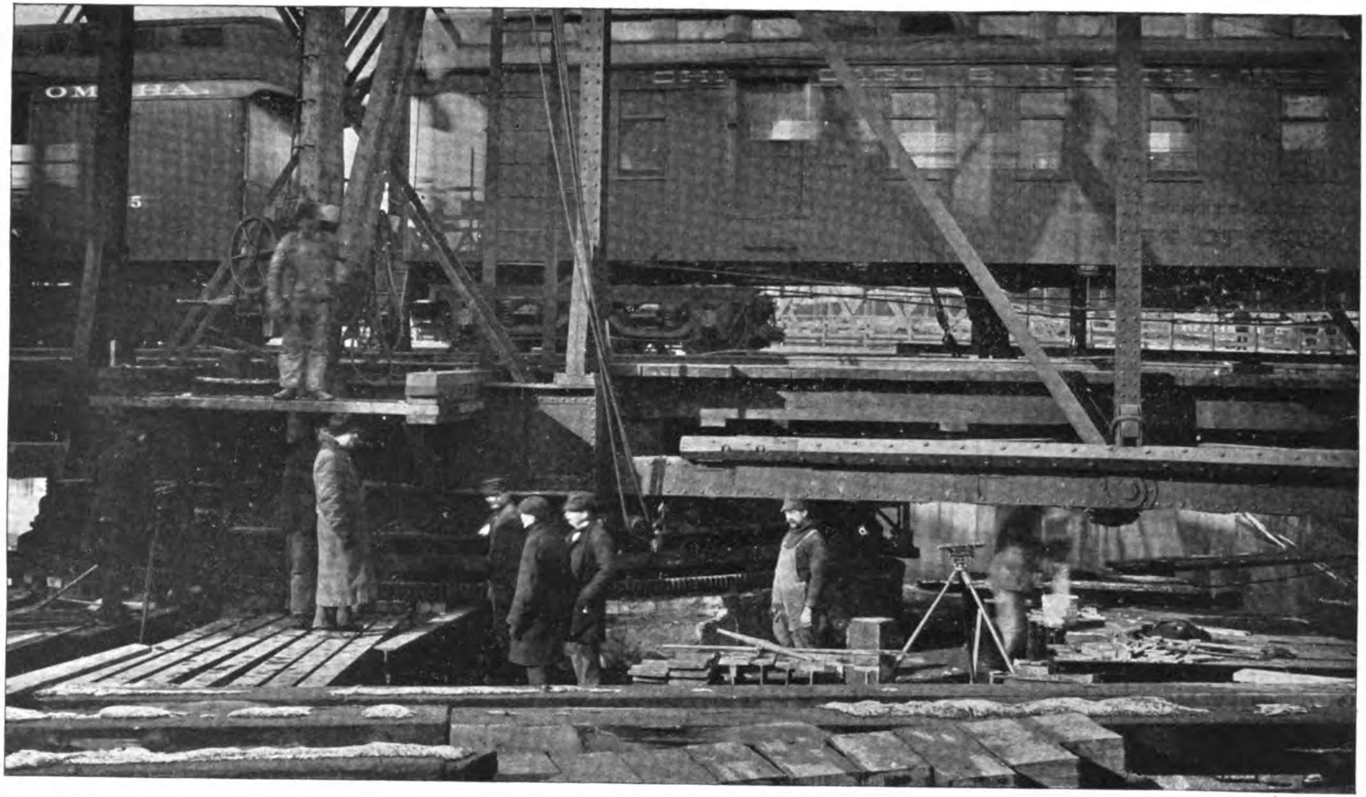

Fig. 14.

per rack successively engages and disengages these pinions, there being in all positions two pinions in mesh with both racks. The upper and lower tread plates are of cast steel. The lower tread is supported by cast iron girders which rest on 24-inch I-beams. The wedges shown between lower track and beams were introduced for the purpose of leveling up the track in the event of unequal settlement of the pier.

Fig. 9 gives a better idea of the arrangement of the beams for distributing the weight of the bridge while being swung and when at rest. On Figs. 7 and 10 is shown the arrangement of the gearing for swinging the bridge. The motive power is two 30 H. P. Jeffery electric motors connected up in series. These motors are operated by a 220 volt system from the Railway Company's power-house just east of the bridge.

On Fig. 11 are two charts from the recording ampere meter on the bridge circuit, and they show the amount of current required to swing the bridge. The great difference in amount of current used in day and night swings is due partly to the manner in which the controller is handled by the night and day operators, and partly to the reason that the bridge during the day has a greater reaction on the end bearings—due to expansion—than it has at night. The bridge has no end lifts, simply rolling up on end rest wheels on the abutments. The rail lifts, center wedges and end latches are operated by compressed air taken from the Company's power house. The latches are on the floor level, and are so constructed that they will close and center the bridge if the operator brings it within five inches of its closed position with the electric motors. The time required to open or close the bridge is one minute. This includes the operation of the center wedges, rail lifts and latches.

Substructure—The center pier of the old bridge was octagonal in shape, and consisted of 4 ft. of masonry, resting on two solid courses of grillage, 12-in. and 8-in thick, respectively, the whole supported by piles. Fig. 13 shows the old pier and the additions to it to accommodate the eccentric swing of the new bridge. In making this addition to the center pier there were used 213 50-ft. Norway pine piles, driven to Chicago city datum. The steam hammer of the pile driver weighed 3,500 lbs., and the movable parts resting on the pile weighed 6,000 lbs., making a weight of 9,500 lbs. altogether. It required from 280 to 400 blows to drive these piles the depth given above, and the penetration at the last blow varied from ½-inch to ¾-inch. The driving disturbed the existing pier to such an extent that it required constant work on the approaches in shimming the stringers and cutting away the back walls to permit the bridge to close. The pile driving being nearly all on the east side of the old pier, resulted in a movement of the latter to the west, of about five inches, and also raised it up about two inches. After all the center pier piles were in a cof-

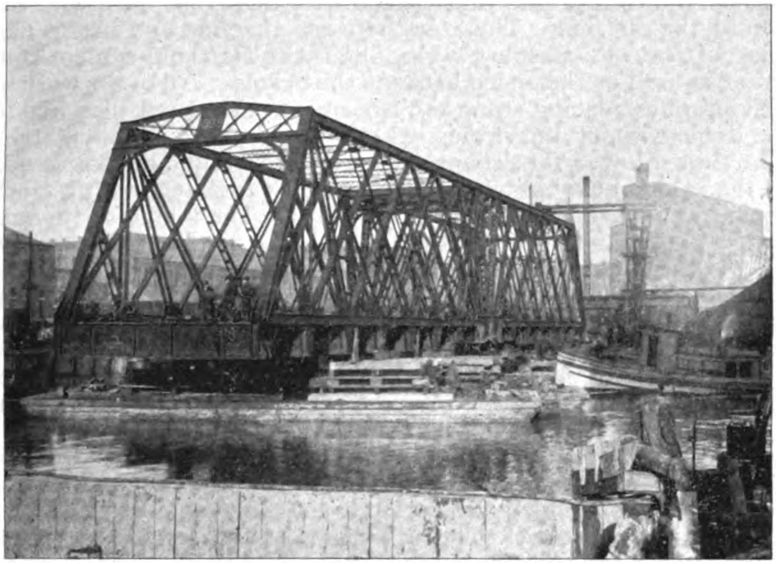

Fig. 15.

ferdam was driven around the pier and pumped out and the piles were then cut off on a level with the piles in the old pier and capped with 12x12 oak. On top of these caps was laid a solid course of 12 in. x 8 in. oak. This grillage was bonded in with the grillage on the old pier. The new masonry was laid on top of this platform and bonded in with the masonry of the old pier. The I-

Fig. 16.

beams shown in Fig. 9 were placed with their tops flush with the top of the old pier. The areas between the line of I-beams and that of the old masonry were filled with Portland cement concrete, as well as the space between the beams. All of the work of driving piles, placing stone and I-beams on the center pier, had to be done without interfering with railroad traffic or navigation. The time allowed for driving piles was after midnight, possession of the bridge being obtained from 1 o'clock to 2:45, from 3 o'clock to 4:45 and from 5 o'clock to 5:45 A. M. The laying of the masonry and placing of the steel beams was done during the day. To put the beams in place required the cutting away of the stone of the old pier under the bottom tracks of the draw, and for a distance of about 8 ft. inside of the track. Great care had to be exercised in doing this work, for the reason before mentioned, that the operation of the bridge could not be interfered with. As the stone was cut away piece by piece from under the bottom track, wooden blocking was inserted to take its place, and after sufficient stone had been removed and the bed carefully dressed, the beams were placed in position one at a time, by removing a section of the blocking and carefully leveling up each beam before the next one was placed. Fig. 14 is a view of the work while the beams were being put in position. The derrick shown in the center of the truss was used for handling material at the pier, there being a similar one on the other truss. The mast of these derricks was placed between the top and bottom chords and the booms swung out from the side of the bridge and commanded the work below. When the bridge was opened for the passage of vessels they were swung to one side and lashed to the truss. All material for the center pier and two abutments was received and unloaded at the east end of the bridge on the north side. A sidewalk was built on the north truss from the east end to the center pier, on which all material was run out.

The piles for the abutments were driven at night between trains from the track level, and after being cofferdammed were cut off and capped. The stone was laid up under the tracks. The only drawbacks in building the abutments arose from the contracted space in which the work had to be done and the great amount of traffic over the bridge.

The difficulty of rebuilding the center pier and abutments without interfering with traffic or navigation can be better appreciated when it is stated that the train movements over the drawbridge for twenty-four hours averaged 703 engines, 1,948 passenger cars and 366 freight cars.

Erection—It was very necessary in making the change from the old bridge to the new one, that some method should be adopted that would delay traffic the least possible, and it was finally decided to erect the new bridge on shore on specially prepared "ways," launch it out on scows and then float it up stream to its permanent location, the old bridge in the meantime being raised from its position by scows and floated down stream.

Fig. 3 shows the location of the new bridge for erection. This is on the railway company's property south of the old bridge and on the east side of the river. The space between Market street and the river was not sufficient to permit the erection of the entire bridge at one time. Two bents of piles spaced 16 ft. from dock line and 16 ft. apart were driven in the river and the west end of the bridge started from the outer bent, and after carrying the work up to the west line on Market street, there were still 30 ft. to be added to the east end of the bridge to complete the span. After the erection of that portion of the bridge on the ways, the piles in the river were removed and a scow partly filled with water was floated under the overhanging end and pumped out until it supported part of the weight of the bridge. The structure was then slid out on its ways a sufficient distance to permit the erection of the remaining 30 ft. on the east end. While this was being done, two scows were placed under the part projecting over the river in their proper position. Fig. 15 is a view of the bridge all completed, ready for final launching.

The old bridge was removed by placing a scow filled with water under each arm and then pumping them out until the span was raised from its piers a sufficient distance to float it down stream.

When the work of setting the machinery on the center pier had progressed far enough, the new bridge was launched out until its east end rested on the edge of the dock, the west being supported by the two scows previously mentioned. While in this position two scows filled with water were floated under the east arm and pumped out until they lifted the east end clear of the dock and the bridge was entirely afloat. Fig. 16 is a view showing the bridge across the stream resting on the scows ready to be towed to its final location.

The clearing off from the top of the pier of the center pivot and bottom track of the old bridge and the setting of the heavy distributing girders, pivot bottom, track guide and swinging racks, spider frame and rollers for the new bridge took considerable time, as the successful working of the new bridge largely depended on the accuracy with which this work was done. The total weight of the material handled on the center pier amounted to 125,000 lbs.

The weight of the old bridge was 400,000 lbs. The weight of the new bridge as it rested on its scows in the river was 720,000 lbs. The cross ties and rails were laid on the new bridge before it was launched.

The work of replacement began at 1 o'clock A. M. Sunday, March 13th, 1898. The old bridge was floated at 11 o'clock A. M. New bridge was launched at 4 o'clock P. M., towed into place at 10 o'clock P. M. and landed on the center pier at 12:45 A. M. Monday, March 14th The first swing was made at 4:30 A. M. Monday, and the first train crossed the bridge at 6 o'clock A. M. Monday. In other words, it was just 27½ hours from the time the work was begun until the new bridge was swung to test the turning gear, and 29 hours until the bridge was ready for traffic. The work was begun under difficulties. It began to rain shortly after operations were commenced and continued until daylight. There was an unusually swift current in the river that night, making the placing and blocking of the scows under the old bridge slow and difficult work.

Notwithstanding the great volume of traffic over the bridge during the work of building the foundations, and the number of men constantly passing back and forth, there were no accidents or loss of life.

The plans were made in the Engineer's office of the railway company and the work was carried out by the writer under the direction of the Chief Engineer, Mr. John E. Blunt, member of this Society.

Before concluding, I wish to express my appreciation of the services of Mr. Lincoln Bush, member of this Society, who assisted me in the preparation of the plans and supervision of the work in the field.

DISCUSSION.

Mr. Ralph Modjeski: In regard to trusses, why was a multiple intersection truss used instead of a Pratt truss? I presume that the short panels were made for the purpose of making this floor shallow.

Mr. Finley: Not altogether; we considered in this instance that a riveted bridge was to be preferred to a pin-connected bridge.

Mr. Modjeski: I ask the question because I should think that it would have been preferable to use a single intersection truss where the distribution of stresses would have been well defined.

Mr. Finley: One other reason for it was the fact that the bridge was likely to meet with accidents from boats in the river, and the multiple system of trussing would give much better security and less likelihood of collapse, in such event, than the Pratt system or any single or double system of trussing. The old bridge was struck by boats and seriously damaged on several occasions, causing annoying delays to traffic.

Mr. Modjeski: That is a good reason, indeed. Another question occurs to me. I am surprised at the great amount of power used at the bridge. Do I understand you had two motors of thirty horse-power each, which would make sixty-horse power?

Mr. Finley: Yes, but it does not necessarily follow that all that power is required. The recording ampere-meter on the bridge circuit indicates that we are using but very little power, in fact, the maximum horse-power at the peak of the load is as low as eight or ten. I do not consider this excessive for a bridge of this size and weight.

Mr. Modjeski: It is very little.

Mr. Finley: Frequently it can be swung with less than that. Remember it is only the load at the starting and stopping point. The bridge has no end lifts, simply beveled plates which roll on end rest wheels on the abutments, raising the ends about one-half inch. This requires the application of considerable power in starting the bridge, and the two motors working in series, furnish the maximum torque for this condition. The speed with which the bridge opens is sufficient for all practical purposes, it opens through seventy-five degrees in about one minute, and with a bridge of this character I do not think it would be safe to open it much faster.

Mr. B. B. Carter: I was looking at the bridge the other day and was interested to note the action of the controlling racks or pinions. that control the roller center. I noticed that at the starting point, whether from the closed position or the open position, that the lower rack especially was pretty hard rubbed on one side of the teeth and very little rubbed on the other side, and at the other end of the rack, the rub was reversed on the teeth, showing that there is actually a tendency of the roller circle to crawl out from under the bridge, but it is held in check by the rack, which the rubbing would indicate Had you noticed anything of that ?

Mr. Finley: Yes.

Mr. Carter: In regard to the motor. The motor was figured originally at about thirty horse-power, it was calculated that it ought to swing at less than thirty, but when the bridge was first started, of course all of the machinery was new and stiff and especially it was found that the pitch of the steel racks was uneven, so that at places there was a very hard rub and some difficulty, as Mr. Finley suggested, in moving the bridge off the ends with a single motor. Of course, after awhile, the friction of the parts was considerably less and there was no further difficulty. The plan of putting in a second motor was originally intended to prevent delaying traffic in case of burning out or breaking down of any part of the first motor.

Mr. Finley: The guide racks were put in to prevent the slip of the bridge on the rollers, or the working out of the rollers from under the bridge. When this bridge was being designed, I took measurements on quite a number of drawbridges and found there was considerable slip on the live ring, in fact it amounted to as much as three inches a week on a drawbridge recently built, so I reasoned from this that there was a likelihood of these rollers, if they were not connected to the bridge, doing the same thing. These guide racks perform the office of preventing that very well, and, just as Mr. Carter says, the work they have to do is essentially at the starting of the bridge from its closed position and also from its open position, and that is the only work shown on the guide racks. Of course, as the bridge comes to the closing position, the stopping of it is likely to cause a sliding of the rollers on the lower track, or sliding of the bridge on the rollers, and these guide racks and pinions prevent any such movement.

Mr. J. W. Schaub: The only thing that I can say is in regard to the pivot, which Mr. Finley adopted, after everybody had condemned it. However, Mr. Finley very wisely provided a spider which takes care of the collar friction on the rollers. If anyone will figure the resistance to turning in an ordinary swing bridge, they will find the collar friction amounts to about one-half of the total resistance to turning, and unless this friction is provided for the rollers will not move in a circular path, but will tend to get out of alignment. As the pivot was used in the Chicago, Milwaukee & St. Paul bridge the rollers were, strictly speaking, wheels with axle bearings, and there was no direct connection between the rollers and the pivot. The rollers being conical the tendency is for the wheels to move out from under the tread; and, in addition to the sliding friction on the axles, which I am informed was also not properly provided for, the collar friction became so great, that, Mr. Bates tells me, five-inch shafts were broken off in attempting to turn the bridge. Mr. Finley avoided the axle friction, and in its place used the rolling friction, and the results speak for themselves. From the experiments made on the Thames River bridge, we know the co-efficient of rolling friction to be about .003, whereas the sliding friction may be almost anything, depending upon the nature of the journal bearings.

Mr. Finley: I think Mr. Schaub is wrong in his statement that anyone ever said anything against that pivot; I think it always gave satisfaction and after it was taken out of the Chicago, Milwaukee, St. Paul bridge, it was in almost perfect condition; I made an examination and found no evidence of any unusual wear in any part of it and am satisfied that it was a well-constructed pivot in the first place and gave satisfaction as far as it was concerned in the bridge of the Chicago, Milwaukee & St. Paul railroad. I would rather Mr. Bates would explain about that bridge. In regard to the pivot, I was perfectly familiar with the construction of it, having worked for the bridge company that built it, in fact, I made the shop drawing of it (not the design), and I was perfectly satisfied that it was well constructed. It was not given a fair test on the bridge on account of the way the rollers were fastened. As Mr. Schaub has stated, there were ten rollers, in two concentric rows of five each and they had an axle bearing. The axles were keyed into a truck and the rollers worked on the axles. and the result was these rollers, having an axle friction, instead of the rolling friction as we have it in the Northwestern Bridge, caused the cutting into the wheels which prevented the wheels from rotating, and produced flat spots in them, until there was a sliding of the bridge around on its bearings every time they opened it, instead of rolling; in fact I think that was the only trouble.

Mr. Carter: I would like to add to what Mr. Finley said about the St. Paul bridge that the shaft in the rollers was, I believe, $4\frac{15}{16}$ in.; the rails and wheels were made of cast steel and the shaft was of some kind of steel, not cold rolled, but probably a turned open hearth or Bessemer steel. The actual pressure per square inch of projected area, if I remember correctly, was about 3,300 pounds to the square inch. No attempt had been made at babbetting, bronze bushing, or to get good wearing surfaces. After taking them out it was found that the bottoms of the shafts were cut or worn in fully one-half inch, in one case nearly three-fourths of an inch. The holes in the wheels varied from about one-quarter inch to one-half inch larger than the original bearing had been, and in spite of all that looseness they still cut, and in some cases when taken out were stuck, almost cold welded.

Mr. Finley: I am satisfied that the difficulty would not have arisen in the Milwaukee bridge if it had not been for the pier. It settled unevenly, throwing the lower tread out of level, and the wheels being in a stiff buggy did not have an equal bearing, and I am not surprised at all that they had flat spots. I believe that if the pier had been a stable one, the difficulty, if it had eventually occurred, would not have developed as soon as it did and could have been remedied by properly bushing the axle bearings.

Mr. Onward Bates: I came here under the impression that I was to hear about the construction of the Chicago & Northwestern bridge, and hardly expected that it would be to hear the Chicago, Milwaukee & St. Paul bridge picked to pieces. If I have to speak on both bridges, I will take the subject of the evening first, and will say that I suppose this is a case without a parallel for the amount of railway and steamboat traffic that had to be maintained during the reconstruction of the bridge. The manner in which the pier was rebuilt calls for my admiration even more than the method of substituting one span for the other. I think we could not have a better example of difficult construction to go in the records of the society, and I am proud that I know Mr. Finley.

Now with respect to the Chicago, Milwaukee & St. Paul bridge, it seems Mr. Schaub was employed on the plans for the bridge, which were sent to Edge Moor where Mr. Finley designed the center. [Laughter.] A number of years afterward Mr. Carter and I got together and rebuilt the bridge, putting in a new pier and new turning machinery. This was in the fall before the World's Fair, I think about four years ago, and since that time there has not been a better bridge on the river. I was thinking when Mr. Finley was speaking about the bridges being struck by steamboats that our bridge gets the worst blows and that it has saved his bridge many a time. Only within two or three months our Kinzie street bridge was struck by a steamer which tore the whole web out of a fifteen inch channel in the chord, curling up and removing a piece of iron 12 in. wide, ⅝ in. thick and about 4½ ft. long. I mention this to show the shocks that these bridges get from time to time.

The Chair: The subject of the Chicago, Milwaukee & St. Paul railway bridge being brought in here, seems possibly somewhat irrelevant except for the matter of the center: but after all, Mr. Finley in opening his paper mentioned the fact that that bridge was a failure, that it was pivoted under one chord, and that notwithstanding such failure the same principle was adopted in his bridge, so, that as Mr. Finley got the old center from that bridge, and also as that failure was the chief argument against his method of swinging, I think it was entirely justifiable to bring up the matter before the meeting this evening, and I am very glad it was pretty fully discussed. The trouble evidently in the Chicago, Milwaukee & St. Paul railway bridge was not because it was pivoted at one side, but that the turning apparatus, or rather the rollers, were of faulty design, all of which has since been remedied and the bridge is now one of the best on the river, as Mr. Bates has just said.

Mr. G. A. M. Liljencrantz: Referring to the track elevation; judging from the solid construction of both the substructure and the superstructure, I presume the road has entirely abandoned its intention of extending the elevated track as far down as the depot. When the bridge was first authorized, some six years ago, I believe, nothing was done for a couple of years, and I was told that the work was delayed pending the question of track elevation; from this I concluded that the original intention was to elevate the tracks all the way down and therefore I would ask whether that has been entirely abandoned or left to future development.

Mr. Finley: I cannot say that the company ever considered the possibility of elevating the tracks down that far. At the time the bridge was authorized, the question of track elevation was in rather an unsettled condition; they had no idea of what it was going to be. A moment's reflection would convince you that it would mean the entire abandonment of the terminal, or the reconstruction of it.

Mr. Liljencrantz: Mr. Finley stated that it takes one minute to turn the bridge, and I presume that there would not likely be any hitch in the machinery requiring much more than that time, yet a short time ago I had occasion to go up the north branch of the river on a tug, with the Real Estate Board, and we were kept waiting about ten minutes before a train appeared, so it seems to me that if it could be moved in one minute, it would not be necessary to delay a boat that long, unless it is uncertain whether it can always be done in one minute.

Mr. Finley: It can always be opened in one minute; the delay mentioned by Mr. Liljencrantz was no doubt caused by waiting to get a United States mail train across. There is one thing about the bridge that I did not mention in my paper, and that is the fact that it will only swing in one direction, through an angle of ninety degrees, which might be considered an objection to that form of bridge; the old bridge always swung in the same direction since my connection with the road. This is due largely to its location and the fact that only one channel is used; the east channel not being used by boats.

Mr. Oliver J. Westcott: I believe that a four-track bridge was originally discussed. I would ask if there was any other reason for abandoning the four-track bridge than the lack of space; and if that was the final reason for abandoning it? It seems to me that a four-track bridge would have given much better service to the suburbanites. I am speaking from experience.

Mr. Finley: I have no official knowledge why the four-track bridge was abandoned, as that question came up and was settled before I became connected with the company.

Mr. Liljencrantz: I presume the lack of sufficient space undoubtedly had much to do with that decision, because it is one of the worst places on the river.

Mr. Finley: According to the plans I think not; the four-track bridge gave seventy feet of opening, the same as this bridge does now. The bridge was built under the permit issued for a four-track bridge.

Mr. S. G. Artingstall: There is plenty of room for the small vessels and tug boats to pass on the east side of the river, while the main channel of course is on the west side; the worst place is at the Chicago, Milwaukee & St. Paul bridge, but the tug boats that are perhaps 15 to 18 ft. wide can pass at all times on the east draw, even while larger vessels are passing through the west draw of the bridges. It requires dredging on that east draw. It is one of the most complicated locations there is in the Chicago river.

Mr. Finley: I should say the solution of that would be to take out the present city bridge, and build a bascule bridge. The trouble with this location in the matter of navigation is the fact that there is a bend in the river and a tow going south and one going north do not see each other in time to prevent getting jammed in the bridge openings.

Mr. Artingstall: If you have a vessel some three hundred feet long, you would have a great deal of trouble to turn around the bend even if you had a bascule bridge.

Mr. Finley: The trouble is not from the long vessels. There are a lot of tugs with scows and other small boats that usually come together there and get into trouble. Those long vessels are not going through there constantly and when they do, there is considerable care taken.

Mr. Artingstall: How would it do to make both bridges, the Milwaukee, St. Paul railway and the city, Kinzie street, bascule bridges?

Mr. Bates: I think this subject is drifting away from the Chicago & Northwestern bridge, and I did not intend to criticise the plan shown by Mr. Finley, but it is drawn from me by the remarks of Mr. Artingstall. That is not a correct plan; it shows the situation as it existed five years ago. You will observe by looking at the plan of the Chicago, Milwaukee & St. Paul railway bridge that it shows the old bridge with the center of rotation under the west truss. Since the bridge was rebuilt we have a much better opening on the east side of our protection pier.

Mr. Finley: Mr. Bates is quite right in that. The object in showing that was of course merely to illustrate the work on the Northwestern bridge. As far as I can see there is no reason why it could not be used for boats, if the city or government that controls it did not allow a lot of bum-boats to tie up alongside of the Kinzie street city bridge and stop up the channel.

Mr. Artingstall: That is only a temporary thing.

Mr. Finley: They have been there almost continuously for the past ten years.

Mr. Liljencrantz: These boats were all ordered out and removed, but have since then occupied the whole space between the north end of the Milwaukee & St. Paul railway bridge and the east draw of the Indiana street bridge, making that part impassable, but in the spring when navigation opens that place will be cleared and made navigable for vessels.

Mr. Albert Reichmann: I would like to know whether the bridge is affected by changes in temperature; taking the structure as a whole, perhaps the top chord would be heated a little more than the bottom chord.

Mr. Finley: I believe there is some effect from that; I have not noticed anything of any importance. There is no question but that in the middle of the day the bridge bears more heavily on its end rests than at night, that is why it requires more power to swing the bridge in the daytime. Then, too, in the daytime they have to operate it more rapidly, while in the night time there is more time and it can be done with more care.

Mr. Lincoln Bush: The method of attaching the axles to the rollers and the guide rack pinions in order to prevent the skidding of the rollers, I believe would be of interest if explained by Mr. Finley.

Mr. Finley: Mr. Bush is familiar with the point he mentions and I would ask that he explain it.

Mr. Bush: The upper guide rack is attached to the drum segment and moves as the bridge is turned, compelling the rack pinions to revolve. These rack pinions and the rollers which are attached to the same axle are left free to turn upon their common axle. By this means the guide pinions and rollers have an independent motion and the skidding of the wheels is thus prevented. The tendency of the drum segment to slip on the rollers is taken care of by the bending resistance of those axles to which guide pinions are attached.

Mr. Finley: That is right; these live rollers are loose on the axle; the axle is not keyed to the frame; and the guide pinions are loose on the axle so that there is no tendency for these guide racks while they are engaged with the pinion, to force the roller to slide under the load. Everything is made loose, and the reason the lower rack is put along the full distance of the bottom tread is to space the pinions, so that the upper portion of the bridge, with the upper guide rack on it, as it approaches each one of those pinions, the latter is in its proper position to mesh with the upper rack. The teeth in the end of this upper rack are cut back to give a little more play, so that in case there is any slip, it would be taken up gradually. The point that Mr. Carter calls attention to shows the condition that we hoped to and did overcome by putting in those guide racks. In opening the bridge as it starts off from its closed position there is a tendency for it to skid over those rollers and these two guide racks prevent it, so we find the only evidence of wear on the guide racks is at the points where the bridge is started from an opened and closed position, while between these points there is very little if any wear.

Mr. Carter: I would like to call the attention of the Society to the fact that for repairs this construction is far in advance of the continuous circle. There is always a position to reach any roll in the entire circle, it can be taken out without jacking up the bridge. Take the bridge closed for the passage of trains, then the free end of the roller buggy, which is the east, can be gotten at until the curved girder and the top tread is reached, and any one or all these rolls can be taken out and replaced very quickly. Then after that is done, simply open the bridge as for the passing of a boat and then the rest of the rollers can be taken out and replaced, so that in case of excessive wear taking place in any one roller it can be replaced. Then in regard to the wedges over the I-beams, when there is excessive settling in one position, as was found in the Chicago, Milwaukee & St. Paul bridge, by moving the bridge, taking the dead load off this position, the wedges can be driven in, which will raise the track to a new level; in this regard I think this construction is far in advance of the continuous circle; also as to the pins in the rollers, they are simply carrying the weight of the riveted structure, they carry no bridge load. These pin bearing surfaces are small when figured for the dead load, but are very large when figured for carrying the riveted structure; then this structure is solidly riveted together, so that the action of the guide pinions is simply thrusting that entire center structure around, and, of course, as it does so, carries with it the shafts and the rollers, so if one roller refuses to roll, it is simply skidded along the lower tread and compelled to keep its position in regard to the rest of the rolls.

Mr. Finley: I think one of the good features of the bridge is the position of the machinery. That is all exposed, all outside, and can be gotten at very readily without interfering with any portion of the bridge. By throwing a block and fall over the top chord, any part of the machinery, wheels, axles, boxes, etc., can be taken out from the bridge without interfering with the use of the tracks, and I think this is a good point. In the event of a breakage it can be quickly handled. This bridge has been in operation since last March, and has not given any trouble in the way of swinging or opening. The wheels work perfectly. The reason why the frame work was made so heavy is that the girders supporting the wheels are quite long, and not being a full circle, if there is any distortion, the wheels would be likely to track in or out, and for this reason the framework is made very rigid, preventing any distortion.

Mr. Gerber: Referring to Mr. Carter's statement as to the difficulty of getting wheels out of a continuous circle, this can be easily obviated, and has been in many recent bridges, by placing the rack below the track, so that any wheel can be removed at any time without disturbing the others or much of anything else.