Moving a Three-Span Truss Bridge*

By C. E. Smith†

SYNOPSIS—The shifting of the Missouri Pacific Ry. bridge over the Kaw River at Kansas City was a noteworthy piece of work necessitated by the disastrous flood of 1903. To adjust the bridge to the new channel its three truss spans of 180 ft. were first raised about 9 ft. above their original elevation. Then the three spans, as one 540-ft. structure, were swung laterally to the new alignment by a radial motion giving a shift of about 3 ft. at one end 26 ft. at the other end. Finally, the three spans (connected to form one structure) were moved about 123 ft. longitudinally to seat them on the new piers. All this involved very delicate work and very careful planning, especially as the bridge had to be kept open for traffic. The foundation work for the new substructure was complicated by the presence of a tangled mass of wreckage of bridges, cars, etc., buried in the river bed. The commencement of the work was delayed by various causes, and the bridge alterations were only completed in 1912. The accompanying article, by the engineer who was in charge of the work, describes in detail the series of operations in building the new piers and placing the old spans upon them.

At the time of the great flood in the Kaw (or Kansas) River at Kansas City, in 1903, the main line of the Missouri Pacific Ry. crossed the river on a double-track bridge consisting of three 180-ft. steel truss spans on masonry piers and abutments. The original footings were 10 ft. below the bed of the river, resting on piles driven to a depth of about 20 ft. About 100 ft. above it was a similar bridge of the Union Pacific Ry. When the water rose this was weighted with cars and locomotives to try and hold it, but the pressure of the water and drift was so great that the superstructure was carried away and (with the cars and drift) lodged under the Missouri Pacific Ry. bridge, forming almost a solid dam, so that the water passed over the tops of the locomotives which had been run on the latter bridge to hold it in position. This bridge stood the pressure, however, and was the only one of the 17 bridges that did not go out.

The War Department appointed a board of engineers to consider plans for improving the situation, and the Kansas legislature created the Kaw Valley Drainage District, with power to issue bonds to cover the cost of the improvements. The plans originally provided for a 600-ft. channel with concrete retaining walls, bridges to be raised and to have not more than two piers in the channel, and all piers to be carried to solid rock. The cost of the walls, however, led to the adoption of levees, with a 734-ft. channel. As nearly all the bridges had been built in 1903 and 1904, many of their owners (including all the railways) offered to reconstruct their bridges on new piers and abutments (adding such spans as might be necessary), and as that involved maintaining more than two piers in the river, the companies offered to join in the expense of widening the river so as to compensate for the additional pier. This being objected to by the Drainage Board, the matter was taken into court. The companies objected also to founding the piers on rock, as being unnecessary, since the river did not scour more than 15 ft. below low water, and pile foundations below that level would be amply sufficient. This contention was upheld by the courts.

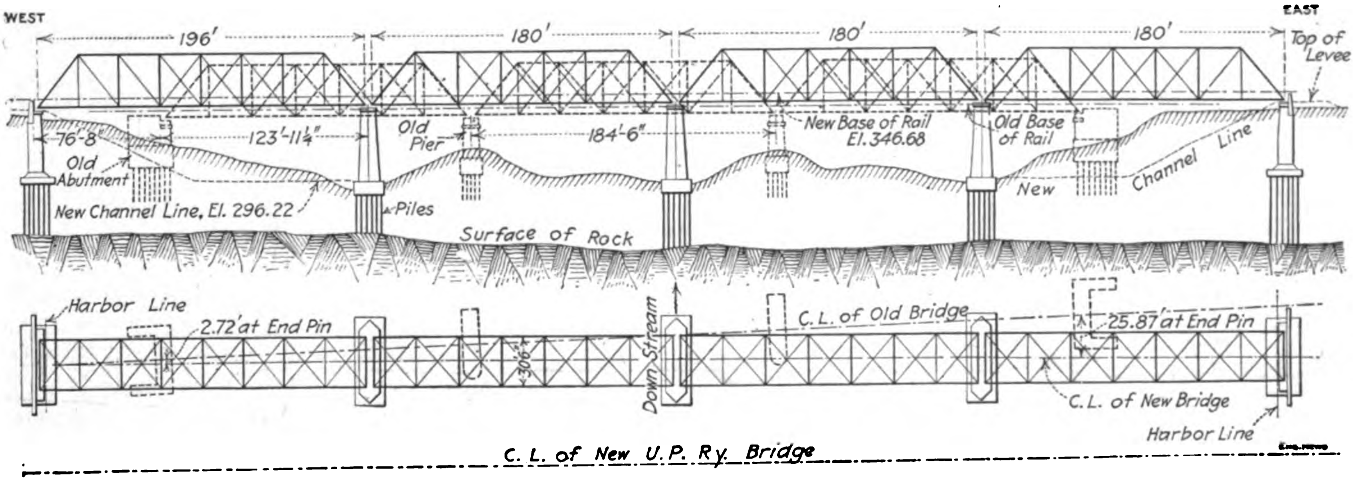

Fig. 1. Plan and Elevation of the Kaw River Bridge of the Missouri Pacific Ry. at Kansas City, Kan.

(Showing the old and new substructures and the old and new positions of the superstructure.)

As to the bridge piers, the court permitted the Union Pacific and Missouri Pacific railways to use their existing truss spans, putting them on new substructure and each adding one span, the width between harbor lines being increased from 734 ft. to 742 ft. at the bridges, to compensate for the width of the third pier. This work involved shifting the old spans so that one end would be at the new harbor line, adding one 196-ft. span, and raising the entire structure about 9 ft., the cost for each company being about $500,000. As two overhead bridges crossed the approaches to the river bridges, the reconstruction of the latter could not proceed until arrangements had been made for altering the former, and this condition resulted in a delay of several years. In the spring of 1910, in anticipation resulted in a delay of several years. In the spring of 1910, in anticipation of a flood, both the river bridges were raised 2½ ft., which was as high as they could be placed without interfering with the overhead bridges. Another year was lost in negotiations but finally work was started on the Union Pacific bridge in March, 1911, and on the Missouri Pacific bridge in September, 1911.

GENERAL CONDITIONS

The reconstruction of the Missouri Pacific Ry. bridge and the location of the new piers were designed with a view to making use of the three former steel truss spans 180 ft. long, which had been built in 1900 and designed for Cooper's E-50 loading. The additional width of the revised river necessitated the addition of a 196-ft. span. Although 734 ft. had been decided on as the width between tops of levees, a modified width of 742 ft. between the extreme front faces of the abutments was chosen to compensate for the width of the third pier. Fig. 1 shows the bridge as built originally and as now reconstructed.

*Abstract of a paper on "Reconstructing and Moving the Kaw River Bridge of the Missouri Pacific Ry. at Kansas City, Kan.," read before the Associated Engineering Societies of St. Louis, on May 7. The paper deals very fully with the great flood of 1903 and the conditions which led to the reconstruction of the bridge, but this portion we have summarized in the first two paragraphs of our abstract. The levee work along the river was described in our issue of Dec. 26, 1912. Editor.

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The modified harbor lines were so located with reference to the old bridge as to necessitate an extension of 123 ft. at the east end and 73 ft. at the west end. Since the original construction of the bridge, the entire yard area at each end had been built up with tracks, resulting in a disagreeable reverse curve at the east end which would have been made worse by extending the bridge on its old alignment. The west end of the bridge was fixed by a number of conditions that prevented any large side movement. The alignment finally chosen necessitated moving the west end of the bridge 8.4 ft. upstream and the east end 26.3 ft. upstream.

After careful study involving the consideration of a number of different schemes, it was decided to treat the three spans as one structure and to move them at one time. This conclusion was reached on account of the necessity of keeping the bridge in almost continuous service during the reconstruction. The construction of a temporary bridge was considered, but was discarded as uneconomical and difficult to maintain.

During 1904, the Union Pacific Ry. had removed part of its old bridge and other débris from under the Missouri Pacific bridge, but had neglected to remove the débris below the water surface. Soundings and borings directly under and in the immediate vicinity of the latter bridge indicated that the débris had not moved since 1903, but that on account of having fallen into the river when the bottom had scoured to unusual depth, much of it was buried 15 to 20 ft. deep in the river bed. It extended up to low water, forming a twisted and tangled mass of heavy steel members, extending the entire width of the river. Inquiry developed that this condition was well known to contractors and that it would be impossible to let the foundation work on other than a force-account basis. Consequently the contract was awarded on a force-account and fixed-fee basis to the Union Bridge & Construction Co., of Kansas City, Mo.

Another condition that influenced the award of the work on a force account basis was the heavy railway traffic and the congested areas in the vicinity of the bridge. The Missouri Pacific Ry. runs the largest number of passenger trains into and out of Kansas City, about 60 in each direction daily. About 25% of these trains cross the bridge on their regular runs, and all the trains cross the bridge between the Union Depot and the coach yard, where the cars and engines are cleaned and trains made up. This makes about 150 passenger train movements each day. Switching movements and through drag freights up to 80 cars in length were also numerous, making about 400 movements across the bridge daily.

On acount of the location being at the throats of two yards, all movements were slow, resulting in practically a continuous stream of traffic on each track. The Union Pacific bridge was under reconstruction only 75 ft. away on the south side, and stock-yards and packing houses were close against the tracks and the river bank on the north. The presence of two stock undercrossings and three overhead bridges under reconstruction at the bridge ends, added to the other congestion, made this a very busy place.

CLEARING THE RIVER CHANNEL

Before work commenced on the piers, many methods of getting through the obstructions in the river bed were considered, and the use of pneumatic caissons and of steel sheetpiling were discussed. It was realized at once that the latter could not be depended on to cut its way through such a tangled mass of steel, and the railway company did not entertain with pleasure the thought of the cost of cutting through the steel débris under the edges of caissons, especially in view of the fact that bridge pins and joints, car axles and wheels, and other very heavy steel parts would be encountered.

As it had been agreed that it would be necessary to remove this material in some manner over the entire river bed, the decision reached was to clear the bottom of the river by dredging through the water with orange-peel and clamshell buckets before placing any coffer-dams. The first barge was put to work at pier No. 2. Several carloads of car trucks, rails, steel members, truss joints, floor beams, bridge stringers, cars and other débris were dredged from the site of each pier. When it was realized how slow this work would be, a second barge was started and night and day shifts were worked.

The dredging was a tedious operation. The bucket would land on steel time after time and come up empty. It would take hold of a mass of iron and fail to move it, or it would get caught in the obstructions and require care to free it. As a rule, however, the free material was dredged as deep as possible around and among the old bridge work. When the dredge failed to bring up any more material, a diver was sent down to attach dynamite to the steel and thus break it up until the parts were sufficiently loosened to be removed. Much of this dredging and dynamiting was done in 30 ft. of water. This method of dredging was continued until all débris was removed from an area somewhat larger than the coffer-dams.

A very stiff blue clay was encountered about 55 ft. below the rail level, and there were few obstructions in this, except such as projected into it from above.

ABUTMENTS

Work started on the east abutment Sept. 1, and on the west abutment Oct. 14, 1911, and was carried on when work could not be prosecuted on the piers. These abutments (Fig. 1) are buried piers 26x54 ft. at the bottom of footing, 50 ft. 6 in. below the rail, and each is supported on 96 piles. The footings are 7 ft. deep. There are no wings, but to prevent the fill behind the back-walls from running onto the bridge seats, the back-walls are extended 9 ft. beyond each end of the pier, forming cantilevers of reinforced concrete connecting the back-walls to the levee.

To carry traffic over the excavations for the abutments the track ties and ballast were first removed from under one track at a time (between trains), and replaced by bridge ties and timber stringers. The stringers were composed of three 8x16-in. timbers under each rail. These were 28 ft. long, packed into a chord 70 ft. long with joints staggered to form 14-ft. panels. Excavation was then continued (under traffic) under these stringers, which were carried on temporary blocking, gradually increasing in height until sufficient depth had been reached to permit the installation of 60-ft. deck plate-girder spans. A wide flooring of blocking was placed for the support of the girders and a quick change made between trains. Open excavation was then carried down with sloping sides to about 14 ft. below the bottoms of the girders and the ground leveled off.

Below this level different methods were followed for the two abutments. At the east abutment, a coffer-dam 26 ft. 10 in. by 54 ft. 10 in. was framed at the bottom of the open excavation, and the interior space excavated by hand. No settlement of the surrounding earth occurred.

The west abutment was in close proximity to the Kansas City Southern Ry. bridge and the stockyards bridge. As the cylinders of the latter bridge were only a few inches from the edges of the excavations for the abutment, and as this bridge had to be kept in service, it was decided to employ other means than at the east abutment for sheeting the excavation. Consequently, bracing frames of 12x12-in. timbers were made and 3-in. sheeting driven by mauls outside of them, belt braces being inserted every 4 ft. as the excavation progressed. When a depth of 16 ft. had been reached, a second course of sheeting planks was driven inside the upper braces and additional braces were placed.

No settlement was experienced until a depth of about 40 ft. had been reached, at which point the sheeting was driving very hard and it was necessary to keep the excavation lower than the bottom of the sheeting. A layer of clean coarse sand was then struck, and while excavating so that the sheeting could be driven, the sand ran into the excavation like sugar, causing the cylinder piers under the stockyards bridge to settle 8 in. in one day. The weight was removed from the cylinders by bridging across the tracks and supporting the bridge on frame bents and blocking. The excavation was then continued and the abutment brought to completion in a manner similar to the east abutment, without further trouble. The rock was 10 ft. higher under the west abutment than under the east abutment, so that piles penetrating 30 ft. reached rock. This abutment was practically completed Feb. 17, 1912.

PIERS AND FOUNDATIONS

The footings of the old piers were 15x45 ft., and each pier was supported on 75 piles, having an average penetration of 20 ft. No settlement had ever taken place. The footings of the new piers were designed 18x54 ft., with 108 piles under each. The footings were established with the bottom about 60 ft. below the rail, and made 8 ft. thick, the pile heads projecting 5 ft. into the footing. The shafts of the piers are 12 ft. 6 in. wide at the top of footing and 9 ft. wide under the bridge seat coping course. The upstream ends are pointed to avoid the collection of drift and the downstream ends are pointed for symmetry. The upstream ends and shoulders of the shafts are reinforced by steel rails for the purpose of offering greater resistance to wear from ice and drift.

While the dredging of the channel was in progress, the coffer-dams for the piers were being built on shore. These were 20x56 ft. The sides were built solid with 12x12-in. timbers laid horizontally, well drifted together, and sheeted on the outside with 2-in. tongued-and-grooved lumber. The sides were stiffened at intervals by verticals 12x14 in., held by 12x12-in. braces in both directions in horizontal planes about 4 ft. apart. This inside bracing divided the coffer-dam into rectangular pockets 10x11 ft.

In order to avoid damage to the lower edge in case the coffer-dam should land on an obstruction lower than the dredge had reached, steel cutting edges were provided. After about 8 ft. of a coffer-dam had been built it was launched, towed into correct position and sunk by building up the sides. When the cutting edge rested on the bottom and the coffer-dam was in correct position, the material inside was removed by dredging through the water. As the previous dredging had extended so deep, the settling of the coffer-dam to correct elevation was a comparatively simple operation, taking from one to two weeks at each pier. No obstructions of any kind were encountered during the sinking.

On account of the porous nature of the sub-soil below the blue clay, it was not possible to pump out these coffer-dams,

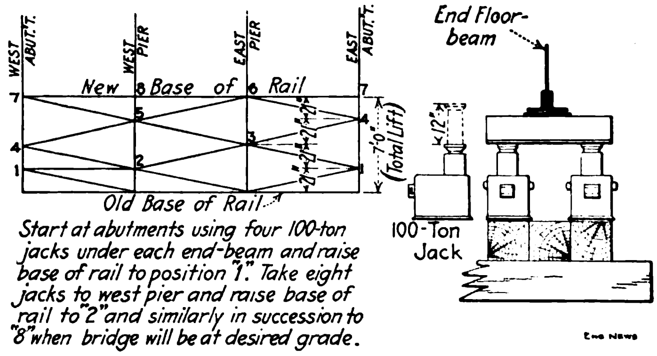

Fig. 2. Diagram Showing the Series of Lifts in Raising the Three-Span Bridge to Its New Elevation

so the piles were driven through the water. As the sub-soil consisted of a clean sand, it was necessary to use powerful 2-in. jets for jetting the piles down to rock. Under each pier 108 piles were driven to a penetration of 24 to 30 ft.

The driving of these piles under the bridge, which had not yet been raised, was a tedious operation, especially in those portions of the footings that came under the old spans. At those places it was necessary to handle the piles from the deck of the bridge by derrick car, in order to stand them up within the coffer-dam and they were started down by short blows of a drop hammer working close to the bridge. When they had been driven sufficiently to permit room for steam hammer, that was placed on them and the jets were set to work. When the tops of the piles reached the water level, they were driven further by the aid of a follower, until they reached rock. The pile driving consumed from two to three weeks at each pier.

After the piles were all driven in a coffer-dam, a hydraulic dredge or sand-sucker was used to remove the accumulated sand and débris down to the proper level, after which a 5-ft. sealing course of concrete was placed around the pile heads by means of a tremie. The tremie consisted of a 10-in. steel pipe surmounted by a square trough, dished in the shape of a steel wheelbarrow tray. The bottom of the tremie was placed on the bottom of the excavation and the pipe filled with 1:2:3 concrete, mixed very wet. The tremie was moved slowly from side to side of the coffer-dam, working from end to end between the rows of piles until the desired thickness of 5 ft. was placed. The sealing course was then allowed to set six days. The coffer-dams were then pumped out in a very short time, although the head of water was 25 to 30 ft. After the pumping a 1-in. steam jet kept the water out. The piles were cut off 6 in. above the sealing course and the remainder of the concreting was finished in the dry.

The term "in the dry" came near being a joke as applied to the middle pier. The concrete in that pier had been placed to 14 ft. above the footing and was 5 ft. below the water level when it was learned that a flood wave was coming down the river which would raise the water 15 ft. and overtop the coffer-dam. As the other two piers were safely out of the water all efforts were concentrated on the middle pier, and the building of forms and depositing of concrete went on simultaneously and continuously, night and day. The concrete and the flood reached the top of the coffer-dam about the same time, but the level of the concrete was maintained about one foot above the level of the flood until the crest was reached. The concrete was raised 20 ft. in 24 hr., and some fear was felt as to the possibility of the forms bursting, especially as large cakes of ice coming down the river were striking the forms violent blows. After the flood subsided, however, it was found no damage had been done and the concrete set as well as any in the bridge.

In the construction of the tops of the piers it was necessary to make provision for the track and stringers which were being placed to carry the bridge when moving it longitudinally, which movement required the trucks that were to carry the spans to pass over the new piers considerably below their tops. The ends of the piers were finished to final height to provide supports for the spans, and recesses 8 ft. 3 in. deep and 24 ft. 6 in. long were left in each pier (see Fig. 10).

On account of the late start, and the time consumed in clearing the river bed, all the concrete was placed during the winter, which was unusually severe. Most of the concrete was placed when the temperature was between zero and freezing. The usual precautions of heating the materials and keeping the concrete warm by fires and tarpaulin covers were taken, with satisfactory results. Work was stopped several times when the temperature was below zero, as it was considered best not to take any unnecessary chances. The three piers were practically completed March 16, 1912.

PLANS FOR MOVING THE SUPERSTRUCTURE

During the construction of the foundations, the contract for shifting the superstructure had been let to the Jobson-Gifford Co., of New York, and the specifications provided that work would commence Jan. 1, 1912. On that date the contractor with his superintendent arrived at the bridge and after spending two days looking over the site they were much discouraged, as the continuous streams of traffic on both tracks and congestion in all directions indicated the difficulty of the work. Unfortunately, this contractor had bid on the job without visiting the bridge, but after the railway company insisted that it was too late to re-advertise for bids with any hope of getting a new contractor on the work in time to get clear of the spring floods, the contractor arranged to go ahead, and from that time on pushed the work with great energy. Pile driving and preparations for raising the spans started the middle of January.

It was decided to proceed in the following manner: 1, raise the spans to full height; 2, move the spans over on to the new alignment; 3, shift the spans endways; 4, erect the new span.

RAISING THE SUPERSTRUCTURE

As the bridge had been raised 2½ ft. in 1910, the remaining raise amounted to about 6½ ft. It was decided that

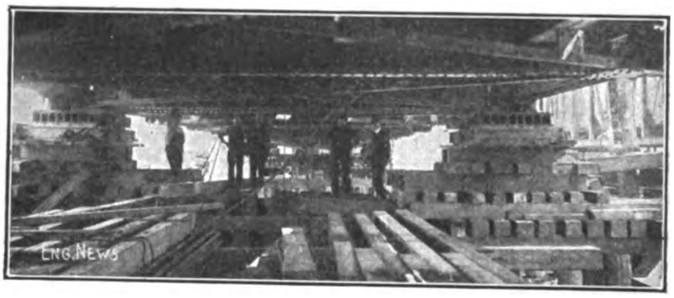

Fig. 3. Bridge Supported on Blocking at Its New Elevation and Ready to Be Moved

(Under the I-beam grillage at each side is a sand-jack, shown in Fig. 11.)

one end of a span 180 ft. long could be raised one-fourth the total lift higher than the other end without detriment to traffic, resulting in a grade of about 1% on the span. The Kansas City Southern Ry. and stockyards bridges were still in the way while the jacking was going on, but by making a very sharp incline in a distance of about 50 ft. it was found possible to raise the west end of the bridge one lift of about 1½ ft. The diagram, Fig. 2, shows the numbers of the various lifts that were made. The contractor furnished only sufficient jacks to lift on one pier at a time. These were 100-ton jacks of 12-in. stroke, arranged as shown in Fig. 2.

The connections of the end floor beams to the trusses were strengthened by placing flat plates with pin holes bored in them over the ends of the truss pins, the plates extending vertically upward and being bolted to the outstanding legs of the stiffener angles, which happened to be properly spaced for this purpose.

The work of lifting was slow but the work of removing the overhead bridges was slower, and the jacking was very nearly delayed by their presence. They were removed a few days ahead of the day on which it would have been necessary to either quit work or make another raise at the west end of the bridge. As the bridge was raised the load was carried on 12x12-in. blocking, which had to be arranged on each pier with three purposes in view: 1, carrying the truss shoes in their former location; 2, carrying the jacks for raising; 3, making preparations for carrying the load in the new locations that would be assumed by the truss shoes after the side movement.

The intermediate spaces were filled with blocking for the purpose of carrying the trusses while the bridge was being rolled sideways. Rough timber was used for the blocking. Surfaced timber would have been better but that was not thought of until too late.

As the bridge had to be kept in service continuously it was impossible to jack for long periods, but arrangements were made to give the bridge over to the contractor for about 40 min. in the forenoon and about an equal time in the afternoon. During each of these periods the greatest possible lift was made, usually about one foot, although the amount of lift varied with a number of conditions. For example: one Monday morning after an all-day Sunday rain the timber under the jack seats was so soaked and swollen by the rain that it consumed very nearly the entire jacking period to squeeze the water out, and no progress was made on account of the bridge having to be returned to service before the trusses were raised. Jacking was started March 1, and the spans were all up to full height on March 14.

As originally constructed, the trusses rested on pedestal

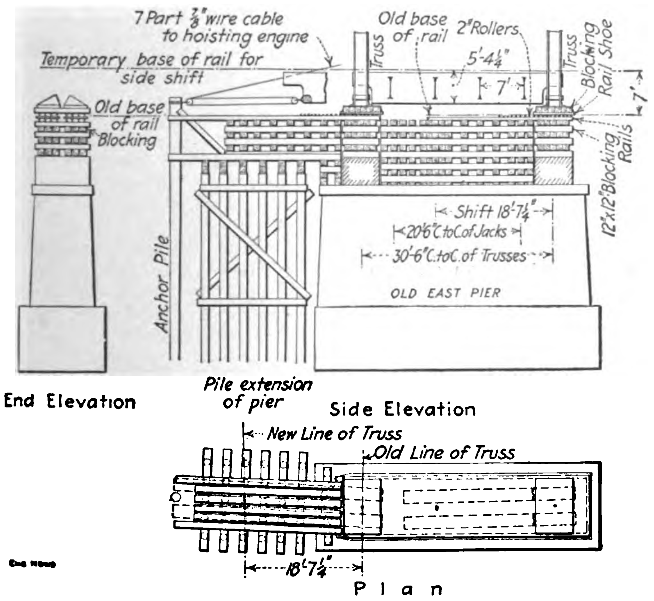

FIG. 4. BLOCKING ON OLD EAST PIER, WITH SIDE EXTENSION OF PIER TO CARRY THE BRIDGE WHEN SHIFTED LATERALLY

stones 2 ft. high, which in turn rested on the bridge seats. When the spans had been raised 2½ ft. in 1910 the pedestals had been built up by grillages of I-beams buried in concrete, which made their tops 4½ ft. above the top of the main pier. The further raise of 6½ ft. made the pile of timber blocking on the piers 10 to 11 ft. high for the support of the jacks and for the support of the spans in their new positions. Fig. 3 shows the bridge supported on blocking at its new elevation.

RAISING THE APPROACH TRACKS

Track raising in the yards at the ends of the bridge was started Oct. 1, 1911, and was well advanced by the time the bridge raising commenced. The tracks were raised as close as possible to the bridge, and dropped down to the bridge level by short sharp grades with a view of minimizing the amount of track raising while the bridge was being raised. This track work required the raising of about 12 miles of main and yard tracks which could not be taken out of service for long periods. At one throat it was possible to get the track for only 30 min. each day. This condition required the use of material that could be easily worked and about 200,000 cu.yd. of sand and cinders were used.

The sand was obtained from borrow pits on the river front that had been filled by the hydraulic method, and the borrow pits were later filled again by the same method. Although much of this work was done in severe winter weather the sand could always be easily handled and good track conditions were maintained throughout.

MOVING THE SPANS LATERALLY

Pile driving for the falsework to support the superstructure while moving it to its new position was started Jan. 26, 1912. For the reason that much of the falsework came under the trusses in their old location and could only be driven from the bridge, it finally became necessary to take one track over the bridge out of service continuously.

For the side movement at the west abutment, amounting to 2.7 ft., a frame bent was set on the upstream projection of the footing course, and the blocking on the pier was extended over it to form a support for the trusses in their new position. At the two river piers and the east abutment, posts were set on the footing projections and pile bents were driven 3 ft. apart, each bent having five piles 3 ft. apart. The blocking on the piers and east abutment was extended out over these bents to form pile pier extensions for the support of the upstream trusses after their movement, as shown in Fig. 4.

Just before rolling sideways, the trusses were jacked up and the blocking immediately under the shoes was removed and replaced by two nests of rails separated by rollers, Fig. 5. The lower nest consisted of four rails spaced 7 in. apart, and covering the new and old locations of the truss shoes as well as the space between them.

The upper nests consisted of four inverted rails slightly longer than the width of the shoes. Between the upper and lower rails were placed a number of 2-in. rollers 4 ft. long, made into nests by angle irons which served as spacers for the rollers. The length of each nest was equal to the width of shoe plus half the distance through which the shoes were to move. The rollers were spaced 6 in. apart for the rolling. As it was necessary to put them in under some shoes several days in advance of the movement, the rollers were spaced 3 in. apart in order to avoid danger of the rails cutting into them and increasing the difficulty of rolling.

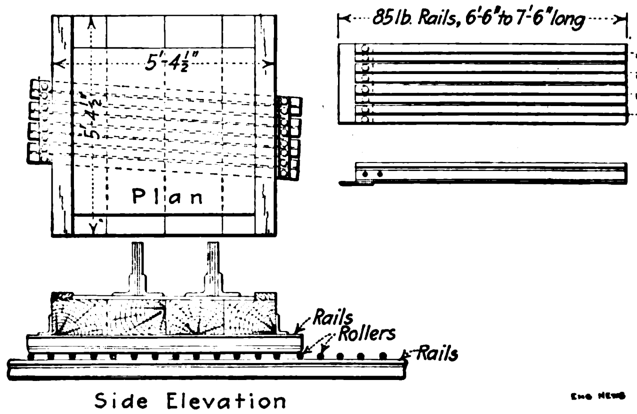

FIG. 5. RAILS AND ROLLER SHOES FOR MOVING TRUSSES

When all the shoes had been placed on rollers, the ice in the river was broken up by a sudden rise and the river rose rapidly, reaching a point considerably above the tops of the old piers and so far up on the blocking that serious consideration was given to the temporary removal of the rollers. The rising water and the ease with which the spans could have been rolled off the piers appeared to invite a catastrophe. Arrangements were made to load the bridge with coal cars heavily loaded with sand in case of necessity, but the rise was not great enough to require that precaution.

The side movement of the bridge amounted to 3.4 ft. at the west abutment, 11 ft. at the west pier, 18.6 ft. at the east pier and 26.3 ft. at the east abutment. A large cypress pile was driven as an anchorage at the end of each pier and each abutment, and falls (consisting of 7-part ⅞-in. steel cable) were placed between the pile anchor and the truss shoes at each support, the lead lines extending to hoisting engines. The lead lines were operated by derrick cars at each end of the bridge and by hoisting engines on flat cars over each pier.

As the side movement of the bridge was not the same at each support it was necessary to make a motion somewhat similar to the spoke of a wheel, the center of rotation being 60 ft. west of the west abutment. This is shown by the diagram, Fig. 6. In order to permit this to be done with ease, the direction in which each truss shoe had to move was carefully calculated and the rails and rollers placed so that

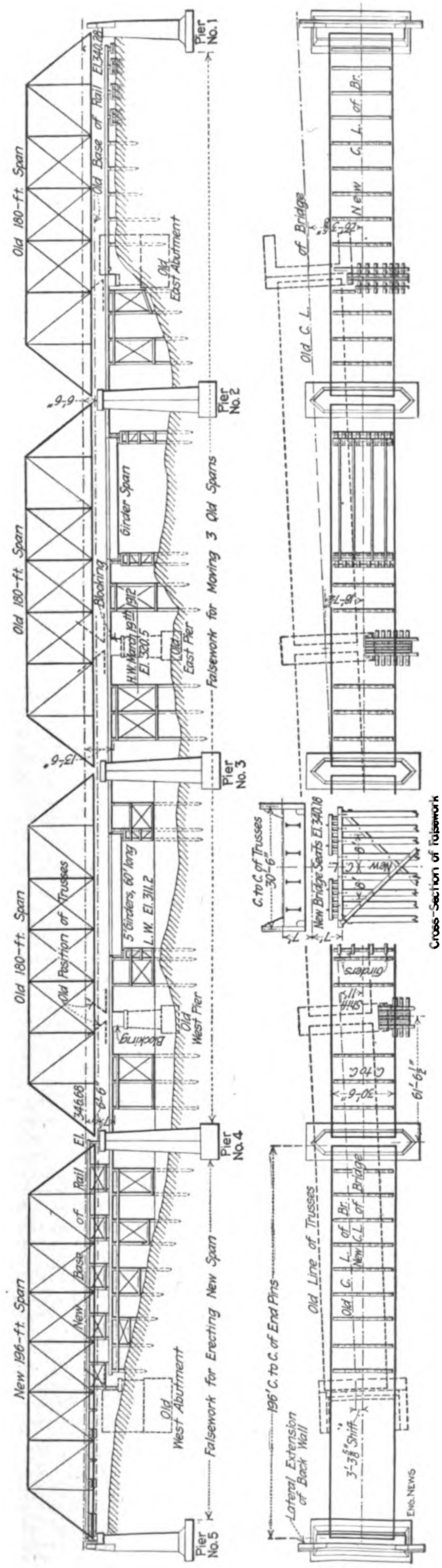

FIG. 7. FALSEWORK FOR SUPPORTING THE THREE 180-FT. SPANS OF THE BRIDGE DURING ITS LONGITUDINAL MOVEMENT OF 123 FT.

(The two 60-ft. girder spans in the falsework were to provide waterway in case of flood. The 196-ft. span at the left is an additional span which was erected in place after the three 180-ft. spans had been moved.)

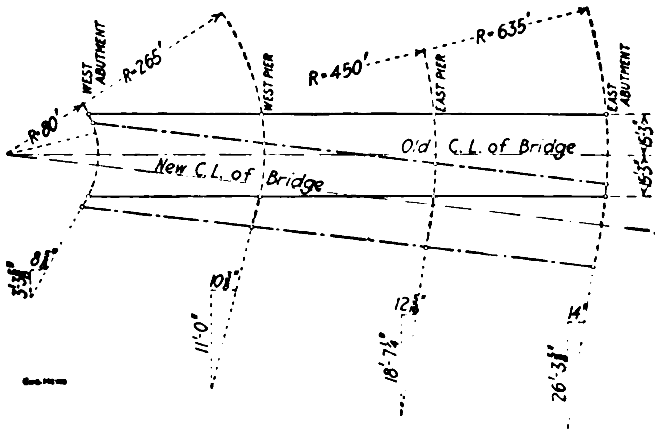

FIG. 6. DIAGRAM SHOWING RADIAL MOVEMENT OF THE BRIDGE IN SWINGING IT TO ITS NEW ALIGNMENT

the motion would take place along a chord to the curve through which the shoe moved. The angle of inclination of the rails and rollers was different at each support, on account of the different distances from the center of rotation.

It was thought that considerable difficulty would be experienced in so controlling the side movement that the west end of the bridge would move 3.4 ft. while the east end was being moved 26.3 ft., the intermediate portions to be moved their proper amounts. The movement was so well controlled by the men at the hoisting engines, however, that at no time was the bridge more than 2 or 3 in. out of line. The men understood what was expected of them and the side movement went off smoothly.

The track was cut at 10:35 a.m. and connected up again in the new location at 1:15 p.m., April 5. The entire time the track was out of service, including the track changes and blocking at the ends of the bridge, was 2 hr. 40 min., of which 50 min. was consumed in the movement of the spans. The actual rolling consumed only about two minutes.

PREPARATIONS FOR MOVING THE SPANS LONGITUDINALLY

The superstructure having been raised to its new elevation and shifted laterally to its alignment, the next step was to move it longitudinally in order to seat the spans on the new piers.

The winter of 1912 was unusually severe and the Kaw River ice broke up early, coming down the river on a rise in great heavy floes. Had it broken up a few weeks later no trouble would have been experienced, but the heavy rains caused a sudden rise which also brought down considerable drift. The Union Pacific Ry. had a temporary tramway trestle entirely across the river just upstream from the Missouri Pacific bridge, and little effort was made to keep the ice and drift moving through the trestle. The result was that the drift jammed against it and formed a mat, the pressure against which washed out six or seven bents with a rush.

They came down with such impact as to carry out seven bents of the Missouri Pacific falsework, causing the railway a loss that compensated for its saving in cost of pumping at the east abutment. For several weeks the current was too swift and the water too deep to allow of replacing the piling. When it became possible to redrive, it was decided to install a 65-ft. deck plate girder opening at the point of washout, in order that there might be less difficulty in passing drift in case of another flood.

During the raising and side movement of the bridge the driving of falsework piles was prosecuted continuously, and when the side movement was made, practically all the piles had been driven. The falsework consisted of blocking on the ground at each end of the bridge landward of the old abutments and pile bents in the river. The bents were spaced 14 ft. apart. Each bent was composed of eight piles, driven to refusal with drop hammer without the jet, the piles of each bent being capped with a 12x12-in. timber. This false work is shown in Fig. 7.

The U. S. Government required that provision be made to take care of navigation by providing a 60-ft. deck plate-girder span in the middle channel of the old bridge. Four pile piers of 16 piles each were driven for the support of the four 64-ft. girders that the railway decided to put in. When these piles were cut off the water was up to within a few inches of the cutoff and rising, and the caps were set in place in the water. After the girders were in place the water rose over them and remained up for some time. It never fell below the caps until after the longitudinal movement. This rendered it impossible to put any transverse or longitudinal bracing on the pile piers. Fig. 8 shows one of the girders being taken from a barge and placed on the bents by a derrick car standing on the bridge.

A large proportion of the other falsework piling was also driven during comparatively high water and many bents were not braced. The condition of the falsework in this respect was far from what was desired during the longitudinal movement, but on account of the near proximity of the spring flood period it was decided not to wait to place the bracing.

The girders and falsework stringers and ties were placed on the bents to form supports for two standard-gage tracks 15 ft. 6 in. c. to c., 11 ft. below the tracks on the bridge. The falsework stringers consisted of four chords, each consisting of three-ply 8x16-in. by 28-ft. stringers breaking joints to form 14-ft. panels. Standard bridge ties 7x8 in., 9 ft. long, were laid, with 75-lb. rails forming a continuous double-track 660 ft. long, from the new east abutment to the old west abutment, passing through the openings that had been left in the new piers.

MOVING THE SPANS LONGITUDINALLY

For the longitudinal movement of the bridge many methods had been considered, among them the use of small rollers and the use of car-trucks. The small rollers were not used as it was found that the number of rollers and other necessary apparatus would have been very expensive. The car trucks were not used because no satisfactory method could be worked out to certainly avoid the overloading of individual trucks, the failure of any one of which would have been disastrous. The decision was reached to use special trucks built of timber and standard car wheels, axles and journal boxes, so constructed and distributed under the bridge as to spread the load as much as possible.

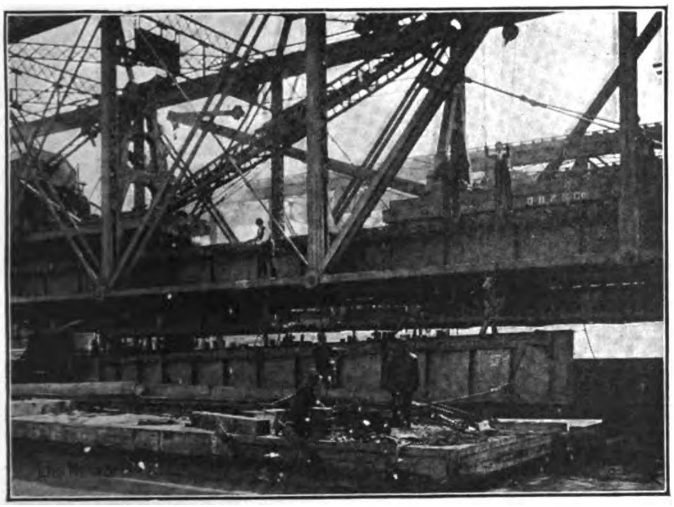

FIG. 8. DERRICK CAR ON THE BRIDGE TAKING A FALSEWORK GIRDER FROM A BARGE AND SETTING IT ON THE PILE BENTS

(The water has risen nearly to the caps of the bents.)

As the falsework piles had been driven during high swift water, many of them fetching up on obstructions at slight penetration, and as the falsework was deficient in bracing, the truck supports were so worked out that the bridge would ride over a soft spot in the falsework without trouble, by transferring a part of the load from one truck to the other. As the load on any axle under the best conditions would be high, it was decided to use only axles and wheels that had been tested in actual service. Consequently, 72 axles and pairs of wheels were removed from 50-ton coal cars, and were made up into 24 trucks. The construction is shown in Fig. 9.

Each truck consisted of three pairs of axles (six wheels) spaced by 12x12-in. timbers bolted to the tops of the journal boxes at each end of the axles. On top of these timbers other 12x12-in. timbers were laid crossways, in such position that any load coming on them would be distributed equally among the three axles. On top of these again, two 8x16-in. timbers were placed on each side, they in turn carrying two 12x12-in. timbers and the small blocking for supporting the bridge. Two of these trucks were placed under each corner of each span, making eight trucks under each span. The trucks were placed under the centers of the stringers in the first (end) and second panels of the trusses and blocked up under the stringers (Figs. 9 and 10).

The weight of the entire bridge to be moved was 1500 tons, or 500 tons per span, making a load of 21 tons per axle, if uniformly distributed. The flexible construction of the trucks and their location with reference to the weight of the steel, made it practically impossible for any one axle to carry double that load, but it was thought that there might be an increase of about 50% on any one truck, bringing 30 tons on an axle. The weight of a 50-ton coal car fully loaded is nearly 80 tons, which is 20 tons static load on each axle. But this load is increased 50 to 100% by impact while wheels are passing over joints and special track appliances, making a load of 30 to 40 tons, and as the axles and wheels had already been tried out in service, no fears were felt in regard to loads of 30 tons or slightly higher during the rolling of the bridge, especially as that load would have no impact.

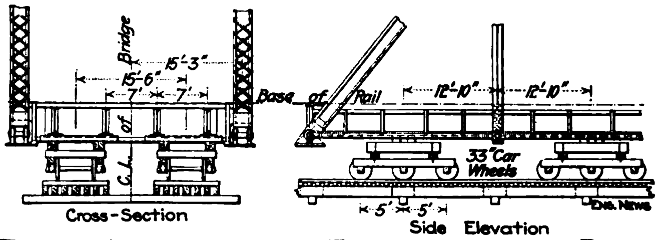

FIG. 9. ARRANGEMENT OF TRUCKS UNDER THE BRIDGE SPANS FOR MOVING THE SPANS LONGITUDINALLY 123 FT.

A few days before the bridge was ready to be moved longitudinally the trusses were jacked up and the rails and rollers which had been used for the side movement were removed and replaced by means of sand-jacks. Each sand-jack (Fig. 11) consisted of a box 10 in. high, with four sides and top and bottom composed of 3x10 in. lumber held together by ¾-in. bolts. The floor of the box was larger than the frame and the frame was made slightly larger than the truss shoes. The top was composed of a number of loose pieces of 3x10-in. lumber, just the right length and width to fit within the sides. Each box was filled level with sand and the cover placed on top of it before the truss shoes were let down carefully on the covers so as to miss the sides. These sand jacks carried traffic a number of days while preparations for moving were being made.

As an anchorage for the longitudinal movement, several heavy bridge timbers had been buried behind the east abutment and both ends of a 1-in. cable led from the deadman to the back wall of the abutment. Two sheaves were attached to the projecting ends of these cables. Two other sheaves were attached to the floor beam at the first panel point from the east end. The lines were run through these sheaves to form a nine-part ⅝-in. steel cable on one side and a four-part 1¼-in. manila rope on the other side. The lead lines were run to drums on hoisting engines mounted on flat cars anchored to the bridge (Fig. 12).

The sheaves were attached to the east span only. It was thought that the rails would be sufficient to pull the middle and west spans, but as an additional precaution 12x⅝-in. plates were bolted to the tops of the brackets that projected beyond the end floor beams of the spans over the piers, making a connection which in effect formed a continuous steel structure 540 ft. long.

On the morning of April 19, everything was in readiness for the longitudinal movement. At 10:25 a.m., traffic over the bridge was suspended and after placing the hoisting engines, the tracks at the ends of the bridge were cut. Blocking as tight as could be placed by hand was placed between the steel stringers and the tops of the trucks. Then the bolts holding together the sides of the sand-jacks were taken out and the sand removed from under the shoes, letting the spans down gently onto the trucks. The application of the weight for the first time to the trucks and the falsework caused a total settlement of the spans of about 3 in., leaving about 7 in. clearance under the truss shoes. Fig. 12 shows the bridge ready to move, and the derrick car at the right is removing the trestle approach to permit of hauling the bridge forward.

The weight of traffic on the sand-jacks had so thoroughly compacted the sand that after the sides of the jacks were removed the sand held up the load until it was scraped out from under the shoes. While the sand-jacks were being removed, a derrick car removed the 125 ft. of temporary frame trestle at the east. Then the bridge was ready to be moved.

A simultaneous pull on all the lines was not sufficient to overcome the inertia of the bridge, and the heavy pull broke the deadman cable. A new hitch was taken on it by digging down a short distance. Jacks were distributed and set at an angle at various points under the shoes, and a locomotive was set to push against a strut on the floor beam at the west end. Simultaneous application of all the power started the bridge, and it rolled 123 ft. to the new piers in about three minutes.

In arranging for the longitudinal movement, provision was made for settlement of the falsework of about 4 in., which it was thought would be ample. Later developments indicated that the settlement amounted to practically nothing, but difficulty was encountered from another cause which was not anticipated. During the construction of the falsework, cutoffs for the piles were given by level. It developed during the moving, however, that some piles had been cut off lower than others and the falsework had a wavy upper surface, which was not noticed.

The trucks supporting one corner of a span before movement rested on a high point in the false work and during movement rolled to a lower point, causing the shoe at the end of the span to drop down sufficiently to interfere about ½ in. with the top of the new concrete pier which it should have cleared by about 3 in. For this reason the movement of the bridge was stopped when within about 3 ft. of its final location and work was delayed until the I-beam grillage attached to the bottom of the shoe at this corner was removed, after which the bridge was readily rolled to final position.

After the spans reached the new piers, wedges were driven under the shoes to carry traffic temporarily and the weight was not otherwise removed from the trucks, as it was thought that the deflection in the end panels over the trucks on which the bridge rolled would meet with such elasticity in the timber blocking on the trucks as to cause no damage. Within the next few days each of the spans was jacked over, placed in final position, and the weight removed from the trucks.

It had been the intention to fill the gap at the west end of the bridge by setting frame bents and timber trestle on the false work over which the bridge had rolled. But on account of the frequent interference that would have resulted while changing out the trestle for the erection of the new steel floor under traffic, arrangements were made with the operating department to keep the bridge out of service until the steel floor (for the additional span) was placed. The steel was previously loaded on a barge and raised from there to position by a derrick car.

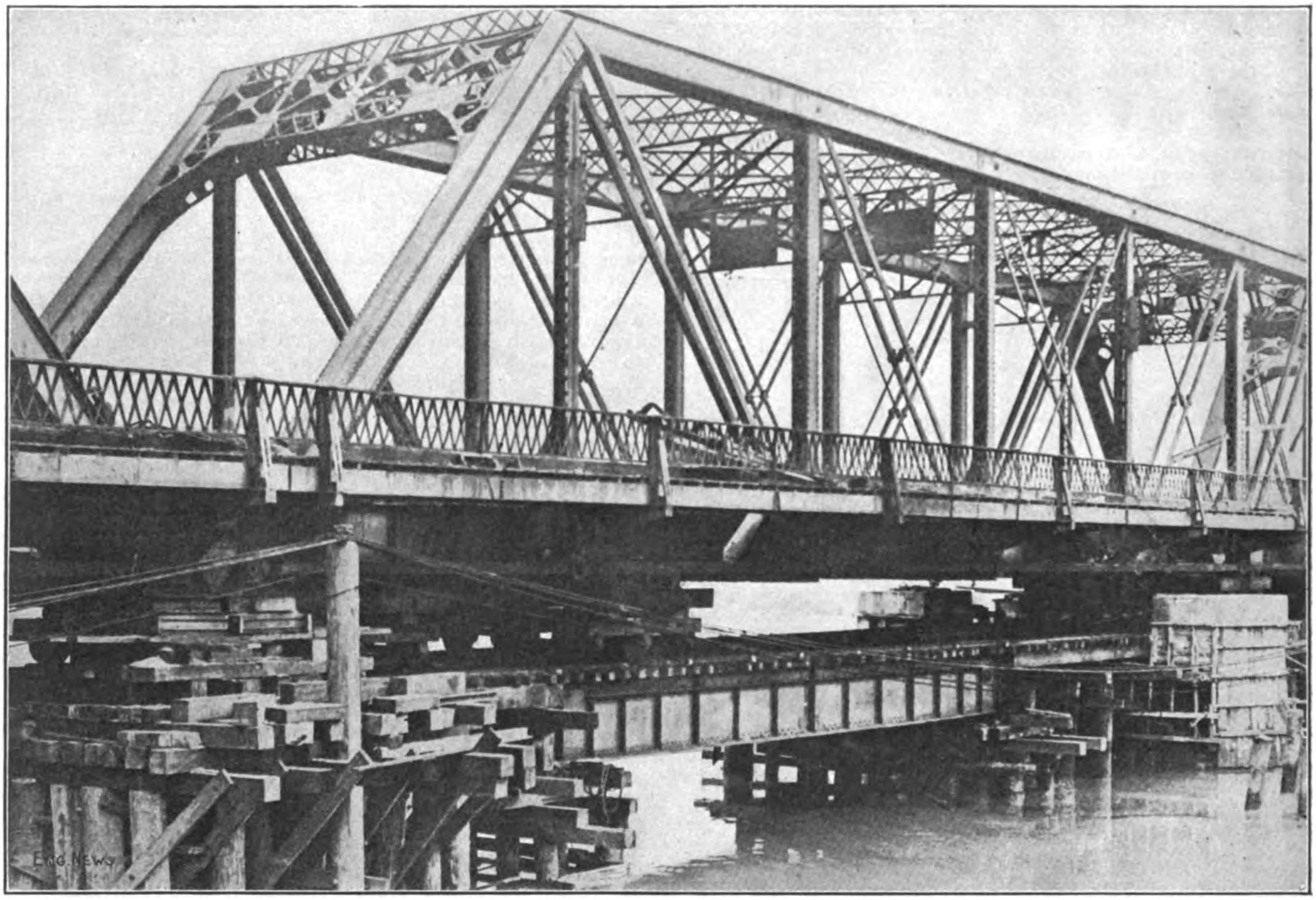

Fig. 10. The Spans Raised and Supported on Trucks Ready for Longitudinal Movement

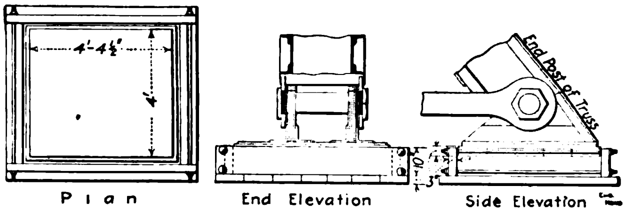

Fig. 11. Sand Jacks for Supporting the Bridge Trusses on Blocking and Lowering Them Upon the Trucks Ready for Movement

The longitudinal movement consumed more time than was anticipated. Track was cut at 10:25 a.m. The removal of falsework at the east end, letting down the 12 sand-jacks and moving the bridge endways consumed about 3 hr. The afternoon was taken up in setting the blocking and steel floor system for the new span to be erected at the west end of the bridge. Track was connected up again at 8:15 p.m.

CLEARING THE CHANNEL

The erection of the new span at the west end followed immediately. In the meantime the falsework was removed with almost feverish haste from the main channels, the deck girders being removed first, as the Kaw River has a bad reputation of coming down with great floods in May. The flood of March proved to be the worst of the spring, however, and there was no flood in May or June. All falsework piles were pulled out by the derrick cars.

The foundation work had been temporarily suspended for about one month while the bridge was being moved to the new piers. After this had been accomplished the work of removing the old piers was started. The cut-stone masonry

COST OF RECONSTRUCTION OF KAW RIVER BRIDGE; MISSOURI PACIFIC RY.

Two abutments:			
4000 cu.yd. excavation	$6.03	$24,110	
7040 lin.ft. piles	1.31	9,230	
1520 cu.yd. concrete	9.31	14,150	
Total for abutments			$47,490
Three piers:			
3100 cu.yd. excavation	$9.02	$27,950	
8960 lin.ft. piles	1.54	13,840	
3500 cu.yd. concrete	7.35	25,730	
Total for piers			$67,520
Removing old foundations and clearing channel to specified level			32,500
Raising and moving three old spans, 1500 tons, at $20			30,000
New 196-ft. span, 440 tons, at $70			30,800
Raising 12 miles of yard tracks and making necessary track changes			166,690
Total cost of improvement			$375,000

was very easily taken down to the water level. Then holes were drilled in the piers and they were broken up by dynamite, the broken masonry being dredged by clam-shell buckets. Then followed the removal of the footing courses (into which the foundation piles projected 8 ft.), the foundation piles, and the riprap surrounding the piers. The remainder of the old bridge iron, cars, car trucks, rails and other débris of every sort was then removed down to 15 ft. below low water, carloads of scrap iron being loaded and shipped.

This cleaning out of the channel consumed about six months and necessitated frequent use of dynamite and divers.

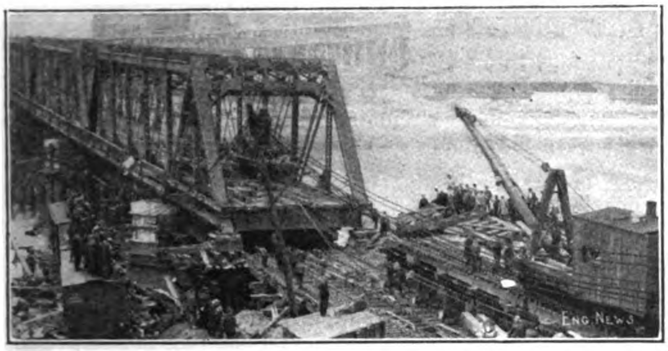

FIG. 12. HAULING THE MISSOURI PACIFIC RY. BRIDGE SPANS A DISTANCE OF 123 FT. ON FALSEWORK TO ITS POSITION ON THE NEW PIERS

At one time five pin joints of an old Union Pacific truss, with all truss members, floors beams and bracing attached, were raised from the river bed and suspended from the Missouri Pacific bridge, other members extending down into the river bed. A heavy pull by a 100-ton steam wrecking crane failed to loosen up the parts below the water, however, and they were shot off as low as possible by dynamite placed by the diver. The removal of much of the débris necessitated the dredging of deep holes far below the required depth of dredging. The work was continued, however, until all obstructions in the entire width of river were removed to the specified level.

Preservative Treatment of Poles*

BY RUSSELL A. GRIFFIN†

The most perfect method of timber preservation is the injection of coal-tar creosote or dead-oil of coal tar. This is done in three ways: (1) By the closed-tank pressure method, (2) by the open-tank method, and (3) by application with a brush.

CLOSED-CYLINDER TREATMENT

In 1897, while in the service of the American Telephone & Telegraph Co., I arranged for the purchase of some 10,000 creosoted yellow-pine poles for a line which was built that year from Washington to Norfolk, Va. These poles were treated their entire length by the closed-cylinder pressure process under a specification requiring the injection of 12 lb. of dead-oil per cu.ft. A recent inspection of this line showed it to be in a practically perfect state of preservation. These same poles, if untreated would have served their usefulness in about four years, as yellow-pine rots very rapidly in the ground.

In spite of the excellent results that have been obtained both here and abroad by the full-cylinder treatment, the proportion of poles thus treated has been relatively small. This method has been resorted to principally in the South, where, on account of the climate and soil conditions, exceptionally rapid decay makes a preservative treatment almost essential. The chief hindrances to a more general adoption of this method for treatment of poles have been the high cost of the treatment and the expense of the transportation of the poles to a treating plant.

Recent investigations have been conducted mostly with cheaper and simpler methods, and with treatments which could be applied locally by the consumer, or at the large cedar pole yards. Approximately 60% of the poles in use are cedar, and about 20% chestnut, and these woods lend themselves readily to the method of partial treatment described below.

BRUSH TREATMENT

The brush treatment consists in painting the pole with a preservative, preferably creosote oil. The portion of the pole most subject to decay is just below and just above the ground line. Therefore the pole should be painted about 2 ft. below and 2 ft. above the ground line. Only seasoned poles should be treated, and care should be taken to see that the wood is thoroughly dry before the treatment is applied.

It is decidedly preferable that the preservative should be heated to a temperature of 150 to 175° F., and distinctly better results will be obtained from two coats rather than one coat. Particular attention should be paid to the filling of all checks and knot holes, and to working the preservatives well into the wood. An average 30-ft. pole will absorb, by this treatment, about 4 lb. (½ gal.) of oil, and if treated under proper conditions a penetration ranging from $\frac{1}{16}$ to $\frac{1}{8}$ in. can be secured. Brush treating can be applied with ease in any locality, or along the route of a line in the process of construction.

It is a very economical method. In 1911, the American Telephone & Telegraph Co. treated 12,000 poles with creosote oil by this method in Nebraska, at a cost of approximately 25c. per pole. This cost included the cost of the oil and labor. Previous reports of experiments in brush treating estimated an increased life of from two to three years, but these estimates will be substantially exceeded, if not doubled. The depth of penetration is comparatively slight, but experience has shown that the protection afforded by the brush treatment is usually destroyed through mechanical impairment, rather than through loss of the preservative by volatilization or leaching, provided always that the material used for treatment is one of the oils known to possess good antiseptic properties.

OPEN TANK TREATMENT

Treatment by this method consists in placing the butt end of the pole in a tank into which an antiseptic preservative (preferably dead-oil of coal tar or carbolineum) is poured until the poles are covered for a distance of about 8 ft., or to a point equivalent to 2 ft. above the ground line.

The oil should then be heated to a temperature above the boiling point of water, and this temperature maintained until the air in the wood has been expanded and the water in the outer layers vaporized and both driven out as far as possible. In other words, the high temperature should be maintained until bubbles cease to appear on the surface of the oil. The oil should then be permitted to cool, or the poles transferred to another tank containing cold oil. A partial vacuum is thus produced by the contraction of the air and the condensation of the moisture remaining in the wood, and the preservative is forced under atmospheric pressure into the wood. A treatment by the method described consumes about 24 hours, during which the pole is subjected to the hot oil from 8 to 9 hours.

In 1905, the American Telephone & Telegraph Co. treated by this method and by the brush method 600 chestnut poles, which were set that same year between Warren, Penn., and Buffalo, N. Y. The balance of the poles in this line were untreated, part green and part seasoned. The treatment was made in conjunction with representatives of the U. S. Forestry Department, and various preservatives were used. An inspection of this line made three years ago (five years subsequent to its erection) developed the fact that 100% of the green, untreated poles showed an average loss of circumference at the ground line from decay of 1.16 in., 99% of the seasoned, untreated poles showed an average loss of 1 inch.

Of the brush-treated poles, decidedly the best results were obtained from those treated with coal-tar creosote and carbolineum. Decay had commenced sooner and developed

*Abstract of a paper read at the annual convention of the National Electric Light Association, at Chicago, June 3-6.

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