Problems and General Methods of Erecting the Sciotoville Bridge

First of Three Articles on Original Plan Employed, with Elimination of Secondary Stresses, in Placing Large Two-Span Continuous Structure of Chesapeake & Ohio Northern Railway Over Ohio River

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The erection of the Sciotoville bridge of the Chesapeake & Ohio Northern Ry. across the Ohio River had to meet an unprecedented requirement on the part of the engineer in charge of this structure, Gustav Lindenthal—namely, that the members be built together in such a way as to neutralize the secondary or distortion stresses under dead plus half live load. Other facts, however, helped to make the task a formidable one. The structure is of very unusual type, being a two-span continuous truss. It is of record-breaking size, each of the two spans being 775 ft. long and the depth over the center pier being 129 ft. 2 in. c. to c. of chords. The resulting weight and size of the members and connections, and the necessity of erecting at least one of the two spans by the cantilever method in order to maintain an adequate navigation channel, contributed to the difficulties of the work.

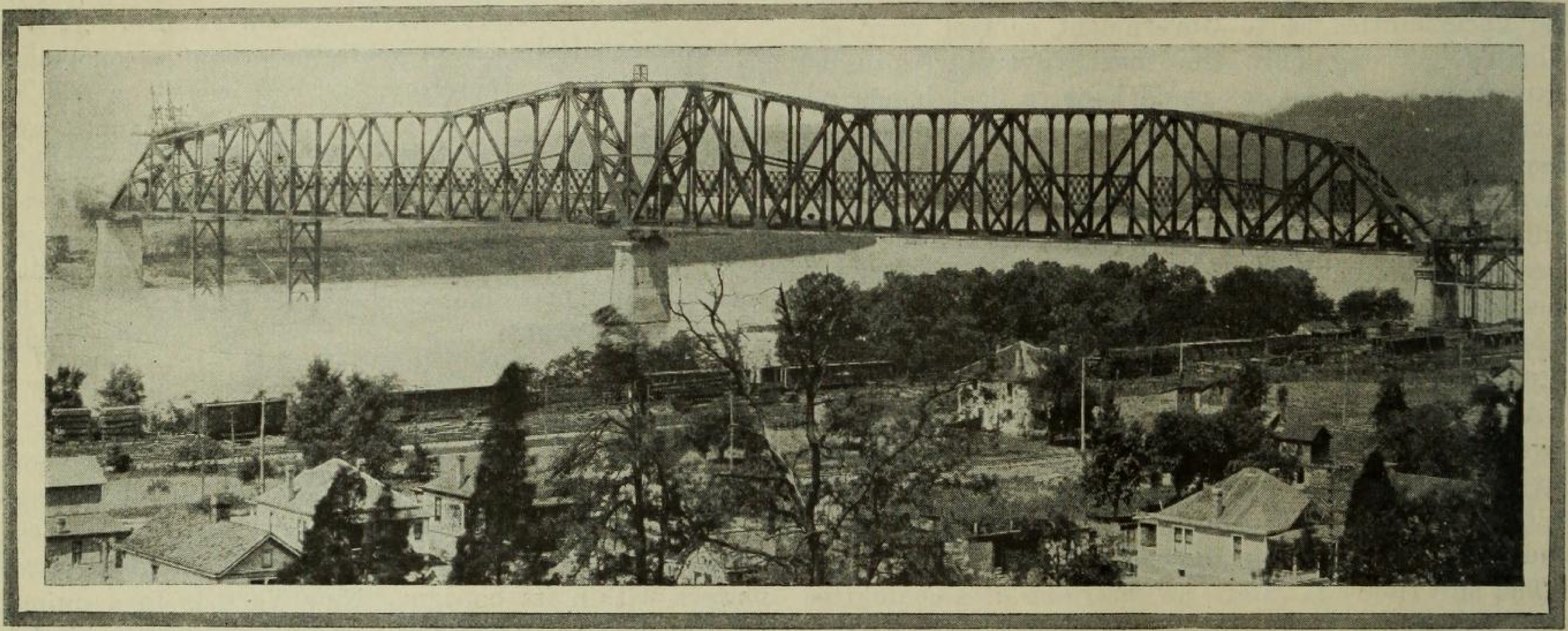


FIG. 1. THE TWO 775-FOOT SPANS OF THE SCIOTOVILLE BRIDGE COMPLETED. CREEPER TRAVELER AND TEMPORARY BENTS NOT YET REMOVED

The unusual form and proportions of the bridge are apparent from Fig. 1, and from the diagram Fig. 2, in which the dimensions are also given. The truss members were very heavy and of large section, therefore unusually stiff; they weighed up to 90 tons, with a cross-section of 596 sq.in. The structure presented an erection problem necessitating careful investigation and leading to several novel and interesting features in the erection methods.

Several auxiliary conditions must be noted: (1) All connections in the structure are riveted; the bridge is by far the largest fully-riveted truss bridge in the country. (2) Not only the great length of the members—up to 75 ft.—but also the fact that during erection the stress in some instances was opposite to that in the completed structure made the changes in length for camber very large and increased the distortions required to connect the members. (3) The distortions were in some cases so large that in making the last connection of a triangle the rivet holes were entirely blind. In many cases the members were too stiff and heavy to have the holes brought fair with pins. Special jacking devices had to be used to bring the connections into match.

It should be said in advance of all further explanation that the erection was successful in every way. The members were erected in distorted condition just as required by the engineer for elimination of secondaries. The contractor's equipment and methods for securing this result proved successful and productive of only the expected degree of extra cost and time. In two cases, where heavy members had to be held by the traveler falls until rivets were driven, a delay of virtually two days occurred. In splices such as the U2 hip where the holes did not match perfectly a large number of drift-pins were driven. This also occurred at top-chord splices in the Kentucky span. Bottom-chord sections were supported on a flying bridge while the splice was being riveted, and the balance of the steel in the panel was erected at the same time. In these cases the delay was not noticeable, but the cost was somewhat increased. No accident to the structure interrupted the progress of the work.

The Ohio River at Sciotoville has a 60-ft. range, and floods may occur very suddenly. Running drift and ice in winter and spring, and a current that makes falsework erection difficult, uncertain and dangerous at all except very low stages, had to be reckoned with. The bridge site is at one of the worst bends in the river. It has the peculiarity, furthermore, that the Ohio side, although on the outside of the bend, is shallow; rock bottom is at the low-water level here. The low-water channel, therefore, is on the Kentucky side, while at flood time the principal current is on the Ohio side.

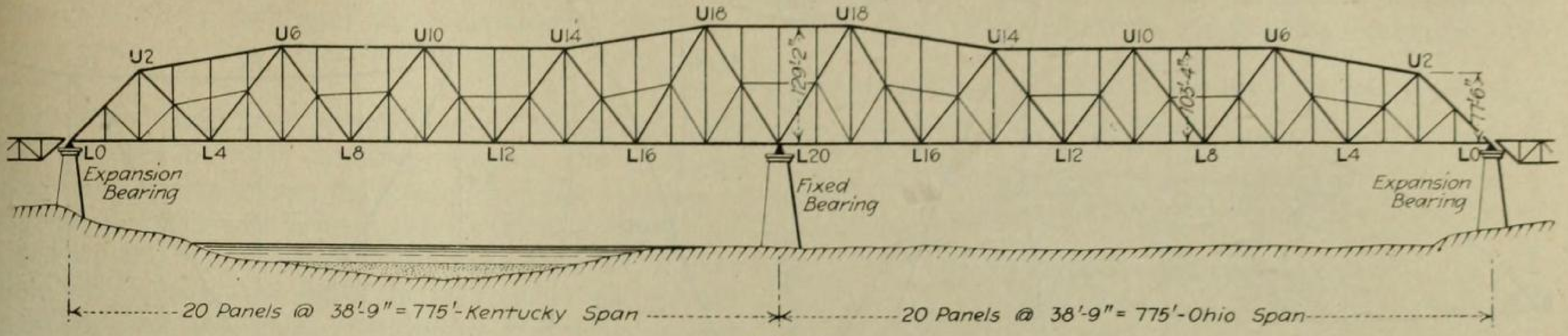


FIG. 2

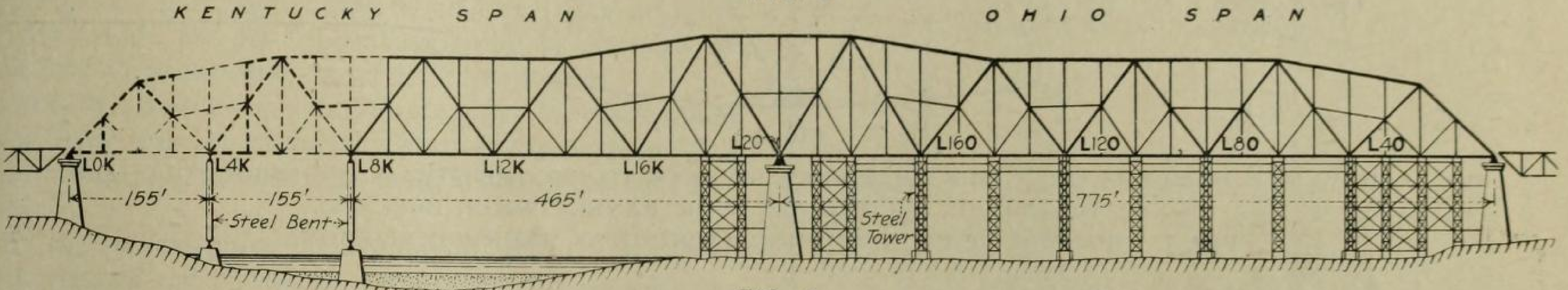


FIG. 3

FIG. 2. SCIOTOVILLE BRIDGE REMARKABLE FOR CONTINUOUS SPANS, WARREN WEB SYSTEM, GREAT SIZE, AND PROPORTIONS OF DEPTH AND PANELS

FIG. 3. FALSEWORK SYSTEM FOR ERECTION—THE LOW-WATER CHANNEL IS ON THE KENTUCKY SIDE, BUT IN FLOOD THE MAIN CURRENT IS ON THE OHIO SIDE, CREATING DANGER TO FALSEWORK

A clear width of 370 ft. had to be kept open in the Kentucky channel at all times during construction to pass the large tows of coal barges. This dictated cantilever erection for the Kentucky span and falsework erection for the Ohio span. The arrangement of supports resulting from these and other conditions is shown in Fig. 3. It will be noted that the falsework had to be placed where the ice hazard is greatest.

It was decided to anchor the Ohio falsework with rockfilled cribs and to build it up as separate towers placed far enough apart to allow drift and ice to pass between them. The panel length of the bridge being 38 ft. 9 in., a spacing of two panels for the larger part of the falsework was considered necessary. Piles could not be driven, but 12 x 12 posts were placed singly on the rock bottom and bedded at low water.

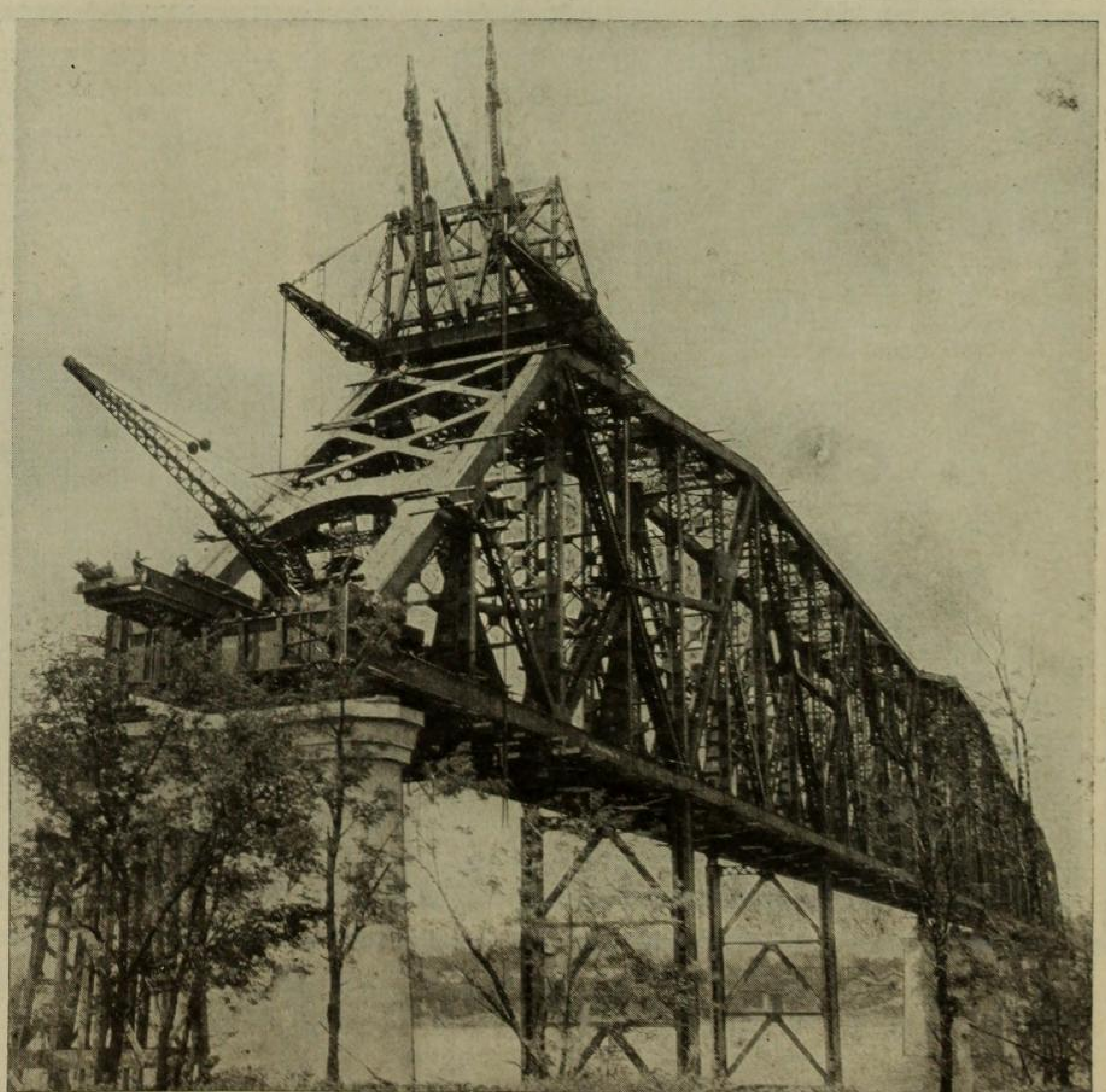
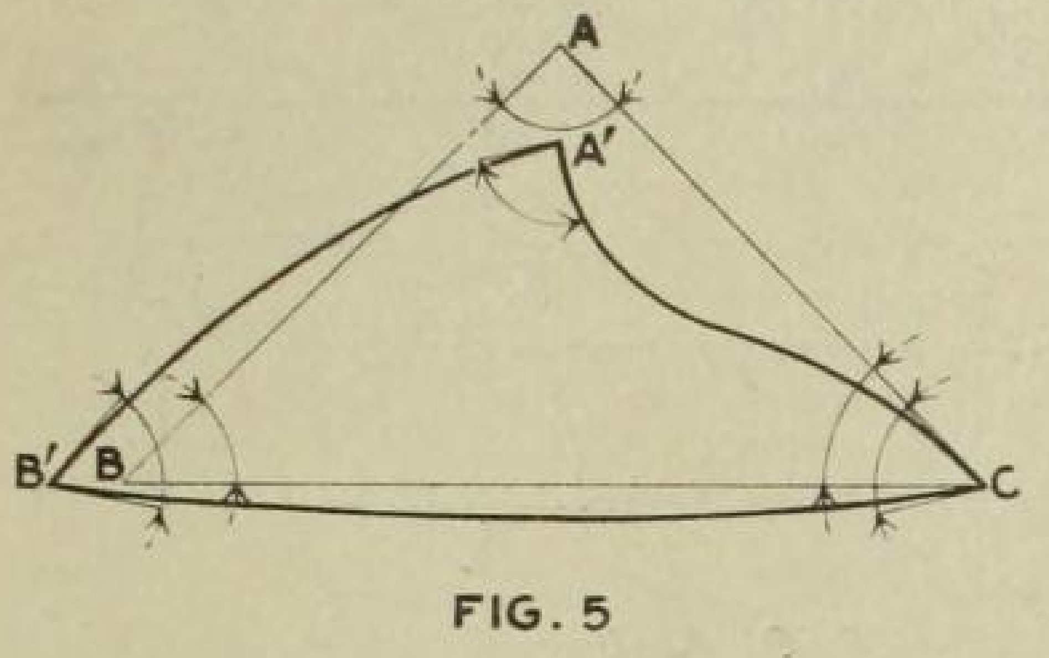
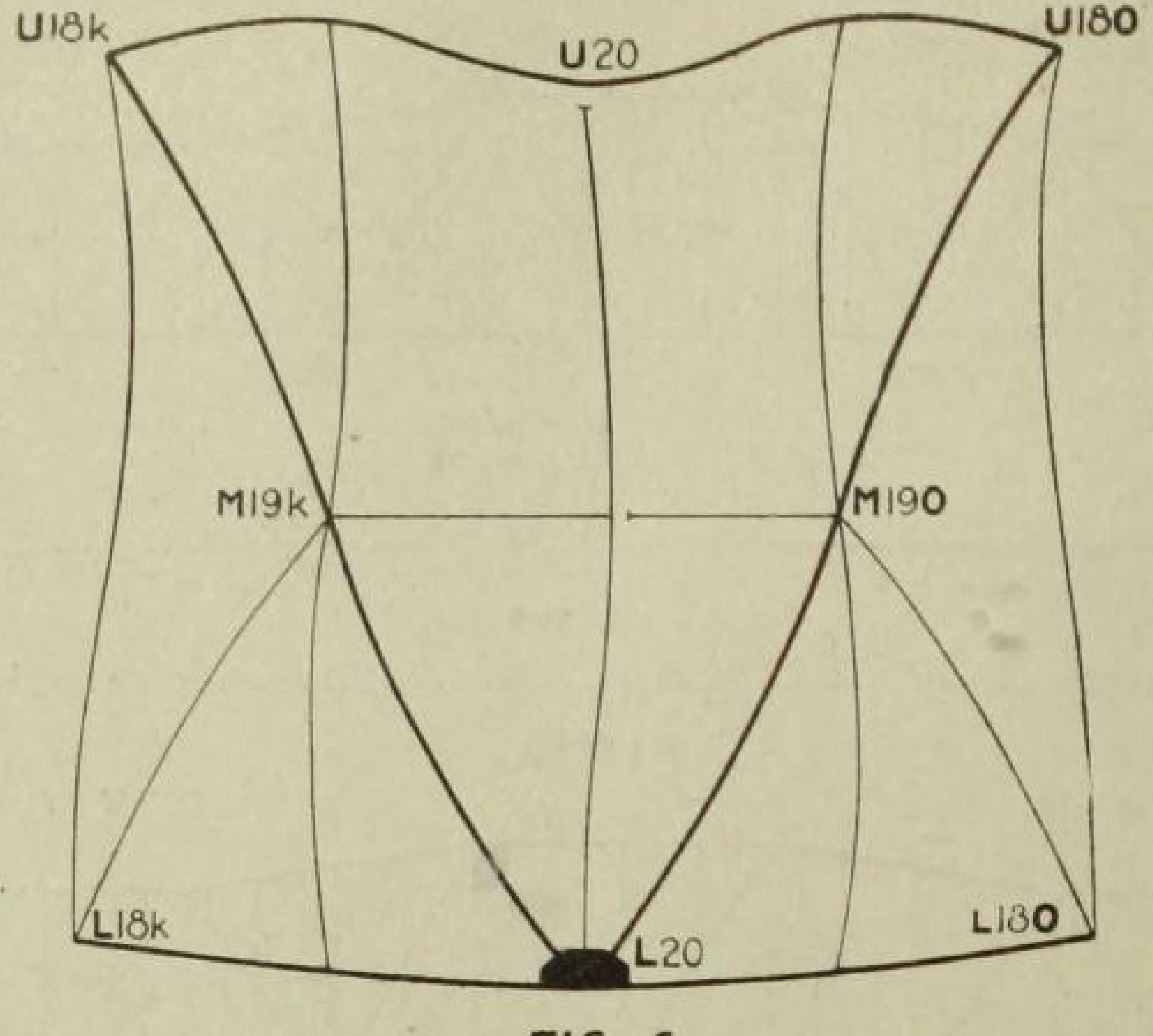


FIG. 4. THE CREEPER TRAVELER'S WORK COMPLETED AT THE KENTUCKY END PIER

The extreme overhang of the Kentucky cantilever, which would have required much extra metal to provide for erection stresses, was reduced by placing two temporary steel bents under the landward portion of the Kentucky span. There was room also for two panels of falsework adjacent to the center pier, which was of service in erecting only the main triangle of the trusses over the center pier.

The design of the falsework was governed by the great weight of the bridge. Originally it was intended to erect about one panel of the Kentucky span as a cantilever to two of the Ohio span on falsework, and to carry the unbalanced load of the Ohio span on steel towers placed at the main panel points. By so doing the progress of erection would be more rapid and the load on the Ohio falsework would be lessened. The Ohio end was to have been supported successively on the steel towers as the erection progressed. This scheme was abandoned when the Kentucky span was completed to only 17 in order to rush the Ohio span to completion as a safeguard against a possible ice jam. The span was left supported on *all* the steel towers (155 ft. apart) since it was not selfsupporting until the Kentucky cantilever was nearly half completed. Thus, should the 70-ft. openings between timber towers have proven too small to allow an excessive run of ice to pass, or should the timber towers have been badly cut by the ice, the steel towers with 155-ft. openings would have supported the span until the Kentucky cantilever was of sufficient length to make it safe to swing the Ohio span.





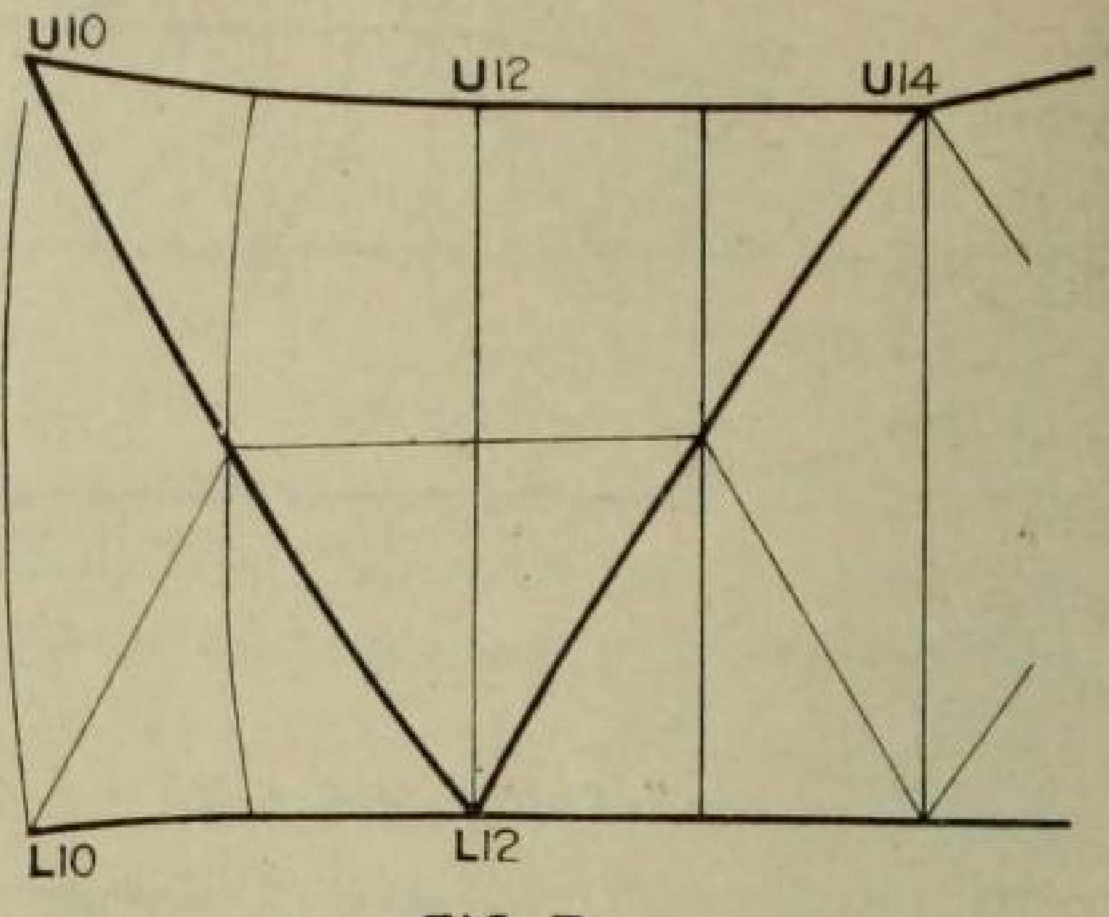
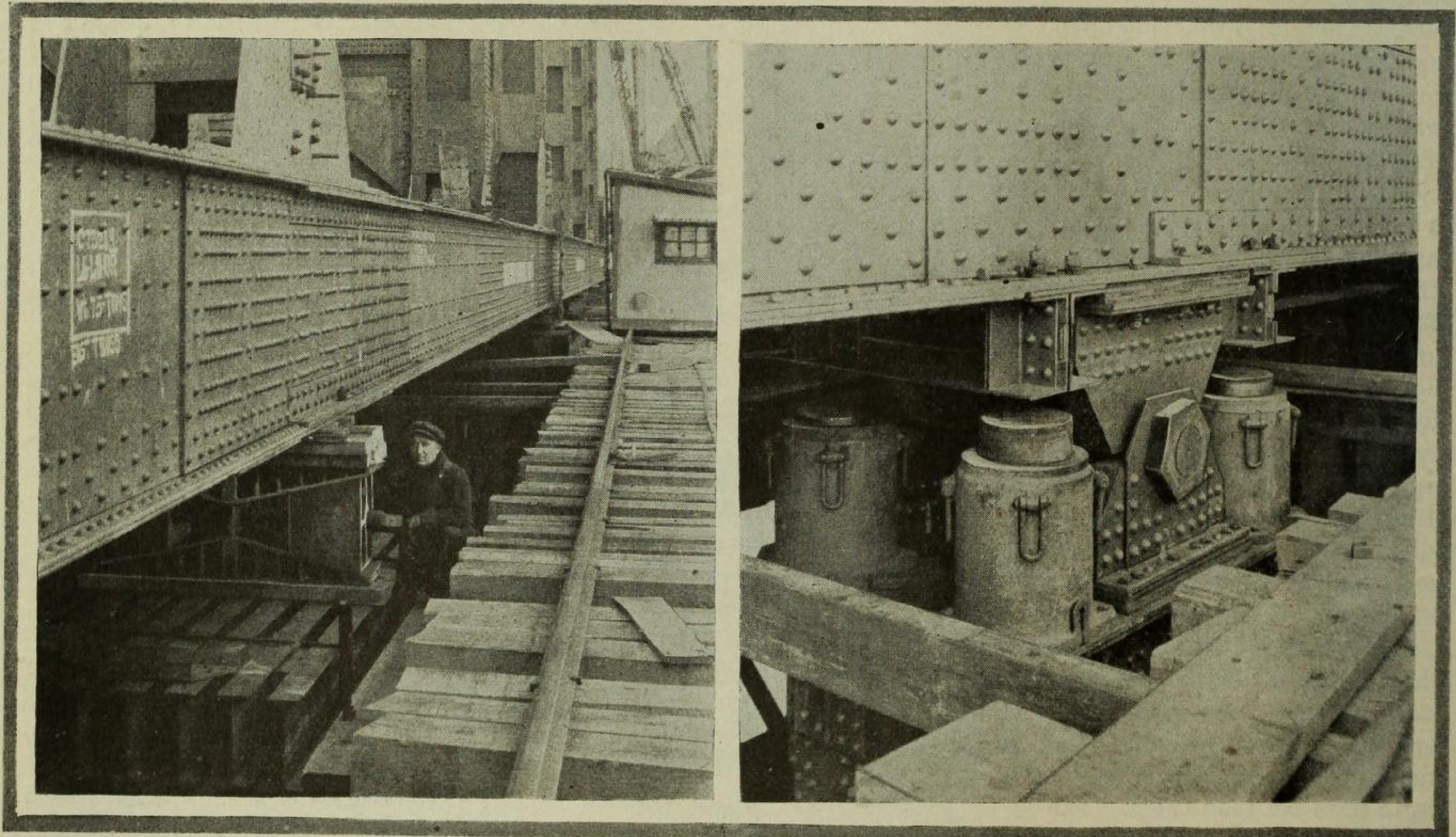


FIG. 5. HOW THE MEMBERS OF A TRIANGLE MUST BE BENT TO BECOME STRAIGHT UNDER FULL LOAD
FIG. 6. DISTORTION OF MIDDLE FOUR PANELS WHEN ERECTED
FIG. 7. OPENING AT U10 REQUIRING JACKING TO MAKE CONNECTION



FIGS. 9 AND 10. THE BOTTOM CHORD OF THE OHIO SPAN RESTED ON WEDGE JACKS ON THE TIMBER FALSEWORK, WHILE ON THE STEEL SUPPORTS ROOM WAS LEFT FOR HYDRAULIC JACKS

Timber towers were used for temporary support of the floorbeams midway between steel bents. The timber towers were built wide enough to carry the traveler track outside of the trusses.

On account of the two-panel spacing of falsework towers to pass drift and ice, 70-ft. girders belonging to the permanent approaches to the bridge were used to span between towers. The 42 girders available provided for seven spans of the falsework, using in each span two girders to carry the intermediate floorbeams, and two girders under either gantry traveler runway. This gave seven openings; the remainder of the falsework, near the two piers, had towers at every panel point.

Since the rigid joint connections of the bridge hold the members in fixed angular relation, the members must bend as the bridge deflects under load. By erecting the members with a bend exactly the opposite of the bends which they would normally experience at a given stage of loading, the effect is secured of having the members come straight and therefore free from secondaries at this particular stage of loading. The designer of the bridge, Gustav Lindenthal, specified that this result was to be attained under half live load.

The bridge thus has high secondary stresses under dead load, but the secondary stresses decrease as live load comes on, and are fully neutralized under half live load.

If the various joint connections of the bridge had all been reamed and riveted as erection progressed, with the members straight and unstrained, the desired angular relations would not have been secured, as the subsequent distortion under load would have caused bending in the members and hence secondary stress. It was necessary, therefore, to assemble the truss in the shop and ream the connections with the members meeting at such angles as would result after distortion of the bridge by load. This was done as follows:

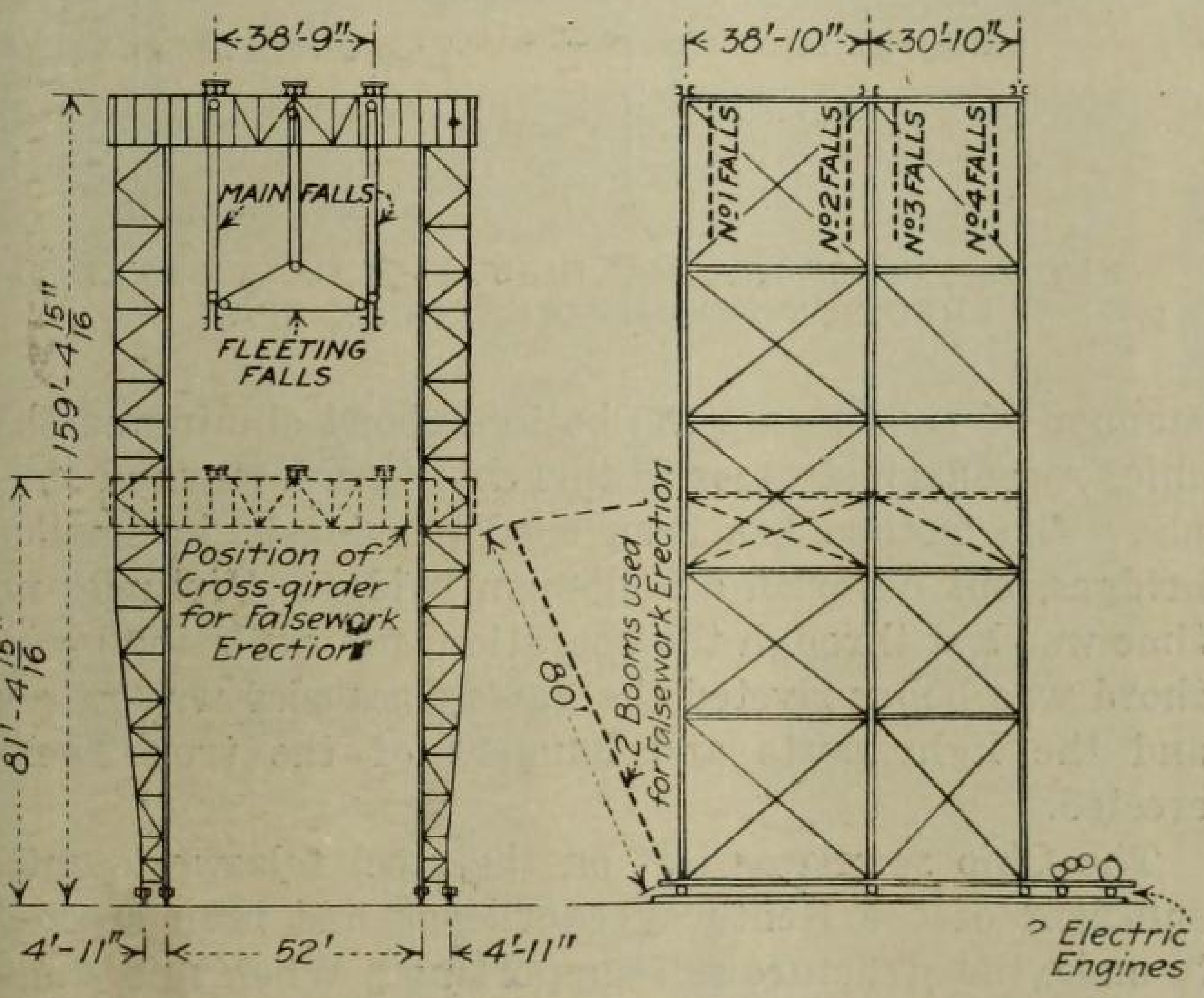


FIG. 11. ERECTION GANTRY USED FOR OHIO SPAN

Every member was originally built to such a length that when erected and under the influence of one-half full live load the bridge would be of its diagram size (Fig. 2). The members when laid together unstressed would therefore not have the diagram angles at the joints. As the joint connections were to be reamed to the diagram angles, the shop had a problem in reaming the connections. Of any triangle of the bridge, only two corners could be fitted up at a time. After these were reamed, one corner was disconnected and the member shifted to make possible the reaming of the third connection. This had to be done with every triangle in the bridge. The angles were laid out accurately with a transit instrument, and distances were measured or checked in the early morning while the steel was of uniform temperature.

In order to connect the three members of any one triangle thus prepared, with rivet holes matching, the members had to be forced together, distorting them about as sketched (in greatly exaggerated form) in Fig. 5. In nearly every such triangle one member, in this case *AC*, is relatively very light and flexible, and can bend more easily than the two stiffer members. The general problem in the erection of the bridge trusses was to secure the proper angle at *B*. In placing the light member *AC* a few pins at *C* and *A* easily brought good holes and therefor the proper angles at *C* and *A*. Jacking was often required to bend the heavy members or to stretch the light members to get pins started at *C* or *A*.

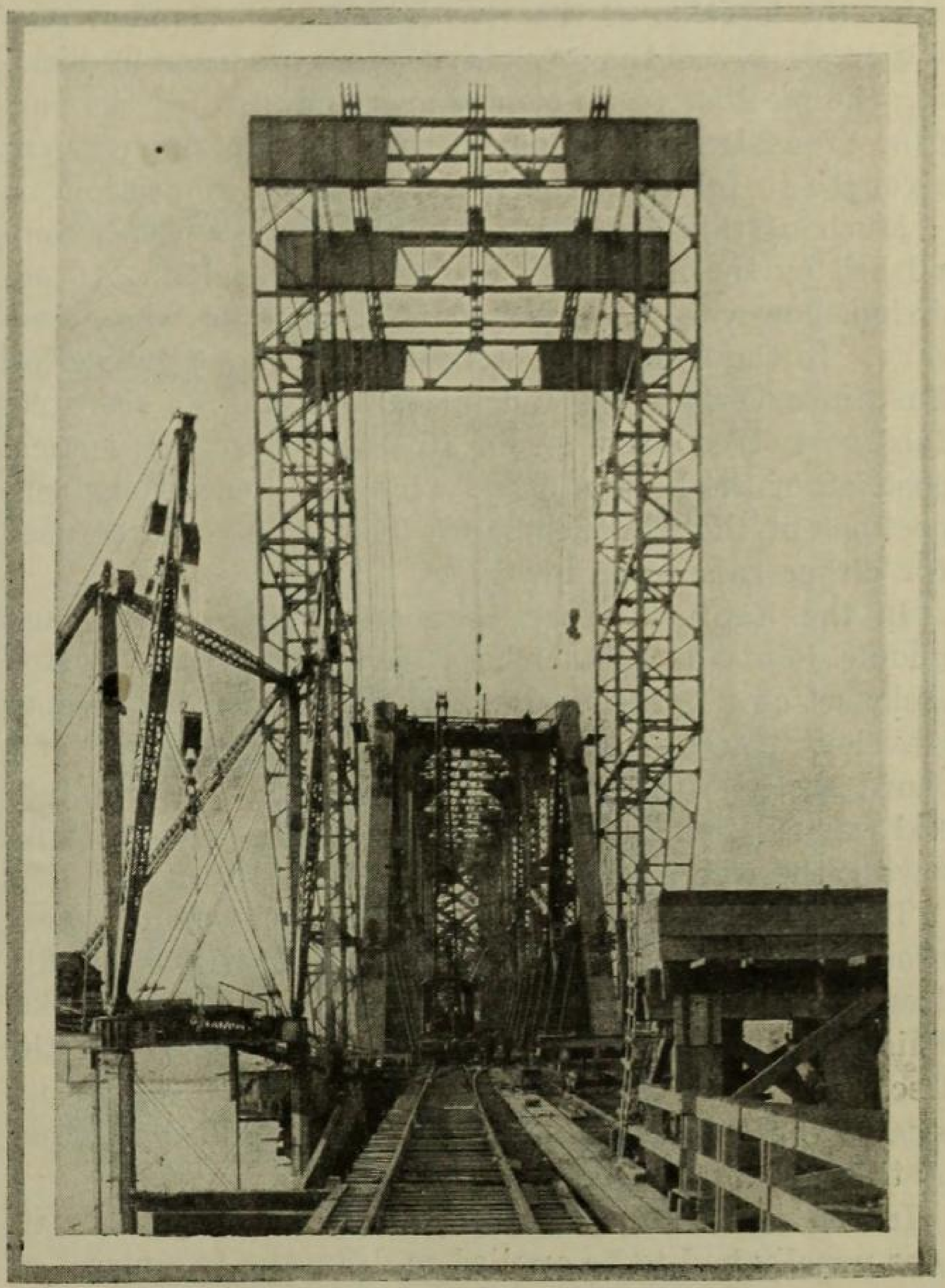


FIG. 12. FULL-HEIGHT GANTRY AS USED FOR OHIO SPAN TRUSS ERECTION

One of the serious problems in bringing about this distortion was encountered in the four middle panels, illustrated by Fig. 6. Here the members are extremely heavy. As none of them will ever undergo reversal of stress in the completed bridge, and since they will always be under large stress in the completed bridge, their changes in length for camber are comparatively large. During their erection the direct stresses were virtually zero. Unusually heavy forcing was required to bring the members together. The two joints shown open in Fig. 6 were left unconnected until both spans were swung and the chords had become virtually straight.

Extensive computations were made in order to determine for every member and splice in the bridge just how much the holes would mismatch at one point when the other end of one of the members was normally connected, and also to determine the force necessary at the free end to bring the connection fair.

These computations were made in order to predetermine the location of the free end of each member during erection, and the secondary stress produced by bending the member to its connection; and also for the purpose of designing equipment and rigging of sufficient strength to force the members into true connection.

Much of this distortion during erection was accomplished by the main falls of the two travelers. In addition, however, a large amount of jacking was necessary. In the Ohio span, wedge jacks were provided on the timber falsework, and hydraulic jacks on the steel falsework (see Figs. 9 and 10), to adjust the vertical position of the bottom chord while making various connections of the web members. The jacks could be used for either raising or lowering.

In the Kentucky span the bottom-chord joints and middle joints of submembers were made with Norton jacks set on a flying bridge suspended from the creeper traveler. These jacks supported the projecting end of a chord section just placed, until the splice at its rear end was riveted, and thereafter raised the chord for allowing the web members to be connected to it.

The top-chord joints at the main panel points were brought to connection by means of two 200-ton hydraulic jacks used in a specially designed jacking yoke. This was shown in service by the cover picture of the Dec. 13 issue of *Engineering News-Record;* Fig. 7 indicates the location of one of the gaps pulled together by this jacking yoke.

In the top-chord splices of the Kentucky span drift-pins usually had to be applied to draw the two pieces of chord into true tangency at the splice; the holes were almost fair without any forcing, and drifting was sufficient to make the connections. The top chord rested on posts at all but main panel points. In the Kentucky cantilever erection these posts held the chord too high at the free end to allow perfect holes at the splice, in a few cases. The kink in the chord was almost imperceptible and a few pins at such points brought the holes to almost perfect match.

For the erection of the two large spans a special erection calendar had been prepared in advance and manifolded, which prescribed to the men in the field the order of procedure and sequence of movements for each piece of the trusses when going into place. This feature contributed materially to the complete success of the erection without confusion and without accidents to the structure, in spite of interruptions by high water and some labor troubles.

Erection Features, Ohio Span

The erection on falsework was handled by a gantry traveler running outside of the trusses, in accordance with regular practice. There were certain special points in the work, however, apart from the distortion of the members of each triangle during erection in accordance with the general scheme already mentioned.

Since the floor had to be started at the Ohio end, where material was brought in, while the fixed shoe at the middle pier and the floorbeam there had to be set in true final position when that point was reached, it was necessary to provide against uncertainty in pier spacing and overrun of floor. With the long floor system supported on high and rather flexible towers through the middle, and on comparatively stiff towers at the two ends where the towers were braced to each other, it was uncertain whether expansion would cause the floor to creep sufficiently to prevent placing the floorbeam at the middle pier. For this reason the floor was first placed 6 in. nearer the Ohio end of the bridge than its final position.

The lower chord of the span was erected level and straight and all splices were riveted; then it was jacked to approximately the shape of a predetermined no-load camber curve, such as to connect the web members to the chord without further jacking the chord. This manner of riveting up the bottom chord eliminated the chief secondary stresses in this chord perfectly and simply. The method has been used previously in smaller bridges, but never in a long-span bridge. Virtually no time was lost through the operation, for while the lower chord was being riveted the gantry traveler was raised and the light posts and hangers of the truss were erected.

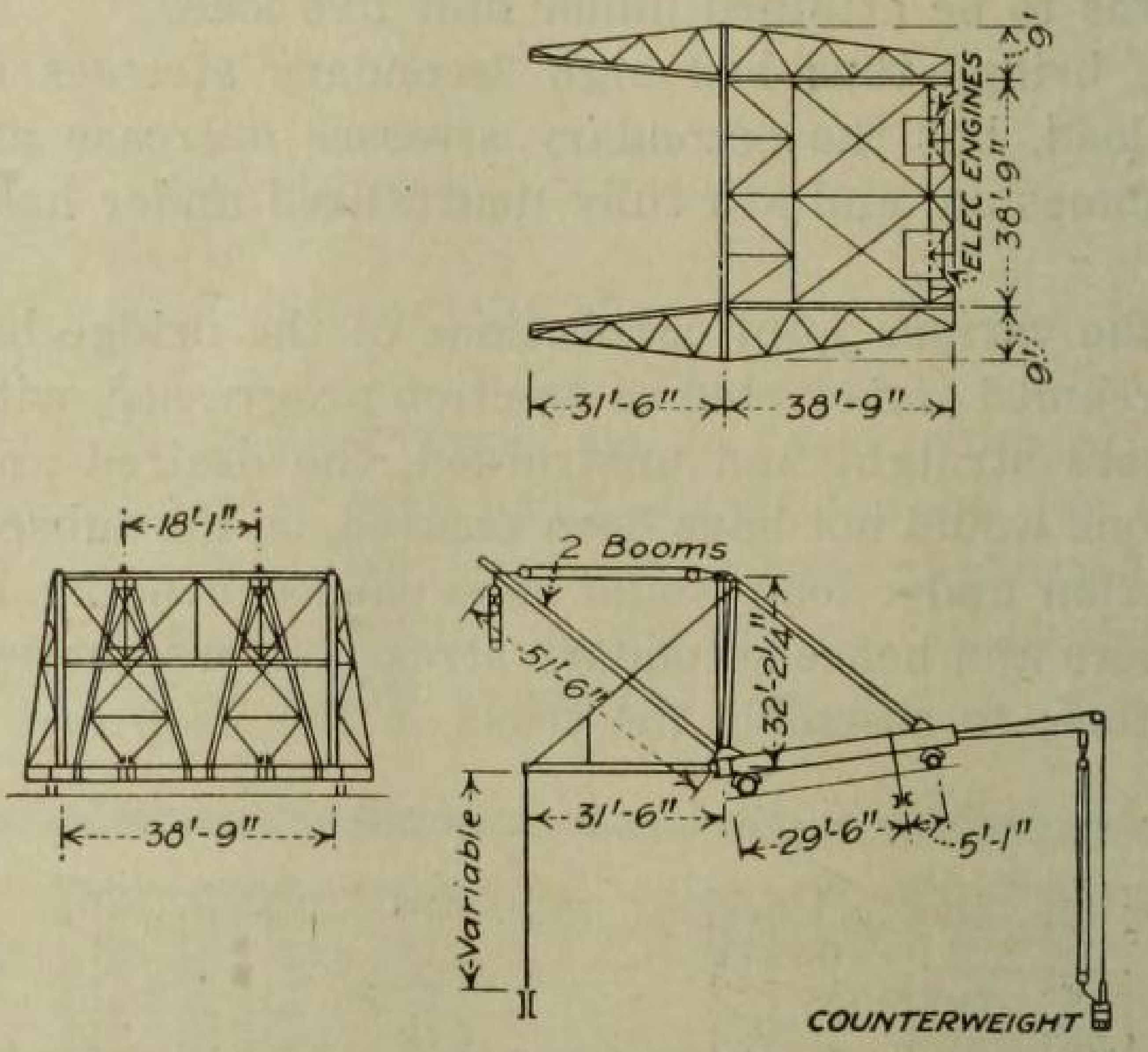


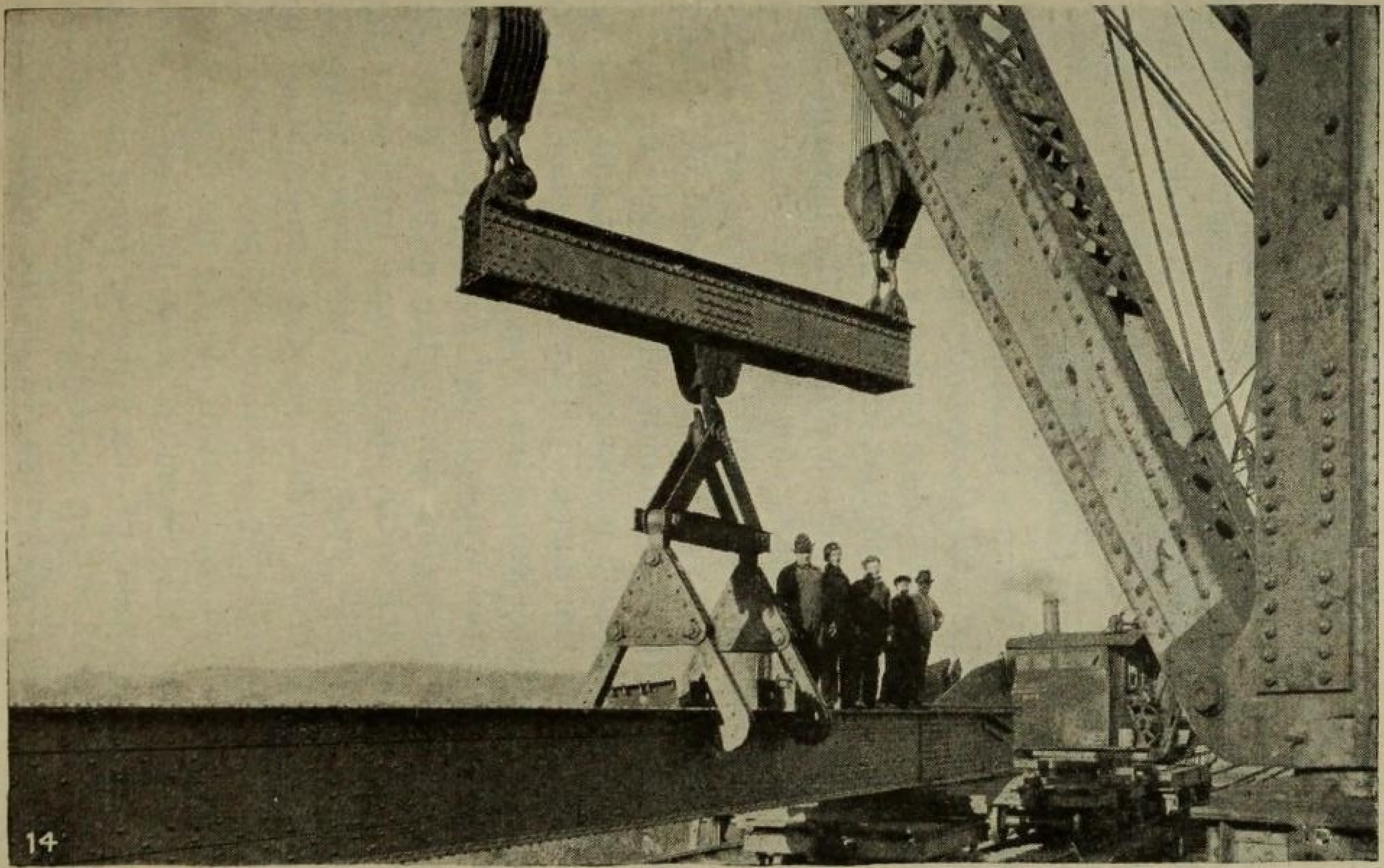
FIG. 13. CREEPER TRAVELER FOR CANTILEVER ERECTION OF THE KENTUCKY SPAN

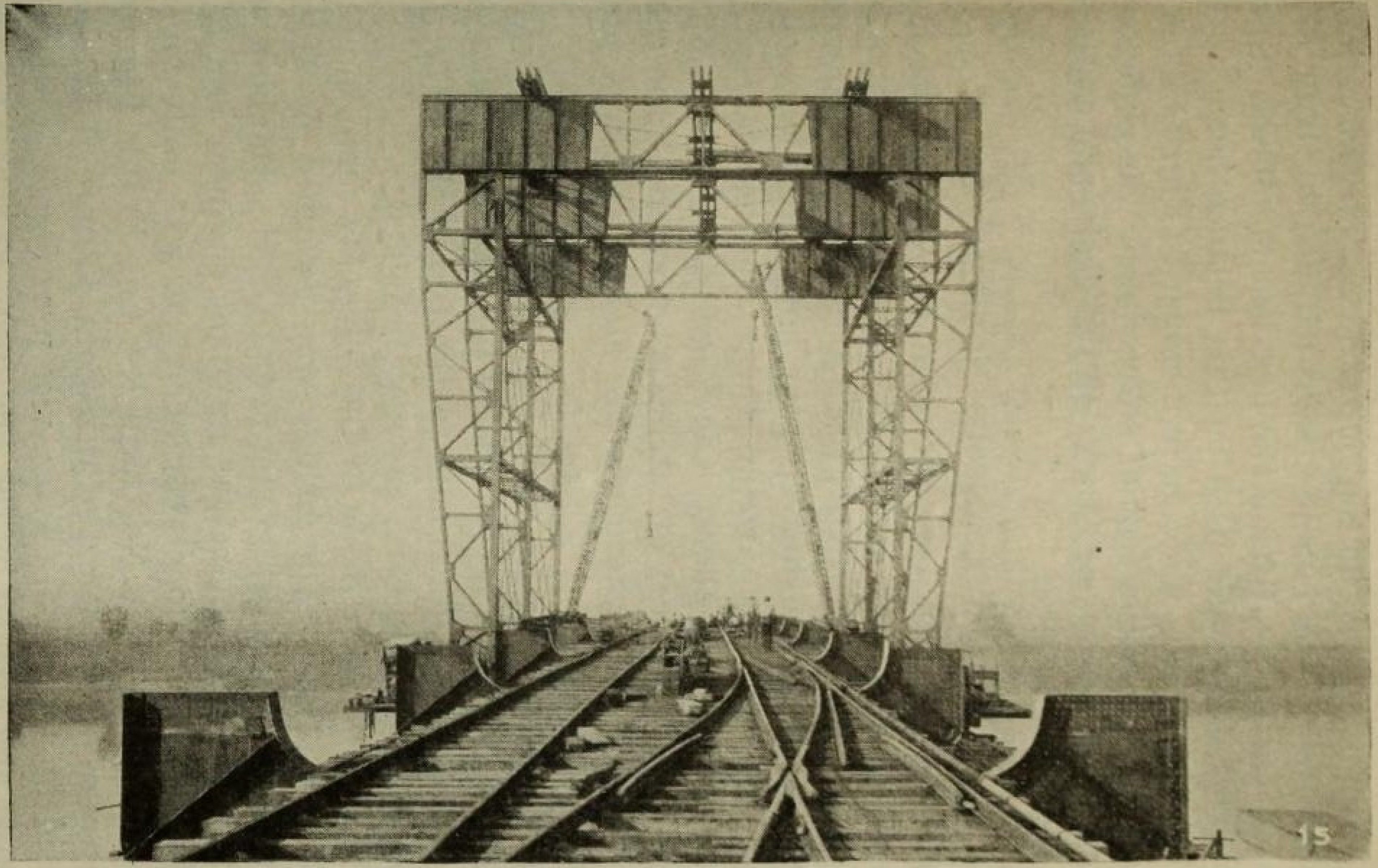
The Ohio span was left on the steel falsework until sufficient of the Kentucky cantilever had been erected to make the structure self-supporting. When this stage was reached, the Ohio end was jacked up 8¼ in. to its final level, releasing the span from its support on the steel falsework towers.

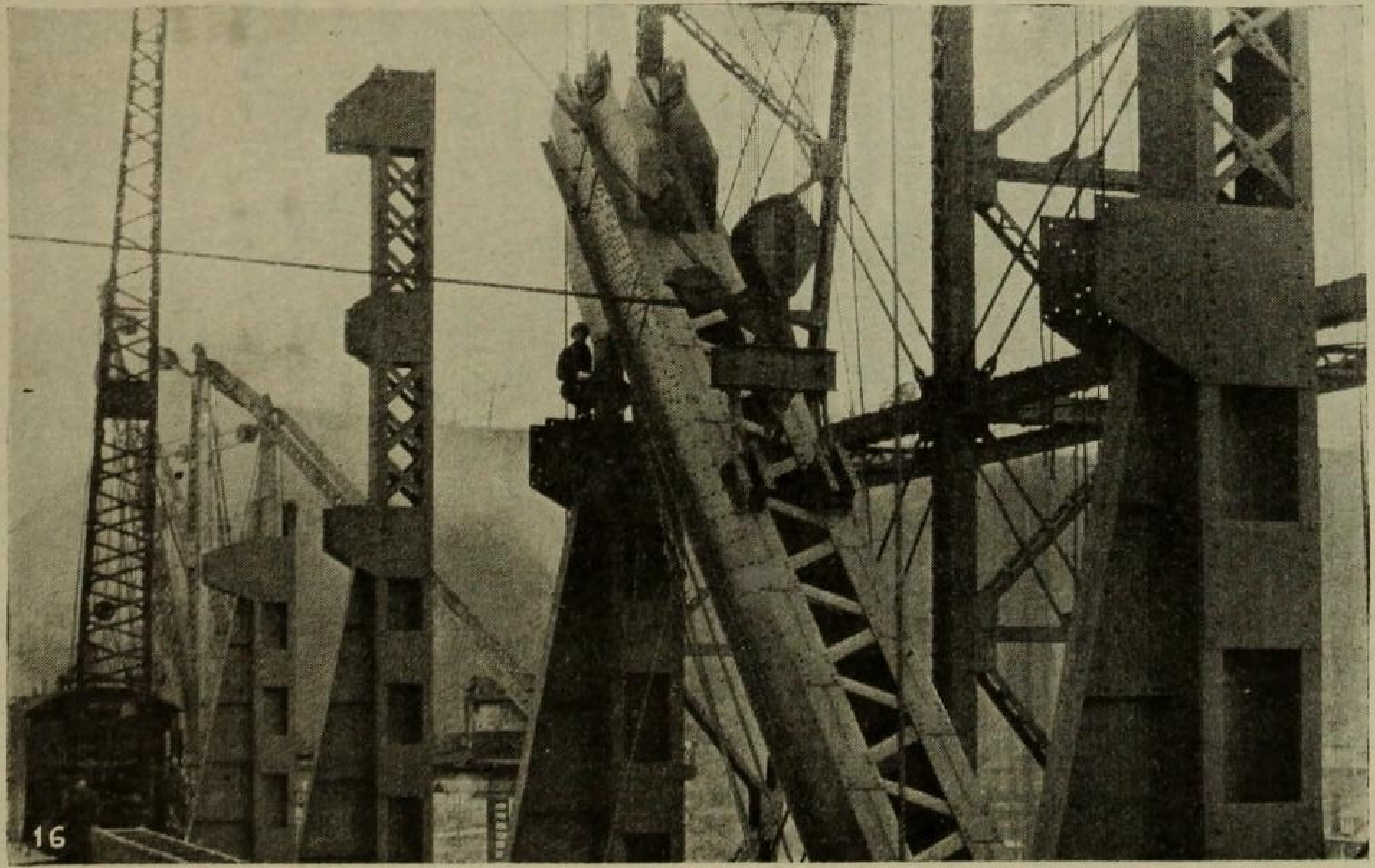
Kentucky Span Erection

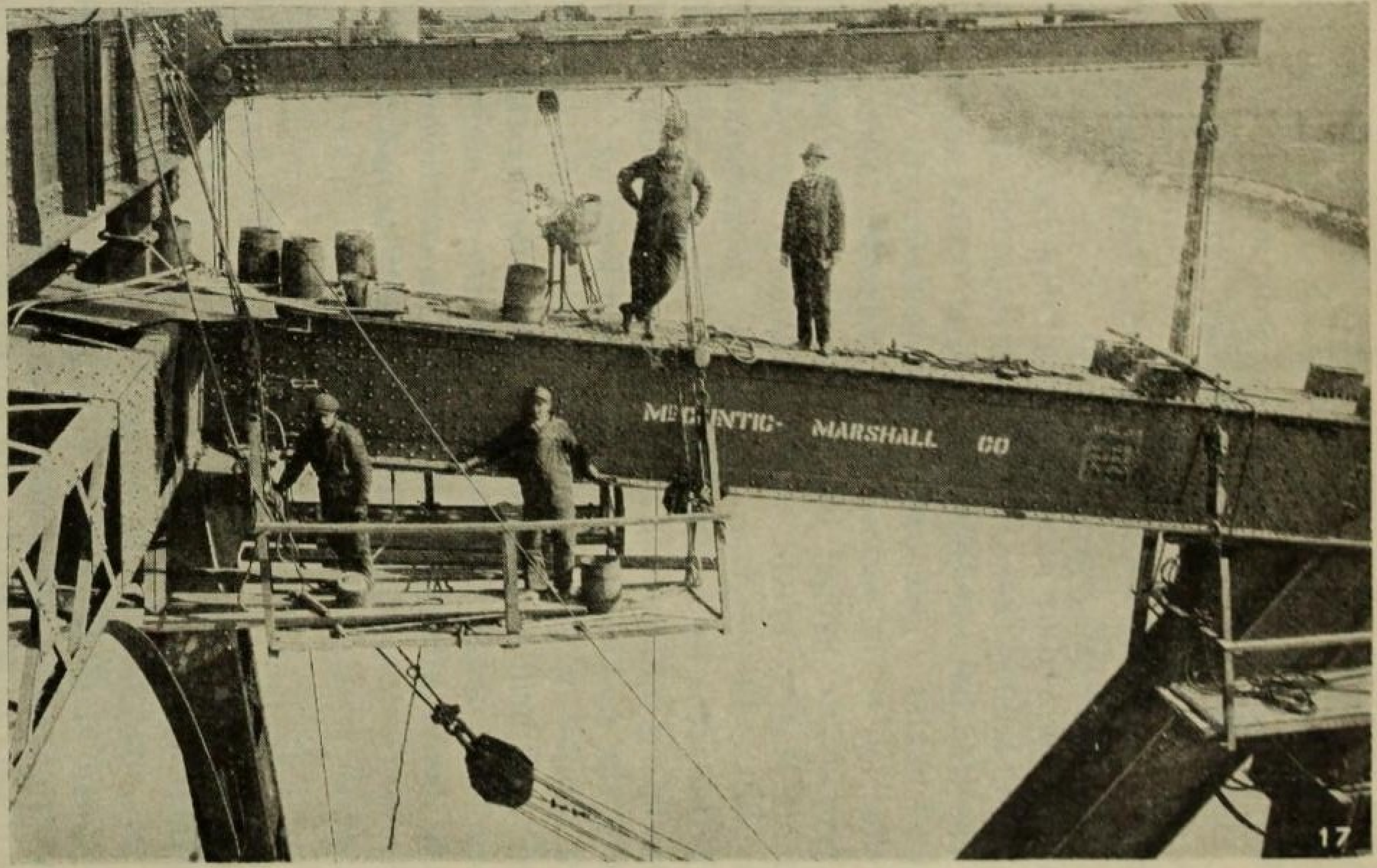
The cantilever work of the Kentucky span was done by the regular top-chord or creeper-traveler method, with the important exception that two temporary supporting bents were provided, under panel points 8 and 4, respectively. These were bents that had previously been used under panel points 8 and 12 of the Ohio side. The maximum cantilever length therefore was 465 ft., instead of the full span length of 775 ft.

At the time the cantilever reached the first supporting bent, at panel point 8, the stress in top chord U14 U18









FIGS. 14 TO 17. SOME OF THE ERECTION EQUIPMENT USED AT SCIOTOVILLE

Fig. 14—Handling a heavy member with both booms of hoisting tower. Fig. 15—Gantry at half height for floor work. Fig. 16—Hitches provided on a diagonal for lifting in proper balance. Fig. 17—Under the creeper. Note falls for holding diagonal, and special platforms

amounted to more than 18,000 lb. per sq.in.; had a longer cantilever projection been necessary, by not using temporary bents, considerably more steel would have been needed in the top and bottom chords and in the main web members of both spans near the middle pier, to take care of erection stresses. The temporary supports served also to reduce the deflection of the cantilever.

The span was jacked up at each of the temporary supports as soon as landed there. Since continuation of the cantilever erection beyond the first support would again increase the top-chord stresses, it was necessary to reduce the deflection at the second support in order to keep these stresses within proper limits. At the same time the amount of jacking at the supports had to be so adjusted that, with the erection continually progressing, the load on the steel bents would not become excessive (these bents being taken from the falsework of the Ohio side). Thus, the jacking problem involved keeping the loads on the temporary bents within safe limits, keeping the stresses in all bridge members safe, and keeping the Kentucky end sufficiently high for jack clearance under the end floor beam after completion of the cantilever. Temperature variation, wind effect and the like had to be considered as contributory factors.

SPECIAL TOOLS REQUIRED

The Ohio span was erected by the gantry traveler shown by sketch in Fig. 11 and by view in Figs. 12 and 15. This was first erected to about 60-ft. height and carried two special 80-ft. booms on the front end for erecting falsework, floor and lower chord. For erecting the trusses it was raised to its full height of about 150 ft. In this condition its equipment comprised three main falls of 50 tons capacity each, hung on the center line of either truss, and two sets of fleeting falls suspended over the center line of the bridge. All were operated by electric engines.

The creeper traveler (Figs. 13 and 17), which handled the cantilever work of the Kentucky span, a tool designed and built especially for the work of this bridge, was equipped with two booms, operated and swung by electric engines, and with a jacking bridge suspended from outriggers. This bridge served for supporting and jacking the free ends of the lower-chord sections before they were connected to the web members.

The varied jacking which had to be done during the erection was provided for by ten hydraulic jacks (two of 500 tons capacity and eight of 200 tons capacity), several 50-ton Norton jacks, and about 30 screw wedge jacks of 200 tons capacity. These were used partly in connection with the jacking yoke for making the hanger connections at the top chord (Fig. 8), partly on the steel falsework of the Ohio span for jacking the lower chord and the various panels during the truss erection, and partly in connection with special castings, grillages and bolsters under the end floorbeams for swinging both spans. These end floorbeams themselves were made about twice as heavy as necessary for the finished bridge, in order to provide for the jacking.

HOISTING TOWER FOR MATERIAL

To raise material to the bridge deck from the yard, located at the Ohio end of the bridge and about 60 ft. below the floor, a hoisting tower was provided. This was a four-post braced steel tower 40 ft. square and 60 ft. high, with two 50-ton 50-ft. booms on two adjoining corner posts. A balance beam handled by both of the booms served for lifting the heaviest members. Special hooks or dogs were used on this balance beam to take hold of the 48-in. wide main members (Fig. 14). A 30-ft. radius from the foot of either boom was sufficient to place the members on trucks on the deck span at the end of the main bridge.

MISCELLANEOUS EQUIPMENT

Special hitches were provided for lifting the heavy members, as shown in Fig. 16. These were always used in pairs. They consisted ordinarily of two channels or plates, a pin and a sheave on the pin. Cable loops on the load falls passing around these sheaves carried the weight of the members. On diagonals or chords of one panel length one set of hitches was bolted at the center of gravity and, where needed, another set was placed at the free end.

A large amount of special equipment in the way of bolsters under the bottom chord for jacking, special falls to connect main diagonals to the top chord (Fig. 17), riveting scaffolds, etc., was also provided.

Mention is here made of the following men connected with the work. The bridge was designed by Gustav Lindenthal, consulting engineer; O. H. Ammann was Mr. Lindenthal's principal assistant engineer and R. T. Robinson his resident engineer. It was built for the Chesapeake & Ohio Northern Ry. Co., Frank Trumbull, chairman of the board of directors, George W. Stevens, president, and M. J. Caples, vice president. It was fabricated and erected by the McClintic-Marshall Co., with Paul L. Wolfel chief engineer, S. P. Mitchell consulting engineer for the contractor, E. A. Gibbs manager of erection, and A. Toohey superintendent of erection.

Detailed description of the erection work on the Ohio and Kentucky spans, respectively, will be given in subsequent articles.

Panama Canal Forces Still Large

Although the Panama Canal is finished, it is by no means a fact that all Governmental activities on the Isthmus have ceased. A report for the one month of August, 1917, indicates that maintenance, operation and supplementary construction work on the isthmus engage a great number of men. As an indication of what the canal is doing, in that month 172 ships went through the canal, a tonnage of over 521,000, and 57 ships entered the ports of the isthmus without passing through the canal. Over 5500 passengers arrived and over 6200 passengers left the ports. Oil to the amount of 77,000 bbl. was issued to steamships from the canal tanks, and 70,000 tons of coal were landed for similar purposes. Excavation by dredging during the month shows that by no means all the earth on the canal has been moved. In August 379,517 cu.yd. of earth were moved for maintenance purposes, 293,766 for construction purposes, and 102,793 for auxiliary purposes, making a total of 776,076 cu.yd. handled during the 31 days. In addition to this, 817,066 cu.yd. were handled by steam shovels. A statement of the working force shows that there were 19,813 silver employees and 3461 gold employees, making 23,274 engaged in the whole isthmian work.

Truss Erection and Jacking Operations for Two 775-Foot Continuous Spans

Second of Three Articles on Sciotoville Bridge Erection—Central Triangle of Heavy Members Set Difficult Task in Eliminating Secondaries—Methods of Forcing Joints—Deflection and End Lift Curves

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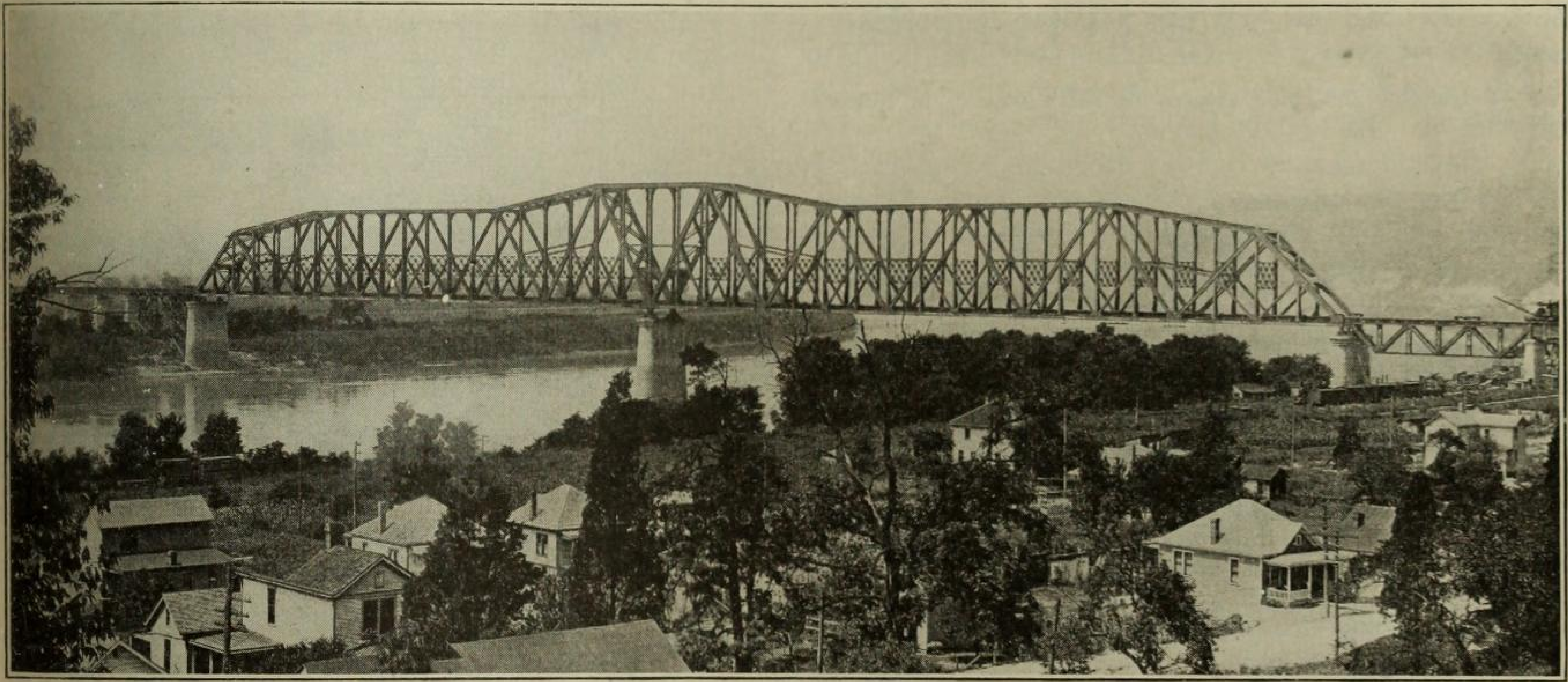
JOINING up the truss members of the Sciotoville Bridge in bent condition to eliminate secondary stresses in service—the distinctively new erection feature of this structure—required different methods in the Ohio and the Kentucky spans, as the former was erected on falsework, while the latter was cantilevered out from the middle pier. How the rivet holes in the connections were laid out to the strained shape of the trusses was described in *Engineering News-Record* of Jan. 10, 1918, pp. 62 to 68, in outlining the general procedure of the erection and the equipment used; in the field these connections had to be brought together by forcing, which involved extensive use of jacks, as described in the present article. Heavy jacking was required also to swing the spans, their continuity making the structure of indeterminate or constrained type. The information obtained through this jacking throws much light on the practical value of continuous bridges.

As shown diagrammatically in Fig. 1, truss erection was started at the middle pier. This was done because: 1. It started the work at a fixed bearing (both end bearings have expansion rockers); 2. Constructing the two spans simultaneously, connected over the center pier, allowed the cantilevered Kentucky span to relieve the load of the Ohio span on its falsework, and made the progress of erection more rapid; 3. Erection of the middle four panels was greatly simplified, and the forces required for bending the members to connection were reduced; 4. The safety of the work was increased in relieving the falsework in the middle of the river first.

The plan of simultaneous erection was abandoned, however, after only one panel of the Kentucky cantilever had been placed. Approach of the season of cold weather and high water made it advisable to complete the Ohio span as rapidly as possible, so that it would be free from at least all the timber falsework should there be a heavy run of ice. The shortage of men and the impracticability of handling material for both travelers on two tracks were factors in the decision.

To start truss erection at the middle pier, the following procedure was adopted: The first four towers of timber falsework (at 1, 2, 3 and 4 Ohio) were erected to provide space for setting up the gantry traveler. The traveler, erected on these towers to 60-ft. height, placed the timber and steel falsework for the Ohio span and set the bridge floor on it while proceeding toward the middle pier. It also set the bearing shoes on the middle pier and laid down upon them the lower chord of the two panels 18-20 K. Then, moving back toward the Ohio end, it placed all the lower chord of the Ohio span.

Before any truss erection was started, the splices between the two-panel lengths of the lower chord were completely riveted while the chord was level and straight. Since the truss members had been fabricated to such lengths as to make the chord straight under full live load on one track of the bridge, the method of riveting described eliminated secondary stresses from the chord. While the riveting went on, the gantry traveler was raised to full height, 150 ft., and the light subposts and hangers were erected with the derrick car. The opera-

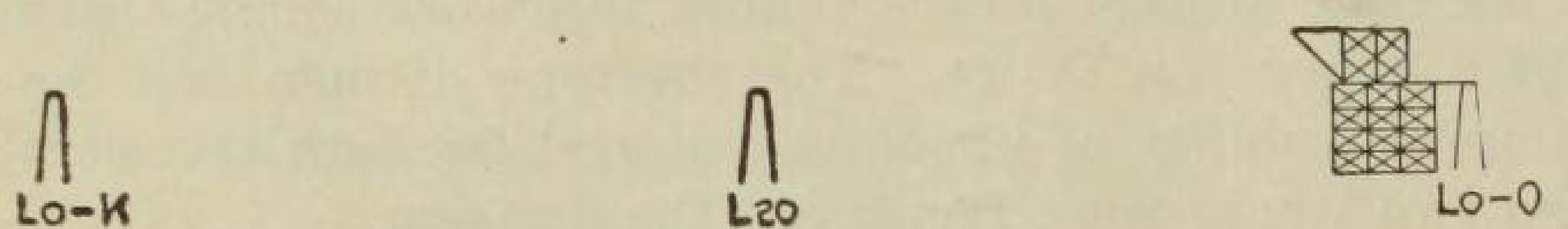


SCIOTOVILLE BRIDGE—THE FAR SPAN, CROSSING THE LOW-WATER CHANNEL ALONG THE KENTUCKY BANK, WAS ERECTED BY THE CANTILEVER METHOD tions so far are represented in diagrams *A* to *C* of Fig. 1.

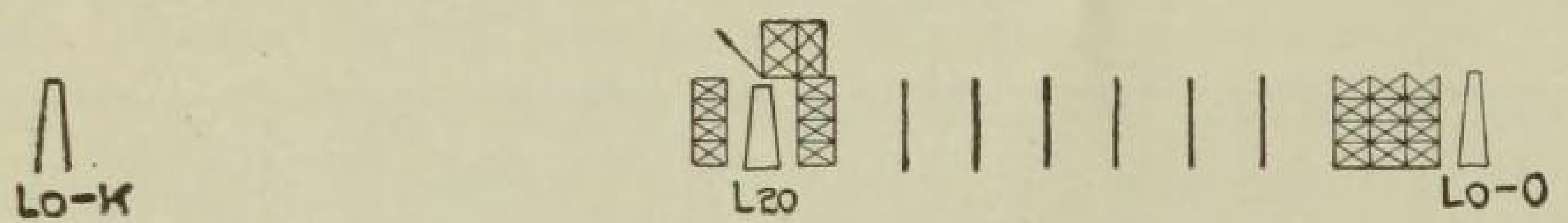
The steps required in the specially difficult problem of erecting the middle four panels are indicated diagrammatically in Fig. 4. For every practical method of procedure in erecting the four panels, extensive computations had been made to determine the position of each member, the amount that the holes would be out of match at every point, and the forces required to bring the holes true.

Owing to the comparatively large changes in length of these members for camber, and the fact that the main members were so stiff that driftpins would not bring the holes to match, the problem was to erect in such an order and in such manner that the holes would match when the member was first put in place. This was accomplished in simple and economical manner, the striking erection features of the method being as follows:

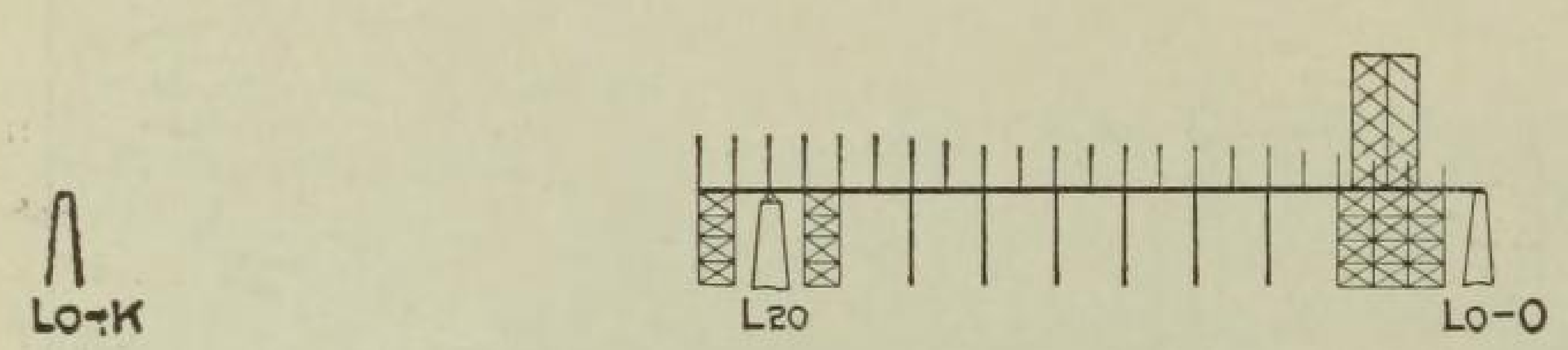
The lower chord was jacked into a decided curve (See Stage II, Fig. 4), with both L18 points 1¼ in. higher than L20, by wedge jacks supported on the timber falsework at 18K. Two 200-ton jacks (as shown in Fig. 9 of the preceding article, *Engineering News-Record* of Jan. 10, 1918, p. 64), were used, since the total load to come on this point was about 600,000 lb. They were operated by a ratchet with 6-ft. handles pulled by a 2-in. runner line of the traveler. This jacking brought the unreamed holes in the subhangers at both L19 points ⅝ in. above the holes of the chord, but the holes came fair with the completion of the trusses and the simultaneous straightening of the lower chord.



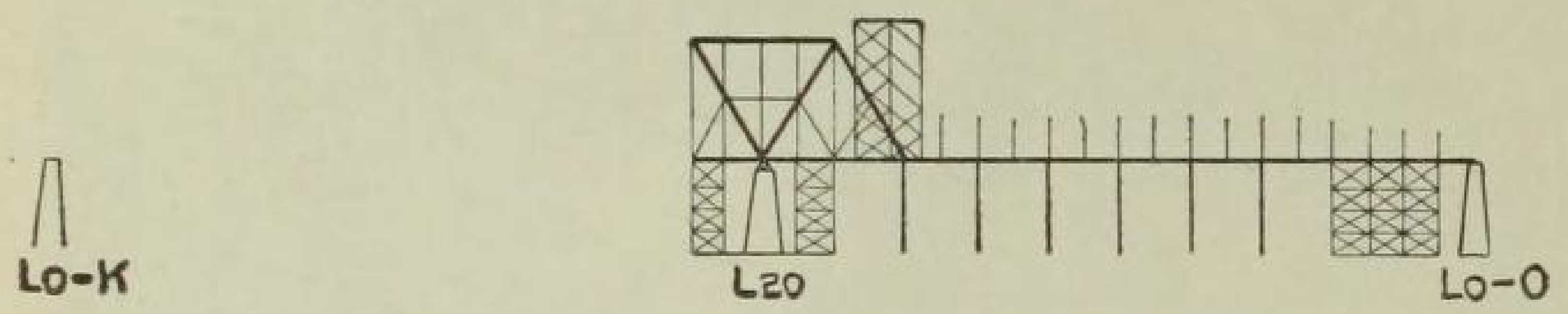
A—Gantry raised to 60-ft. height on timber falsework.



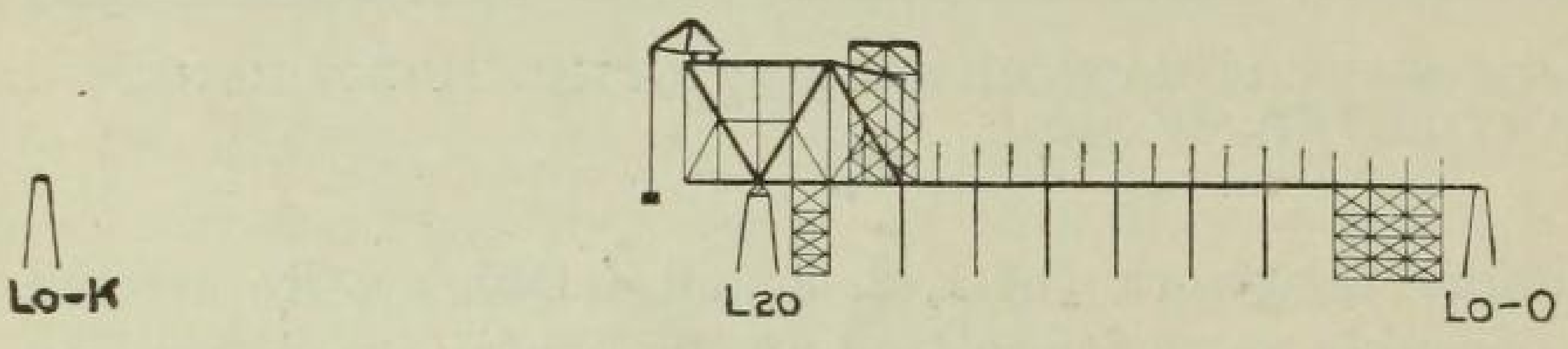
B—Falsework and floor erected to 18K; floor 6 in. toward Ohio end.



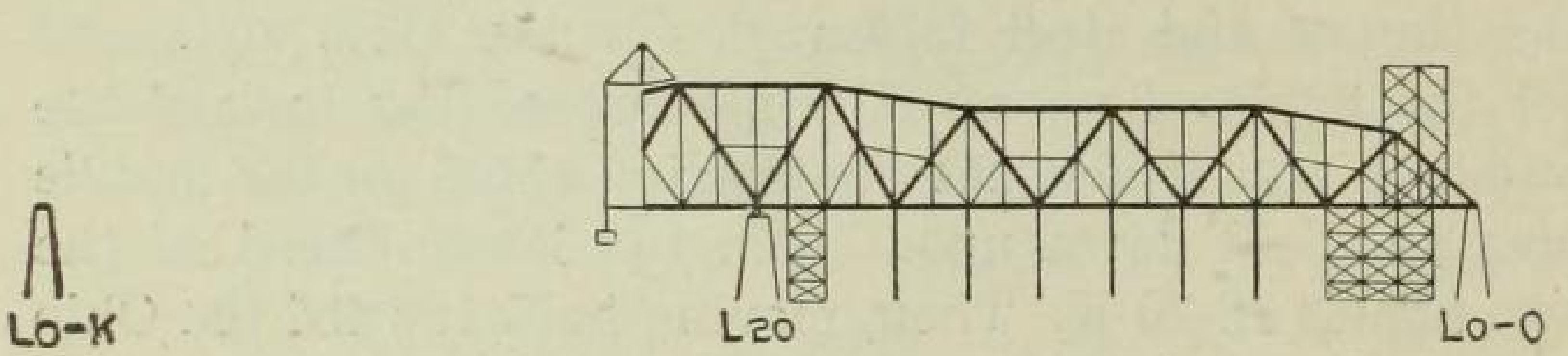
C—Chord erected to Ohio end, splices riveted when level and straight. Floor moved 6 in. to final position. Gantry raised to 150-ft. final height. Chord jacked to initial curve.



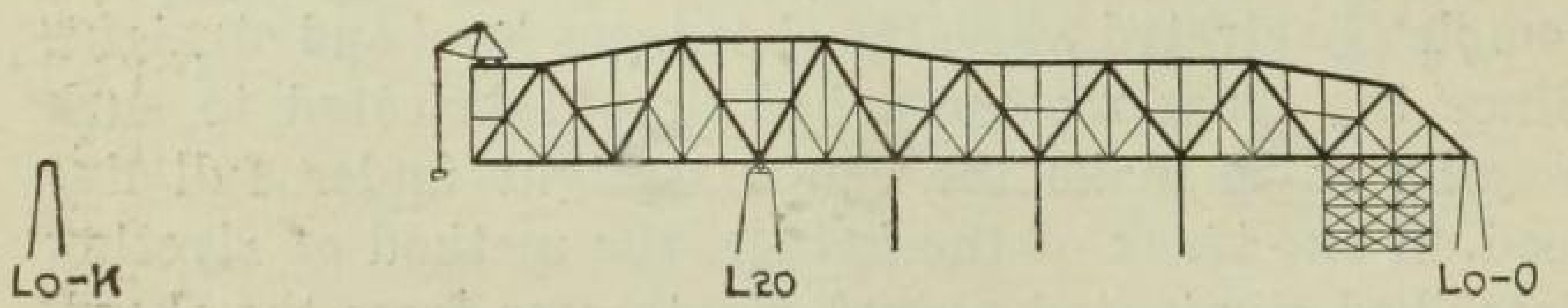
D—Middle four panels completed; timber towers at 18K and 19K released. Ohio span supported on steel tower at panel-point 16.



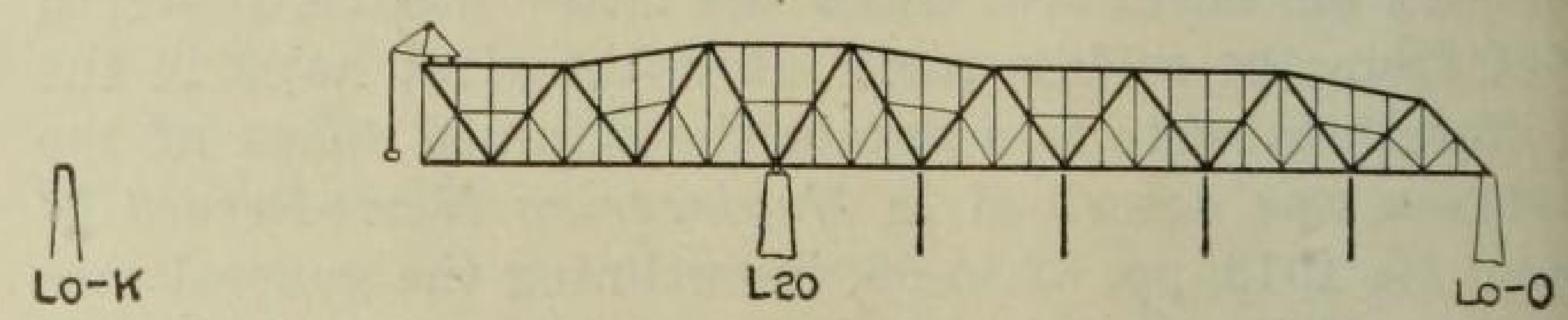
E—Truss completed to 16 Ohio. Creeper traveler erected on top chord. Towers at 18K and 19K removed.



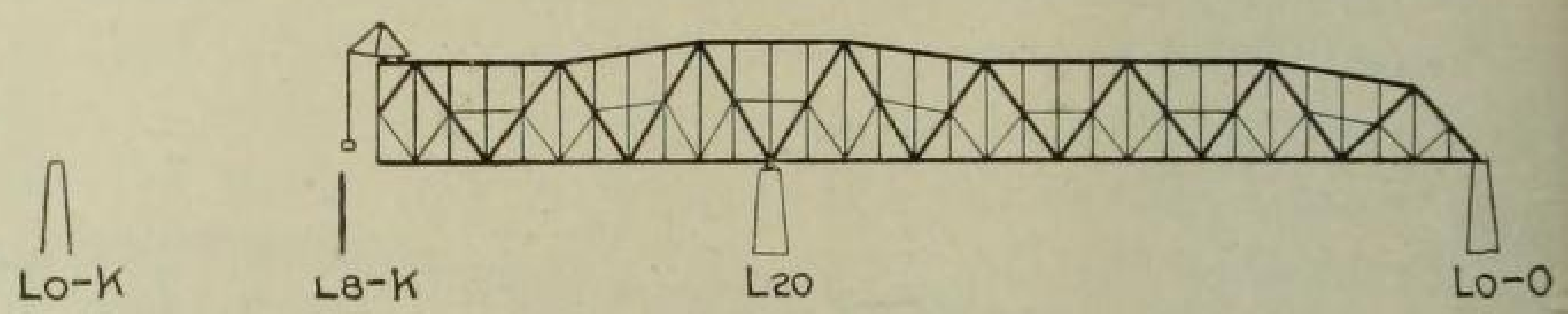
F—One panel of cantilever erected. Ohio span erected complete on falsework; Ohio end 8¼ in. low.



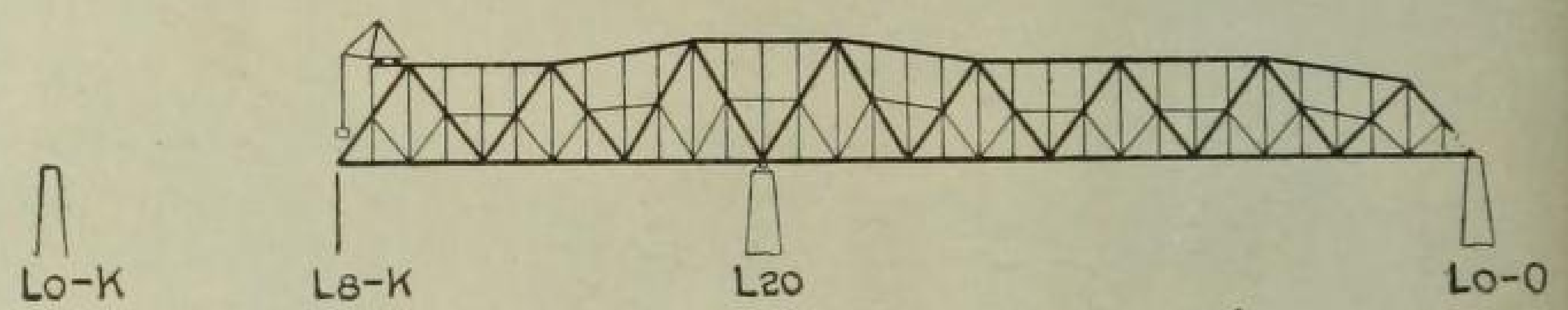
G—Gantry traveler taken down; Kentucky cantilever continued; timber falsework removed, starting at middle pier; load released from steel tower at 16 Ohio.



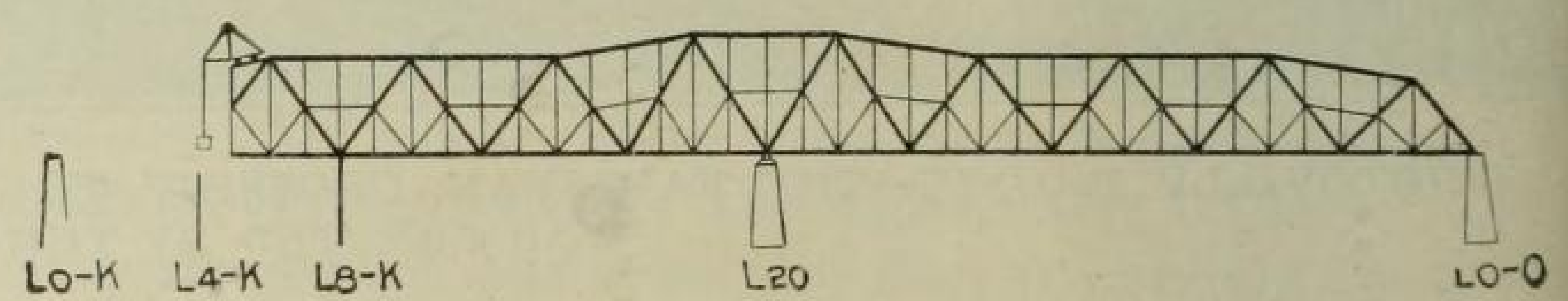
H—Kentucky cantilever erected to 10K; Ohio span swung by jacking end 8¼ in. up and placing permanent rockers.



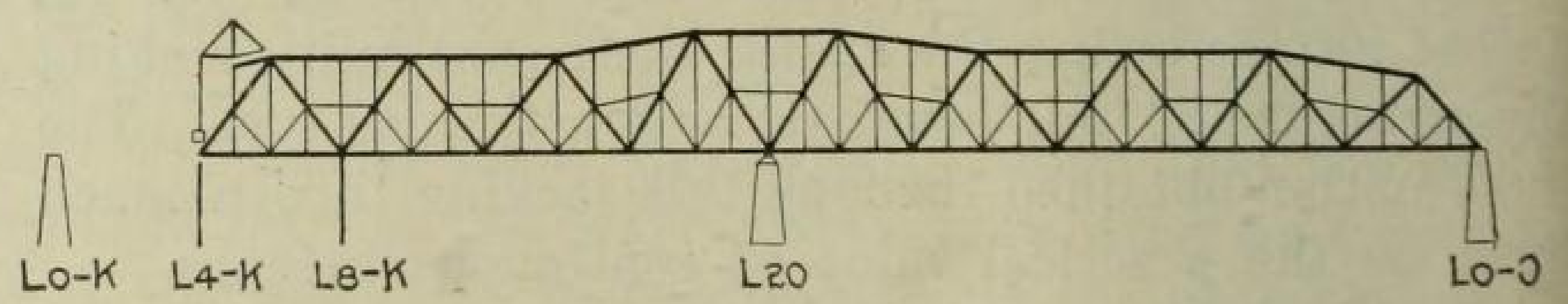
I—Cantilever erected to panel-point 9K; steel tower erected at 8K by creeper traveler.



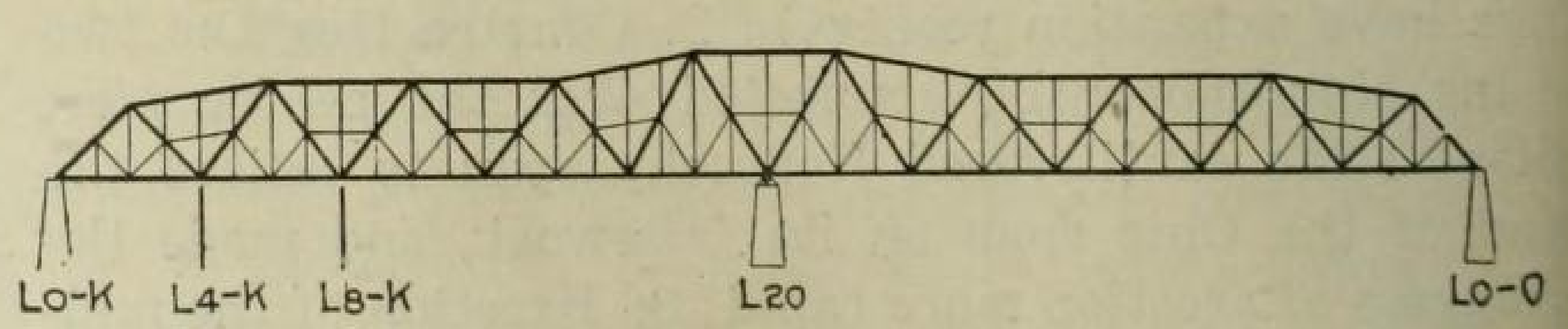
J—Erection continued to 8K and truss jacked up on tower.



K—Erection continued, and second steel tower erected at 4K.



L—Cantilever extended to 4K and jacked up on tower there.



M—Bridge erected complete. Kentucky end 16 in. low. Kentucky span swung by jacking end 16 in. up, placing permanent rockers; steel falsework towers at 4 and 8K removed and creeper dismantled.

FIG 1. SCIOTOVILLE BRIDGE ERECTION PROCEDURE SUMMARIZED BY DIAGRAMS OF THIRTEEN STAGES

When the upper ends of the diagonals M19 U18 were placed (Stages II and IV, Fig. 4) the holes in the diagonal at U18 were 1¼ in. above those in the vertical at that point. These members were held in the falls until rivets enough were driven in the outer rows of holes at M19 to take care of the bending moment at those points when the diagonals were slacked to make the holes in the posts at U18. The delay was about two days in each of these cases. A decided curve was visible in the long diagonals after the upper ends were lowered to connect.

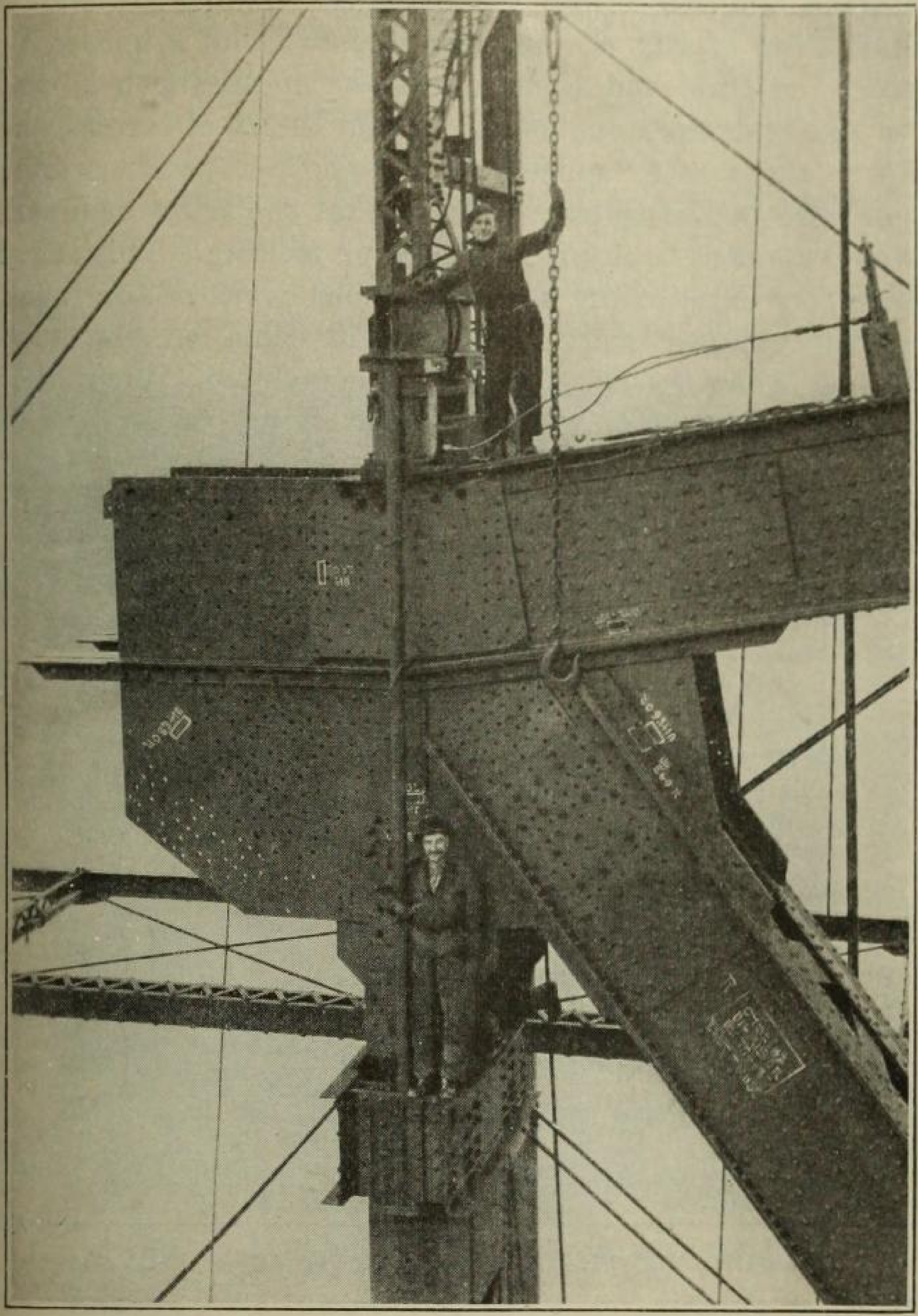


FIG. 2. FORCING THE HANGER AT U14K TO CONNECTION WITH TOP CHORD BY SPECIAL JACKING-YOKE

When the top chords U18 U20 were set (see stages III and V, Fig. 4), the U20 ends were held on 2-in. shims until sufficient rivets were driven in the outer rows of the main diagonal and chord at U18 to take care of the bending moment at that point when the chord was slacked to contact with the posts at U19 and U20. This involved practically no loss of time; while the Kentucky top chord was being riveted, the gantry was moved and some members of the adjacent panels on the Ohio side of L20 were set, and while the Ohio chord was being riveted the bracing was erected. After both U18 points were riveted, the 2-in. shims were removed and the chord was lowered to contact with the posts at U19 and U20. But now the two chords were ⅜ in. apart at U20 and were not tangent (Stage VI, Fig. 4).

In order to close the ⅜-in. gap two large turnbuckles were placed across and turned with long crowbars (Stage VII, Fig. 4). The vertical at L18 U18 O was cut loose from the gusset at U18 O, and the load falls nearest U18 O on the top chord were given a good strain. This closed the gap at U20, but made another gap at U18, and still left the chords not tangent at U20. To bring them tangent, the U19 posts were bolted to the chords, the U20 ends raised (singly, on account of the large force required), and ¾-in. shims were placed under the chords at U20. With these shims in place sufficient of the outer rows of holes in the U20 splice were riveted to take care of the bending moment that would occur at U20 upon removing the ¾-in. shims. To remove these shims the U19 bolts were loosened and the falls at U20 given a strong pull.

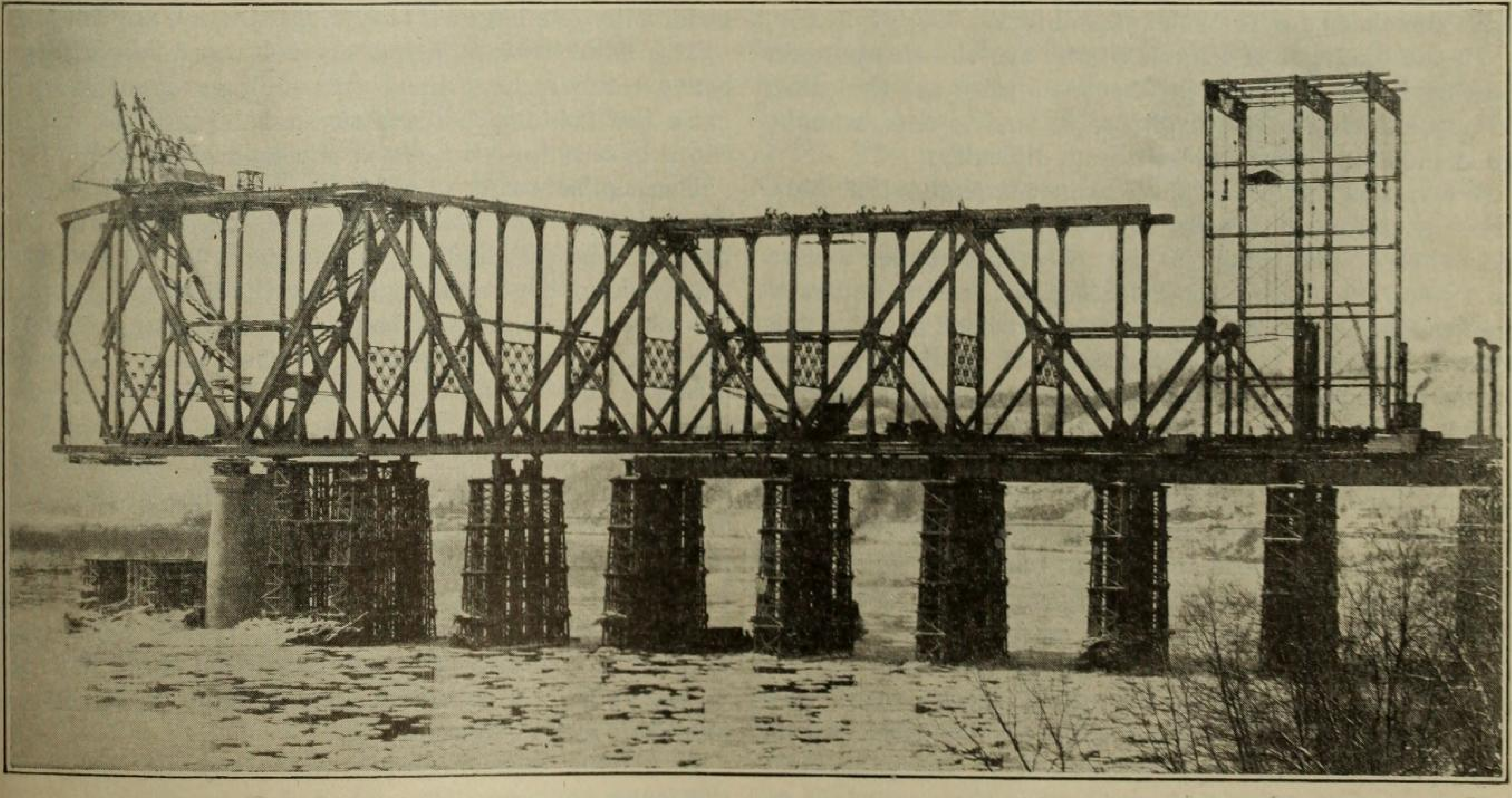


FIG. 3. IN ERECTING THE OHIO SPAN THE WOODEN TOWERS AT INTERMEDIATE PANEL-POINTS WERE RELEASED AS EARLY AS POSSIBLE TO REDUCE DANGER FROM ICE IN FLOOD TIME

Computation had been made and a jacking device built for closing the ¼-in. gap at U18; the force required was 304,000 lb. But, because L18 U18 was much lighter than the members of the main triangle L20 U18 O U18 K, the post lengthened much more rapidly than the main members when the sun first shone upon the structure in the morning, and it was found that the gap closed and the rivets could be driven without any jacking.

When the four panels were riveted complete the top chord at U20 was not in contact with the post by ¼ in. (Stage VIII, Fig. 4). This gap closed as erection of the trusses proceeded and the chords became more nearly straight.

The middle four panels formed a unit that was almost balanced on the middle pier. The load was therefore released from the timber tower at L18 K by slacking the wedge jacks at that point, keeping them just in contact with the chord for the sake of stability.

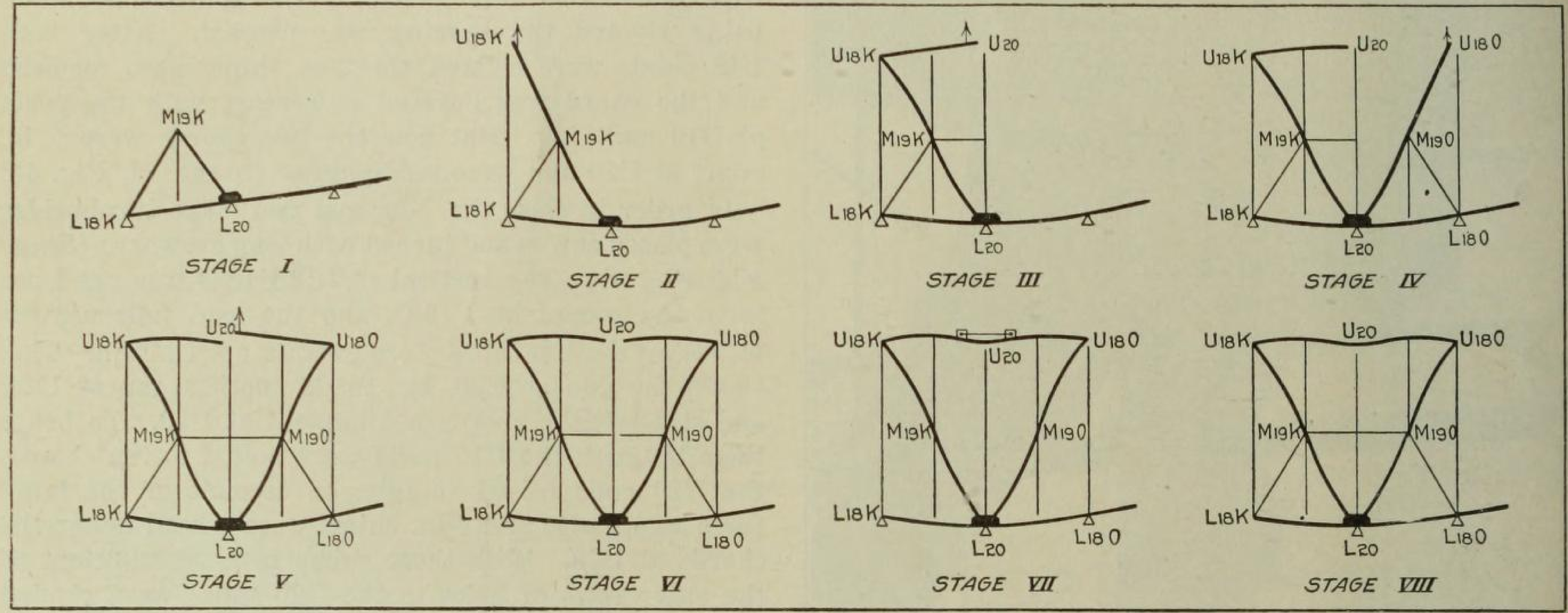


FIG. 4. ORDER OF PROCEDURE TO CONNECT THE HEAVY MEMBERS OF THE CENTRAL TRIANGLE IN THE DESIRED DISTORTED SHAPE

In the diagram of Fig. 4, curves are shown for main members only, as the light members were not the cause of any concern; a few driftpins in their joints brought good holes in every case without difficulty.

When the middle triangle was completed the main truss system was erected to 16 O, where it was supported on a steel tower (D, Fig. 1). The timber towers at 18 and 19 O were not released, but on the contrary the wedge jacks at those points were raised to put a full load on each one; in this way some of the load was released from the steel tower at 16 O, merely as a precaution, not as a necessity.

At this time the creeper traveler was erected on the top chord between U20 and U18 K (E, Fig. 1). It was intended to erect about one Kentucky panel for every two panels of the Ohio span. But when only one panel, 18-17 K, had been erected, the shortage of men and the proximity of winter, with attending danger to falsework from ice, led to the decision to push the Ohio span to completion, postponing work on the Kentucky span. The ice danger also led to removing the timber falsework as rapidly as the truss erection permitted, since the steel towers at 4, 8, 12 and 16 were more than sufficient to carry the weight of the Ohio span. With 150-ft. openings thus left between steel towers, the ice would be unlikely to jam and cause trouble.

As already mentioned, the bottom chord was freed of secondary stresses by riveting its splices while it was straight and level. Its curves before truss erection was started and after the Ohio span was erected are shown at the top of Fig. 6. It being the original intention to erect the Ohio and Kentucky spans simultaneously and to take only the unbalanced load on the steel towers, the lower chord after splice riveting and before truss erection was jacked to such a curve that the truss members would connect to it without further jacking. This curve was very close to the no-load camber curve of the truss, so that almost equal loads would come on the steel towers when the Ohio truss was completed. Very little jacking was necessary as the erection proceeded. Point L16 was purposely left lower than the no-load camber curve to relieve the lighter steel tower at that point, and reduce the tension in U14 U18 O.

The Ohio trusses being erected on falsework to a heavy camber curve there was an easy opportunity to raise the free end of each two-panel length of the top chord to obtain good holes at the connecting end.

From panel-point 18 to 4, the four diagonals sloping down toward the Ohio end were straight when connected. The diagonals sloping up from 16, 12, 8 and 4 O were held at the middle points by the horizontal struts; the struts were of such lengths as to bring good holes at the lower ends and to hold the diagonals straight when the upper sections were connected to the top chords. The upper parts of the same diagonals were well pinned and bolted to the lower sections, as they had to hang free while the top chords were being erected. When these diagonals were pulled up to connect to the top chords with the falls (shown in Fig. 17, p. 67, Jan. 10) the long verticals did not make holes with the top-chord gusset plates. These holes were brought to match by raising the bottom chord with the wedge jacks, which operation put slight bends in the diagonals and top chords.

In placing the end post in one piece and connecting the lower end first, the camber of the lower chord held the U2 end of the batter post about 1½ in. too high for good holes. Bolts and 30 or 40 driftpins served to bring the holes to match.

The Ohio span alone did not become self-supporting until the Kentucky cantilever was completed to about 15K. At about this stage the U14 U18 top chord of the Ohio span became the critical or highest-stressed member, owing to the cantilever load and to the 1,000,000-lb. reaction still on the steel tower at L16 O. The load on the steel tower was therefore released by placing four 200-ton hydraulic jacks under either truss and removing some of the shims. The releasing of this load lowered the chord only $\frac{5}{16}$ in. at L16 O.

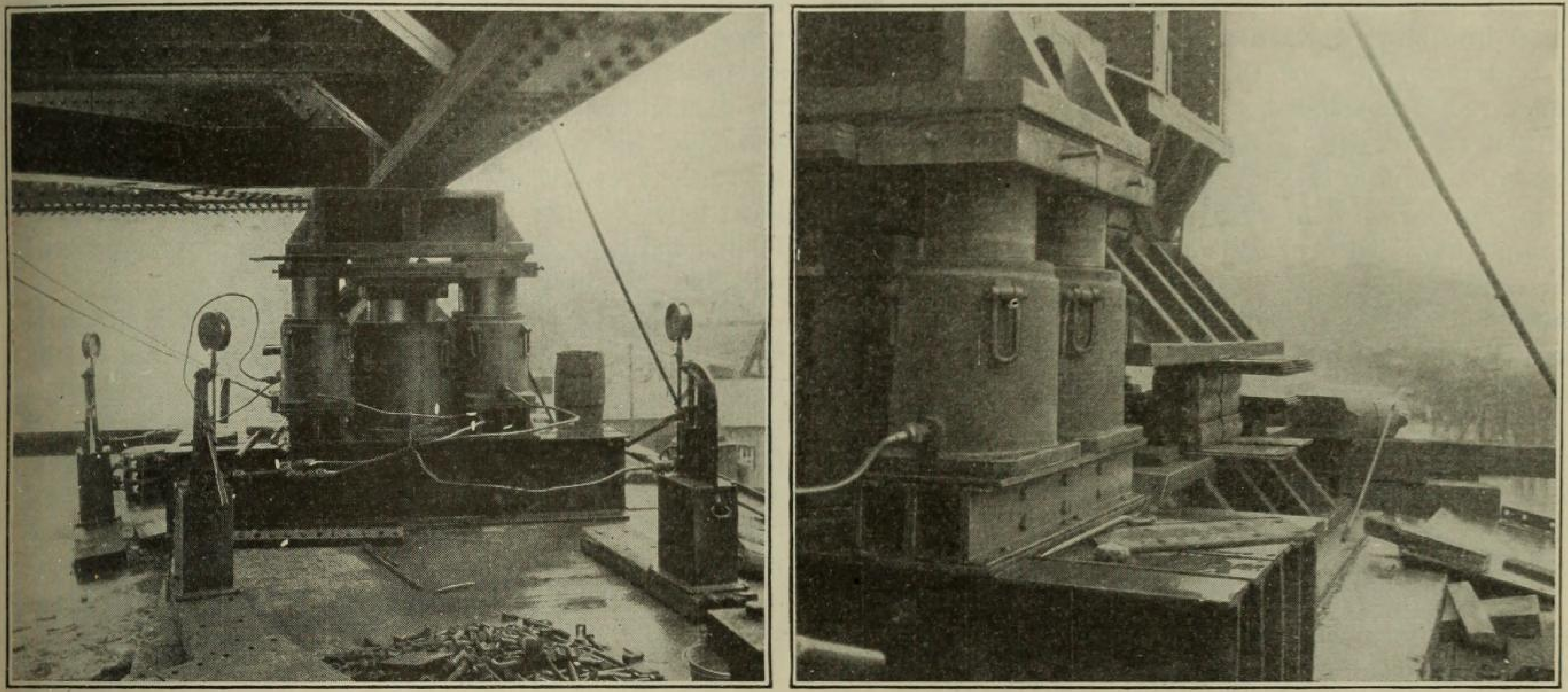


FIG. 5. JACKING THE OHIO END OF THE BRIDGE; SHIMS UNDER SHOE TO HEIGHT OF 16 INCHES

During the Kentucky cantilever erection it was necessary to rivet the horizontal struts such as M15 M17 in order to make a complete truss system on which to carry the creeper traveler. When the main truss system of the next panel of the bridge was connected the subhorizontal was no longer needed. One end of one of the struts was cut loose and left resting on shelf angles at the time of jacking the vertical to good holes at points such as U14; this jacking relieved the stress in the horizontal strut and allowed the rivets to be cut out. Leaving the struts connected would have put redundant members in the bridge. The jacking device used to connect simultaneously the long subhangers and disconnect the horizontal struts is shown in Fig. 2, a small reproduction of the cover picture of the Dec. 13, 1917, issue of *Engineering News-Record.* It consisted of two yokes, two 3½-in. special-steel rods and two 200-ton hydraulic jacks.

When the Kentucky cantilever was completed to 10K (Stage H, Fig. 1) the Ohio span was swung. The Ohio end was raised 8¼ in. by jacking under the end floorbeam (See views Fig. 5). The nest of 20-in. I-beams on the pier rested on a cushion of roofing paper; on the beams was placed a bolster which accommodated a 500-ton jack in the center and brought four 200-ton jacks to the level of the larger jack. A special casting was used to transfer the jacking force to the floorbeam.

Increments to the jacking load were comparatively large—200 tons per inch—until the truss was raised free from the tower at 4 O. The lift-load curve is given in the right half of Fig. 8. As there shown, the increments decreased as the span lifted off its successive supports. Tower 8 went free just before the end was high enough to place the 16-in. rockers under the shoes. In order to free the tower at 12, the end was jacked 4 in. above the height required for the rockers. The original scheme of erection provided for Tower 12 being taken out before this stage, but jacking the extra 4 in. was a simple means of removing it at this time.

During the jacking the lift was followed up with shims (Fig. 5) of ½-in. steel plates, the same number being kept under both trusses. When there was sufficient space the shim plates were removed and rockers from the 150-ft. deck span substituted; with the plates a foot or more high, several inches of the jacking would be lost in slacking the jacks, as had to be done for placing shims on top of the jacks.

The jacking time for raising about 12 in. and lowering 4 in. totaled seven hours for 24 men. Another day was consumed in setting up and removing the jacking rigging, setting the shoes accurately and placing the rockers. During the jacking the lower chord stretched 1¼ in. The deflection curve for Ohio span swung and Kentucky cantilever completed to 9 is shown in Fig. 6.

In placing the bottom-chord sections, the splice at the rear end of each section was made before connecting the web members. The splice joint was held in perfect match by resting the front end of the chord section on jacks on the flying bridge of the creeper traveler. This eliminated bottom-chord secondaries.

The diagonals sloping down toward the Kentucky end between 18 and 4 went in place practically straight, and had good holes at the end when only a few pins were driven. The diagonals sloping up from 16, 12, and 4 K were held at the middle points by the horizontal struts. These struts were of such a length as to make the diagonal holes match those of the bottom-chord gusset plates. The upper parts of these diagonals connected with good holes to the top chords, and the diagonals were straight when connections were made. However, in some of the top-chord splices a few driftpins had to be driven before the splice came into match, as the outer ends of these chord sections were held a trifle too high by the posts.

At U14, 10, 6 and 2K the vertical hangers were too low to connect. The jacking device shown in Fig. 2 was used in these four cases, the two trusses being jacked simultaneously.

With respect to setting the batter post, the same conditions existed as at the Ohio end.

Keeping the bottom chord of the cantilever in line was a rather difficult matter, partly because the downstream lower chord was shielded from the sun in the morning. The expansion of the upstream chord at times moved the end of the cantilever 2½ in. downstream from a straight line. Haze often obscured both backsights and foresights. The center-line marks on several floorbeams were clearly visible at the same time from the instrument set up under the center floorbeam. Each center-line mark toward the end of the cantilever was off center a little more than the preceding one. In setting a section of chord, the floorbeam, with center line marked on its bottom flange, was placed between the chords of the two trusses. It was then set downstream from the mark on the floorbeam set just previously by an amount a little greater than the distance between that mark and the preceding one. On hazy days the center-line marks were used as foresights, and on cloudy days the center-line marks were found to be truly on line.

When the bridge was landed on Tower 8 K it was downstream about 1½ in., from the effect of the sun. It was easily brought to line with two 50-ton Norton jacks placed in the temporary shoes immediately under the chords.

To bring the free end of the bottom chord to correct level, an instrument could not be used conveniently, as the chord already in place was curved. It was sighted by eye and a check taken on it by examining the holes in the chord splice. The free end of the chord was raised or lowered by two 50-ton Norton jacks on the flying bridge suspended from the creeper traveler.

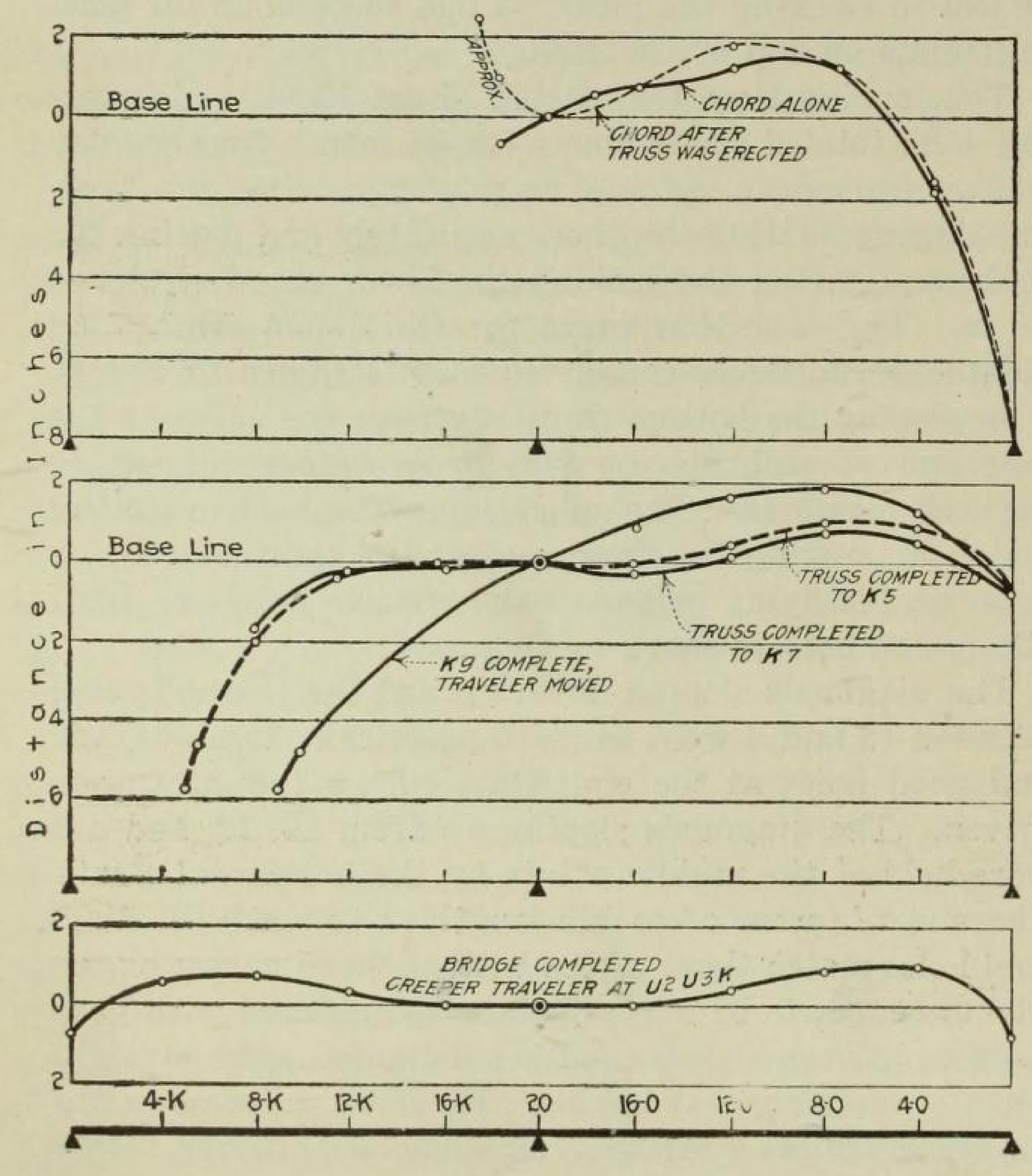


FIG. 6. DEFLECTION CURVES AT DIFFERENT ERECTION STAGES

When the cantilever was completed to 9 K, the steel tower formerly used at 12 O was taken across the river and erected at 8 K by the creeper. The truss was then extended to 8 to rest on the tower (I and J, Fig. 1).

Upon reaching the steel tower at 8 K the intention was to measure the deflection of the free end of the cantilever before jacking at that point, in order to compare actual with computed results and determine better the proper distance to raise the end of the cantilever. Instead, the following procedure was followed: Shims were put on top of the shoes on the columns, of such thickness that when the bottom-chord sections were entered at L9 and supported on the shims good holes would result at L9. The L9 splice was well pinned and bolted, so that when the diagonal L8 M9 was brought to L9 on the trucks the deflection from its weight would be resisted by the bending of the lower chord. The shims made the free end of the chord about ¼ in. too high for good holes for the diagonal, but a few driftpins easily made good holes and left the end of the truss supported on the steel tower (View C, Fig. 7).

In order to determine what the deflection at 8 would have been if unsupported, that point was raised by the hydraulic jacks and corresponding distances and loads plotted for five positions. The truss was jacked up twice, readings taken for jacking up and slacking down, and the average of the four sets of readings used. The actual deflection would have been 8.62 in.; that computed without considering the effect of truss details was 9.14 in., and that computed with allowance of 20% for the effect of details 6.35 inches.

The truss was raised 7⅜ in. with a force of 462,000 lb. per truss (±25 tons for probable error). The computed jacking height was 7.9 in. when no allowance was made for truss details, and 6.52 in, when 20% allowance was made, the load in both cases being 430,000 lb. per truss. This jacking reduced the stress in U14 U18 K so that its capacity would not be exceeded during the erection of the rest of the bridge.

Erection of the trusses was continued to 5 K (K, Fig. 1, and View D, Fig. 7), and thereupon the second steel tower was placed at 4 K. The lower part of the truss was completed in the same way as at 8 K, but the deflection was read with the truss unsupported. The actual jacking height was 1 in. with a force of 384,000 ± 50,000 lb. per truss. The computed jacking was 1.42 in. with a force of 470,000 lb. (no allowance for details) or 1.02 in. for 425,000 lb. (20% allowance). Results indicated that a 10% allowance for truss details would be correct.

Erection was now completed to the end of the bridge. The view opposite shows the bridge completed to 2 K. The bottom-chord section L0 L1 K was landed on 200-ton wedge jacks on the pier. Therefore no accurate reading of the deflection of that point hanging free was obtained, but 16 in. to 16½ in. is probably what it would have been.

The same jacking outfit as shown in Fig. 5 was used under the Kentucky end floorbeam. Curves of actual and anticipated jacking are given in Fig. 8. As shown, the actual jacking corresponded very closely to the computed values for 10% allowance for truss details. An

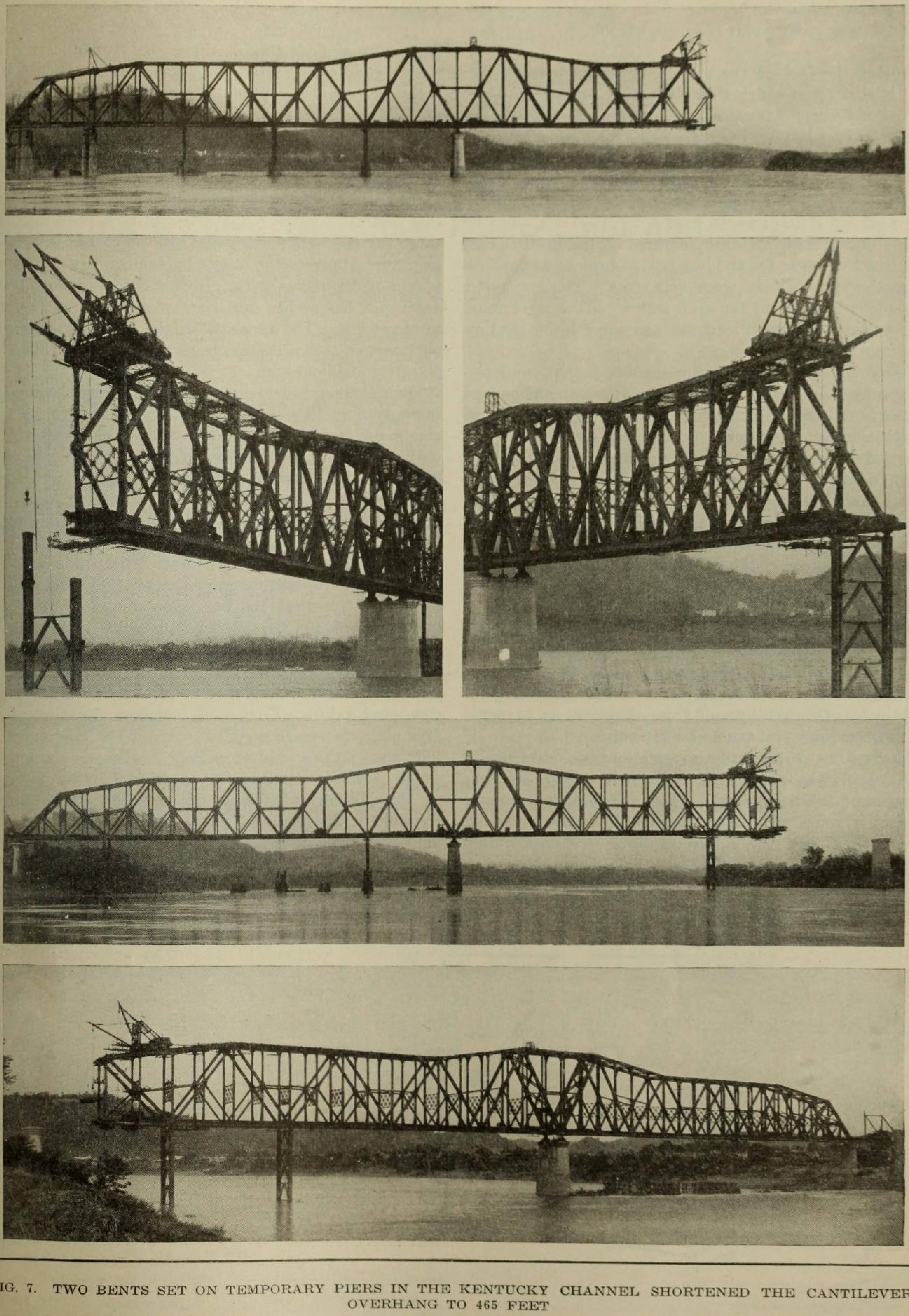


FIG. 7. TWO BENTS SET ON TEMPORARY PIERS IN THE KENTUCKY CHANNEL SHORTENED THE CANTILEVER OVERHANG TO 465 FEET

A—Erection to panel-point 9 completed Apr. 13, 1917. B—Six days later, creeper at 9 sets steel bent. C—Bridge resting on completed bent at point 8. D—May 9, nearing the location of the second bent. E—Bent at point 4 in service May 23, 1917. Two panels still to be erected.

allowance of 4% for friction was made from the start to the stage when the tower at 8 was freed, because the jacking was continuous for all except the first few inches.

During the jacking the bottom chord stretched 1¼ in. The lateral force which this stretching brought to bear on the jacks was sufficient to slide the nest of I-beams on the pier. Between the nest and pier was ½ in. of roofing paper, which was softened by the warm weather.

The curve of the bottom chord of the bridge after L0 K was jacked and before the creeper was removed from U2 U3 K is given in Fig. 6.

One of the most striking features of the entire erection was the curve for the last few inches of the jacking after the steel towers were both free. The computed increment to the load for each inch of lift was 7½ tons. The actual increase in load was too small to be read on the gages.

It is quite evident from this condition that for long-span continuous trusses it is not as vital a point as was formerly thought to be the case to have the supports at exactly correct elevations. In this case an error in setting one of the end supports, say as much as 3 in., would have changed the end reaction 22.5 tons, or the stress in the end post 32 tons, which would be less than the probable error in computing the actual stress in that member. The worst conditions of shop work, erection and setting shoes could not possibly total more than 1 in., so that the certainty of stresses and therefore the safety of such a bridge is left without question.

The fact that complications enter into the design and erection cannot bar the use of such bridges as long as they are economical. The reasons usually given, that the stresses are not statically determinate and that uncertainties of stresses result from slight errors in elevation of the supports, are no longer valid.

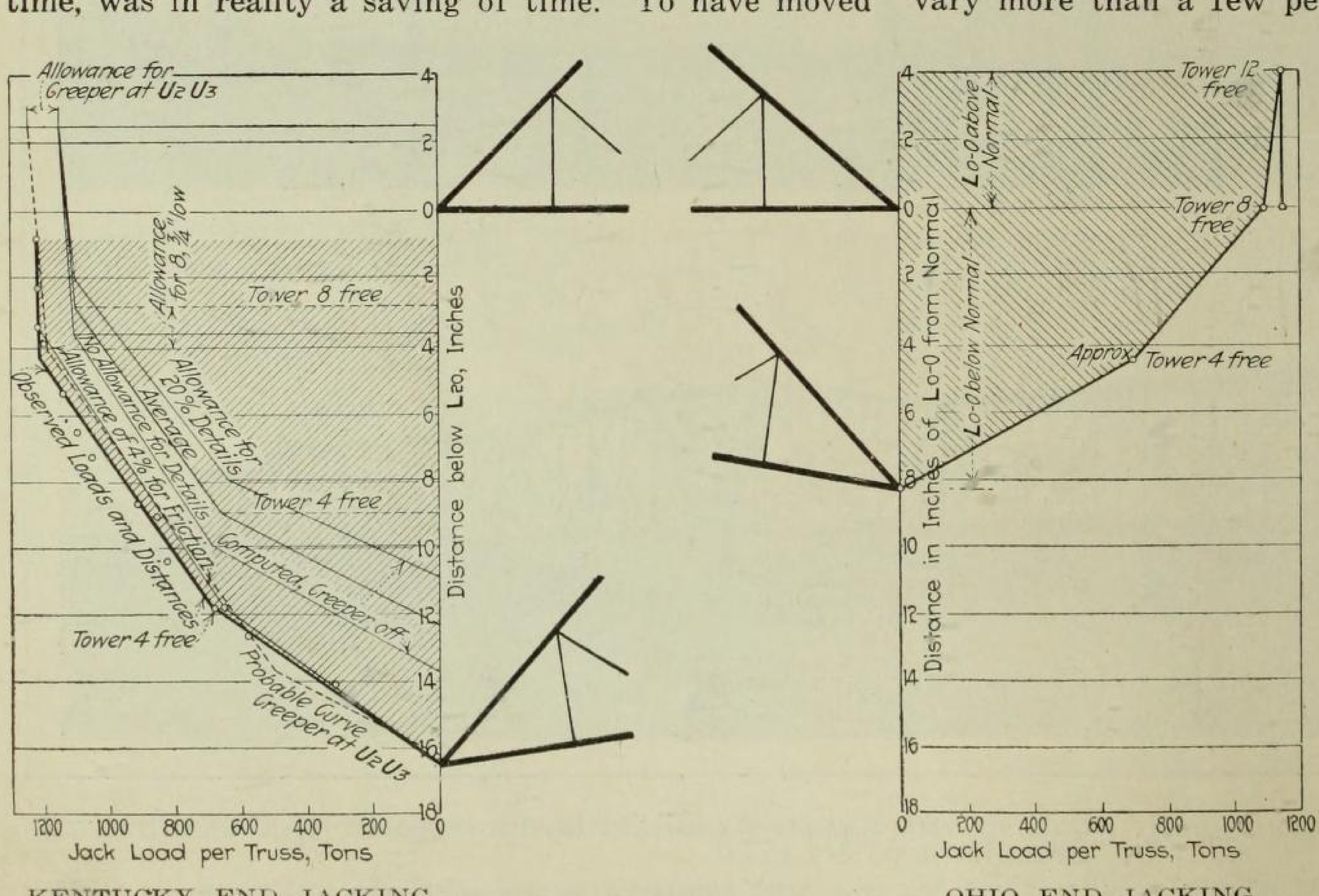
Throughout the cantilever erection the riveting in each panel was practically completed before starting erection of the next panel. This, although it appeared at first, from a superficial standpoint, to be a loss of time, was in reality a saving of time. To have moved ahead with the erection would have necessitated driving a great many driftpins more than for simply fitting up for riveting, and under stress it would have been very difficult to remove these. Since the riveting could not have lagged more than a few panels behind the erection, the most rapid completion of the bridge was accomplished by the least work. Under the conditions, scaffolds were hung from the creeper to the correct position for riveting top and bottom-chord splices and bottom lateral bracing.

In addition to completing the bridge more rapidly, this method greatly reduced the cost of riveting. The safety of the entire work was also increased greatly—a very important factor, since bridgemen are in general afraid of cantilever work. In this case, probably 100 or more quit before the cantilever was landed on the steel tower at 8 K. The apparent safety was of as much importance as actual safety, because it was so difficult to obtain or to hold men.

Several thousand 1¼-in. rivets were driven, some having a grip up to 9⅞ in. It was very difficult to get good rivets, owing to the large number of thicknesses of steel with every surface heavily coated with red lead. Although the joints were well bolted, the paint would melt and burn out to such an extent that in some joints half the rivets would be loose. The air pressure was raised to 135 lb. per sq.in., as lower pressures did not always bring the head into solid contact with the plate. No accurate records were kept of the relative costs of 1-in., 1⅛-in. and 1¼-in. rivets, but it became clear that sizes over 1 in. should be avoided if possible on account of their very high cost.

A most remarkable feature of the erection was the fact that actual results corresponded so closely with the computed values. Curves of members, location of the free ends, forces required to connect the free ends, deflections, jacking distances and loads, were computed under the direction of P. L. Wolfel, chief engineer of the McClintic-Marshall Co., for the entire bridge. In only three cases did the openings at the free ends vary more than a few per cent. from those computed. These cases were the connection of the diagonal L4 M3 O to the horizontal strut M4 M3, the connection of the long hanger at U14 K, and the connection at U2 K. These differences were due probably to changes made in the method of erection, and to having raised L8 and L4 K less than was intended.

The curve of the lower chord of the Ohio span was computed so that every member connecting to it would have holes matching without further jacking. The holes matched as desired except at two points, and the jacking of these points was negligible.



KENTUCKY END JACKING

OHIO END JACKING

FIG. 8. CURVES SHOWING LIFT AND LOAD WHILE JACKING UP ENDS

here, but what will become of it after that only some of our stevedores may know for a while and promptly forget. When so many important things are demanding the best efforts of our engineers the pastime of organizing searching parties to ferret out missing equipment is one which is not popular over here.

All of the machine tools at the new railway repair shops, as well as the big overhead cranes, have individual electric-motor drives. The type of building constructed as shown in Fig. 4, was one ill adapted to the use of shafting and pulleys, on account of the height of the roof. Then, too, a big electric central-station development which the American Expeditionary Forces are completing at a distance of not many miles, makes available by means of a newly-built transmission line sufficient electric power for running the plant. Pending the delivery of this power, however, a temporary plant of steam-driven electric generator units was erected at one end of the shops and has been in service for some time.

A great deal of difficulty has been experienced in obtaining flooring material for the shops. Lumber is hard to get, but this difficulty is being met by employing for the flooring wood obtained from the packing cases in which the machine tools were shipped.

As to the layout of the shops, Fig. 5 shows the location of the various machine tools in the machine shop, while Fig. 6 is a plan of the forge and spring shop. There have been a few changes from the original plans, due to the nonarrival of certain machines and the receipt of others different in size from those expected. The scheme of individual electric drive for each unit, however, offers a considerable amount of flexibility in locating the machine tools, and changes from one place to another have not involved serious difficulty.

Erection Experiences at the Sciotoville Bridge

Machines Used Found Efficient—Adjustment of Bridge Easy—Deflections Agreed With Computed Values—Last of Three Articles on the Field Work

By Clyde B. Pyle
Manager of Erection, McClintic-Marshall Co., Pittsburgh

SUCCESS in erecting the Ohio River bridge at Sciotoville brought with it a number of experiences having application to large bridge work, especially continuous-span construction. On account of the magnitude of the work—the structure has two spans of 775 ft. each, continuous over the middle pier, with riveted connections throughout—and the new problems which arose from connecting the members in strained condition to eliminate secondary stresses, some of the conclusions drawn from the erection may be useful to the engineering profession.

First, notice is due the fact that the suitability and good service of the erection machines were important factors in the success of the work. The sequence of operations, described in *Engineering News-Record* of Jan. 10, 1918, page 62, and Jan. 31, page 219, made rapid and smooth progress a vital matter. Any long interruption of the construction work might have exposed the bridge to risk of destruction by flood. That the machines chosen turned out to be highly reliable and efficient was a most important and gratifying experience.

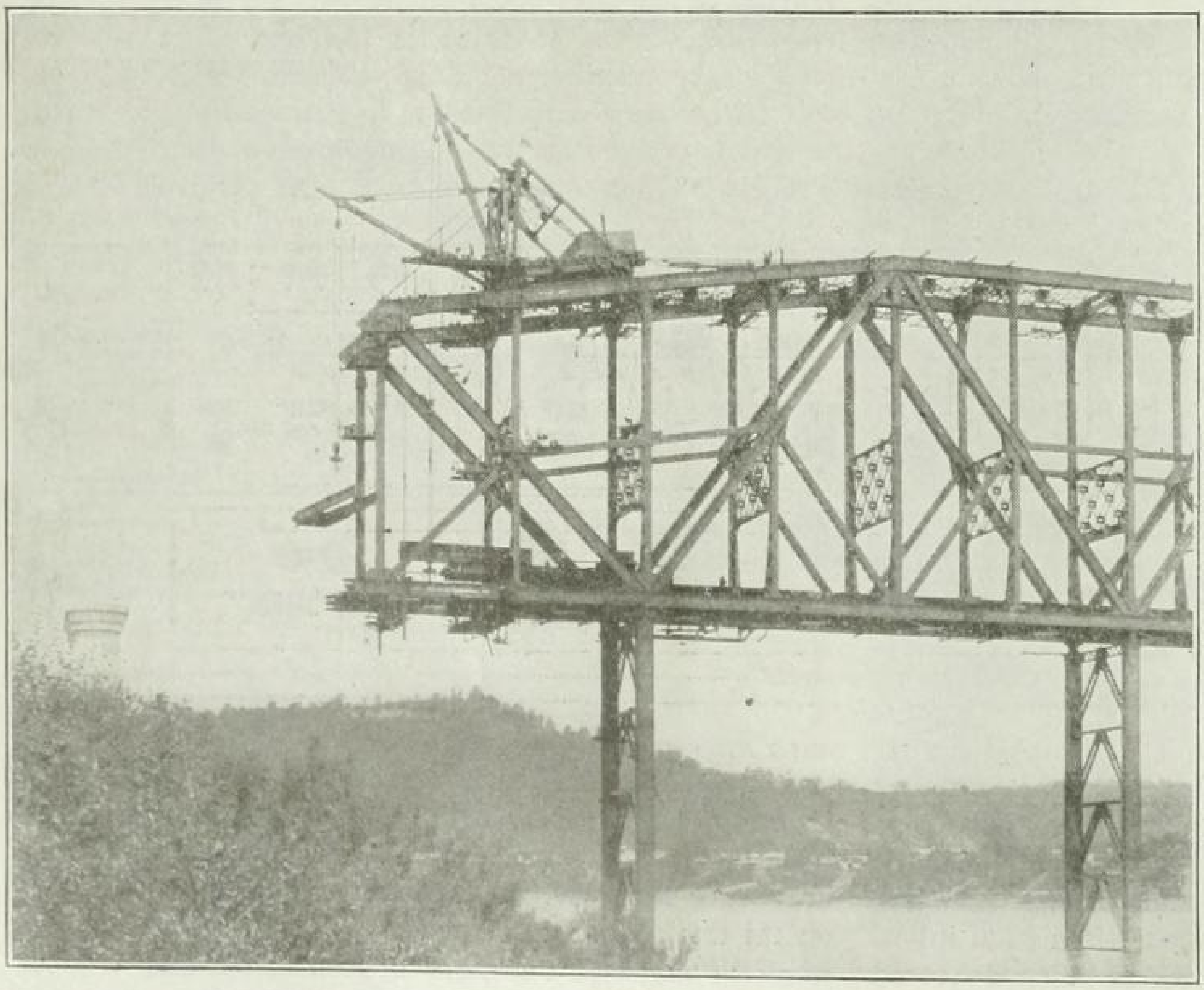


FIG. 1. TWO BOOMS ON CREEPER TRAVELER SPEEDED UP THE SCIOTOVILLE BRIDGE ERECTION

Different machines were used for the erection on falsework (Ohio span) and the cantilever work (Kentucky span), as previously described. Sketches of both machines are shown herewith (Figs. 2 and 5). The following briefly states the reasons which led to the choice of these particular devices.

Several points have to be considered in choosing bridge erection equipment: Simplicity, speed of operation, safety, low cost of construction and transportation, and ease of setting up and getting ready for work. In addition, of course, the loads to be handled and the required reach must be taken into account. Machines that leave the supply tracks unobstructed and that do not have to run off the bridge frequently save time. In respect to all these requirements the machines selected are of high rank.

A gantry traveler running on tracks outside the bridge trusses was used for erecting the Ohio span on falsework because it is a simple tool to operate, it necessitated little or no additional falsework more than that required with any other erection device, it left both material tracks free, and it could erect both trusses simultaneously. A gantry traveler was already in stock, which furnished another motive for using it.

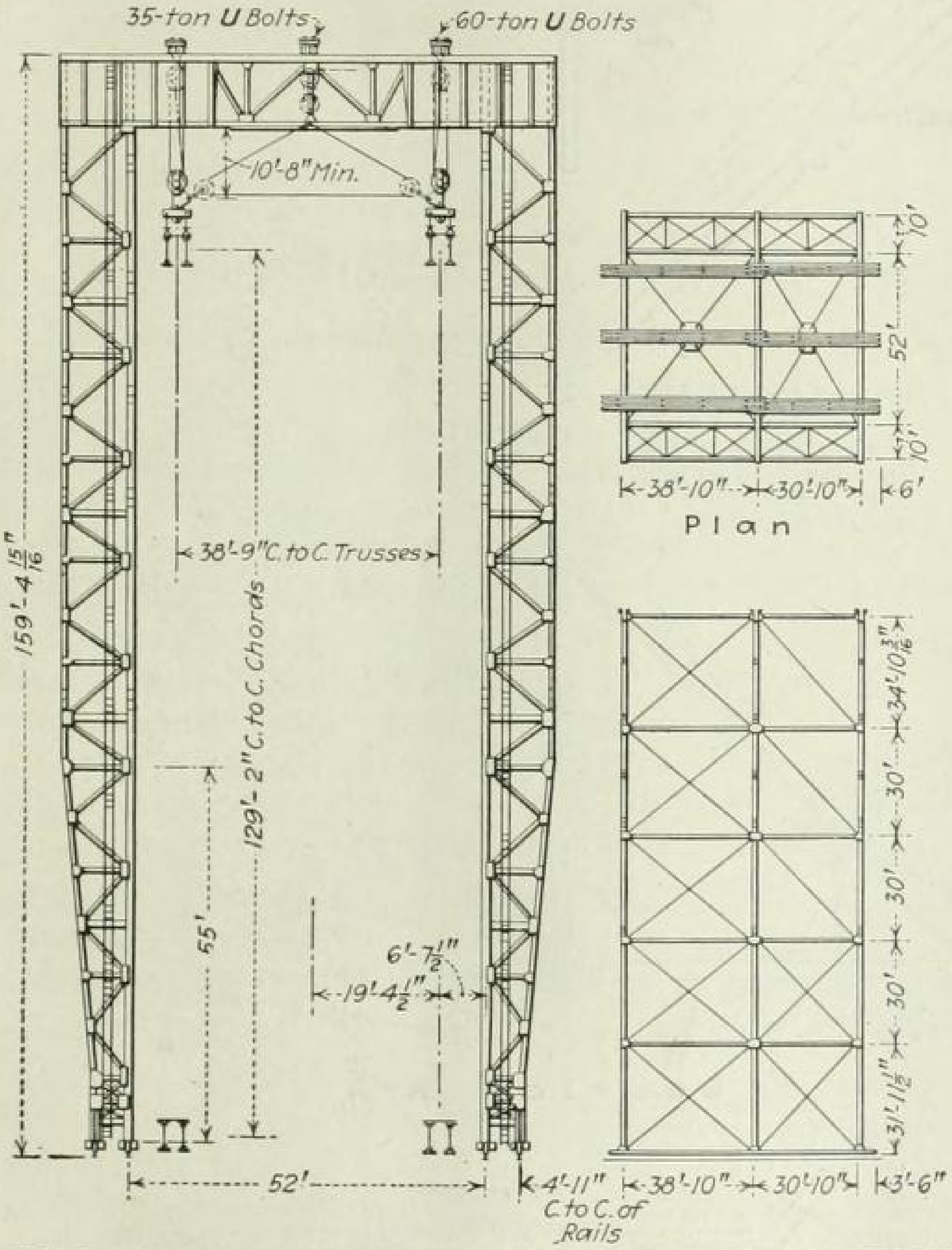


FIG. 2. GANTRY TRAVELER BUILT UP TO FULL HEIGHT FOR ERECTING TRUSSES OF OHIO SPAN

One objection to the gantry is the fact that its erection involves some time and trouble, but the advantages just cited outweigh this objection. The view in the adjoining column shows the temporary floor and the derrick used for raising the gantry.

Safety and simplicity of operation were the main reasons for adopting the top-chord or creeper traveler in the cantilever work.

A creeper with a single derrick boom had been used by the same contractors in erecting the Beaver Bridge (See *Engineering Record* of June 24, 1911, p. 704). While that machine did its work well, a large gain was made in the Sciotoville erection by providing two booms. The added weight was not great, and the speed of erection was doubled—an important matter because of ice and flood danger. Compared with the Beaver creeper, a much simpler structural design was possible, because the Sciotoville bridge has a stiff top chord and because only one slope of chord has to be provided for, in addition to the horizontal; at Beaver the top chord consists of eye-bars and has several slopes.

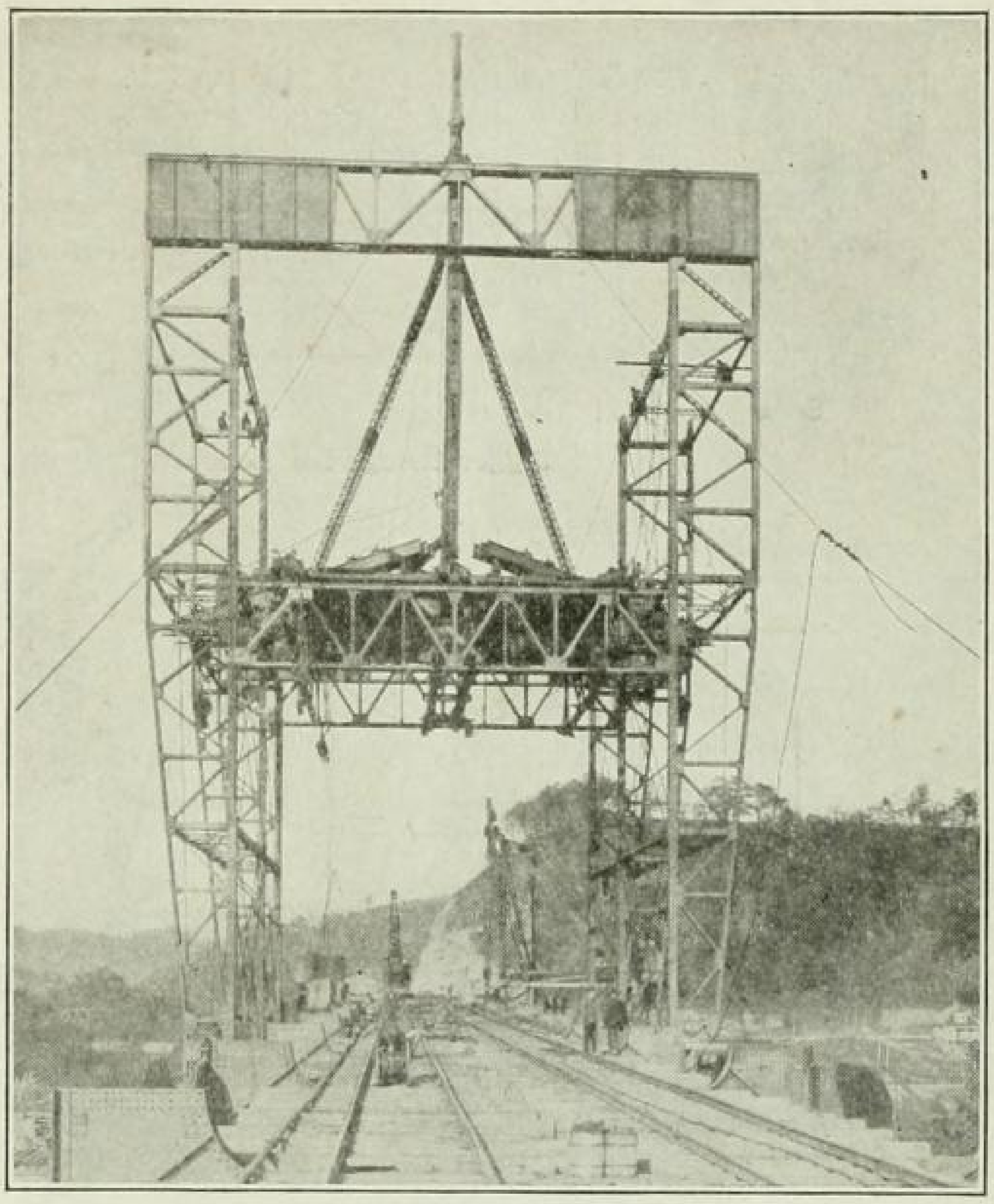


FIG. 3. STIFF-LEG DERRICK ON TEMPORARY FLOOR RAISING GANTRY TO FULL HEIGHT

The outriggers of the Sciotoville creeper were used to support scaffolding. This facilitated work materially. A large float under the bottom chord, suspended from

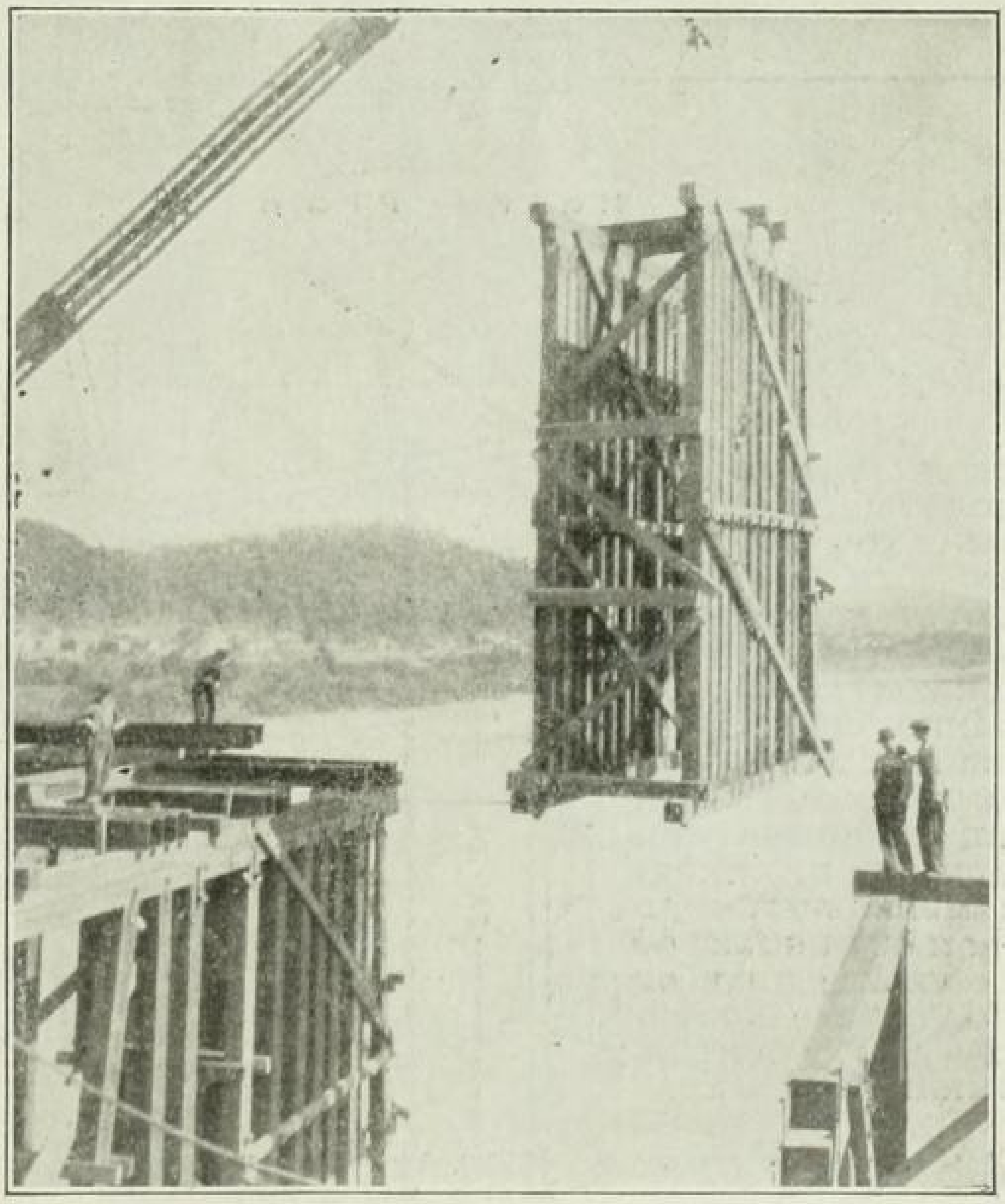
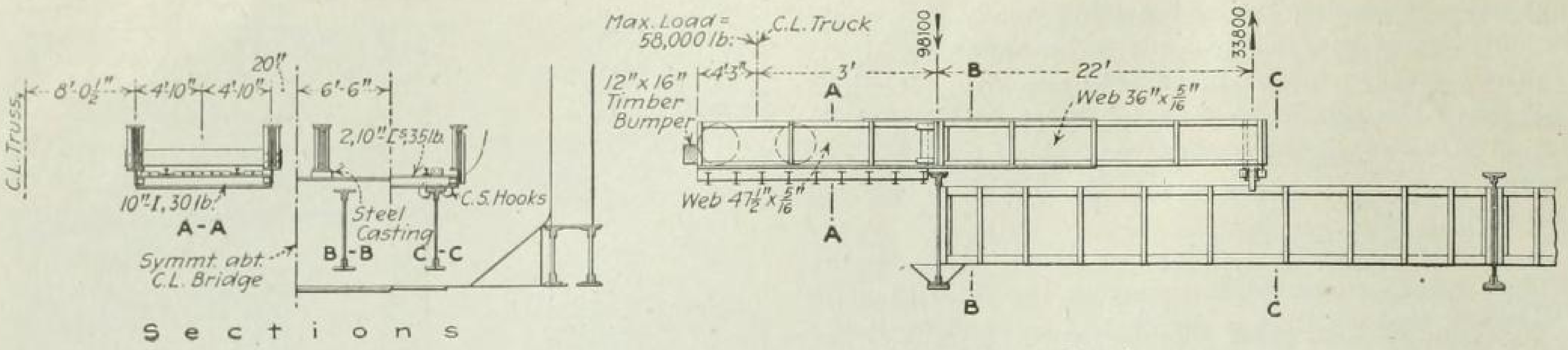
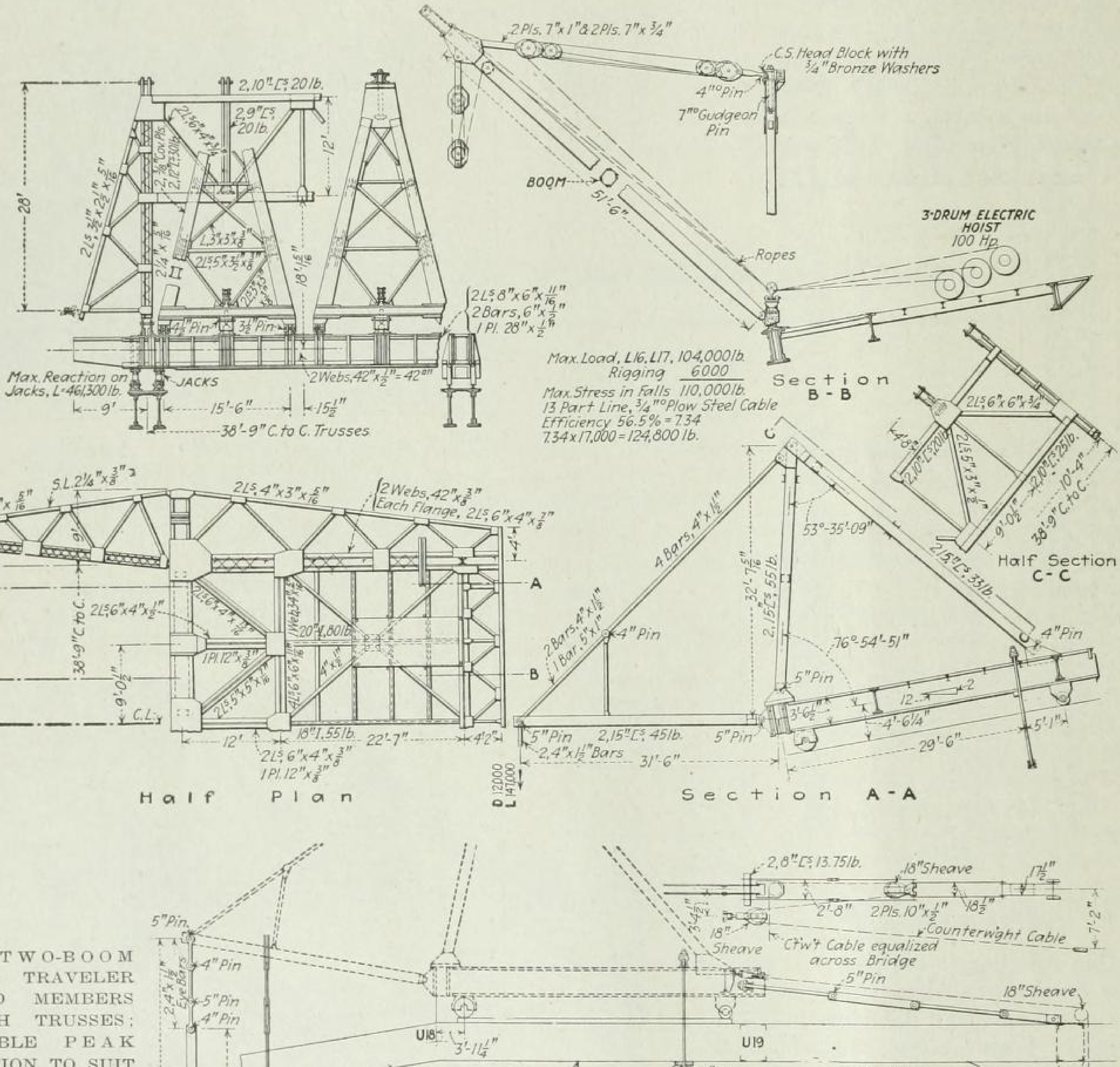


FIG. 4 TIMBER FALSEWORK ASSEMBLED IN PANELS HALF THE WIDTH OF ONE TOWER



Jigger Bridge for Material Cars Cantilevered Over Forward Floor-beam



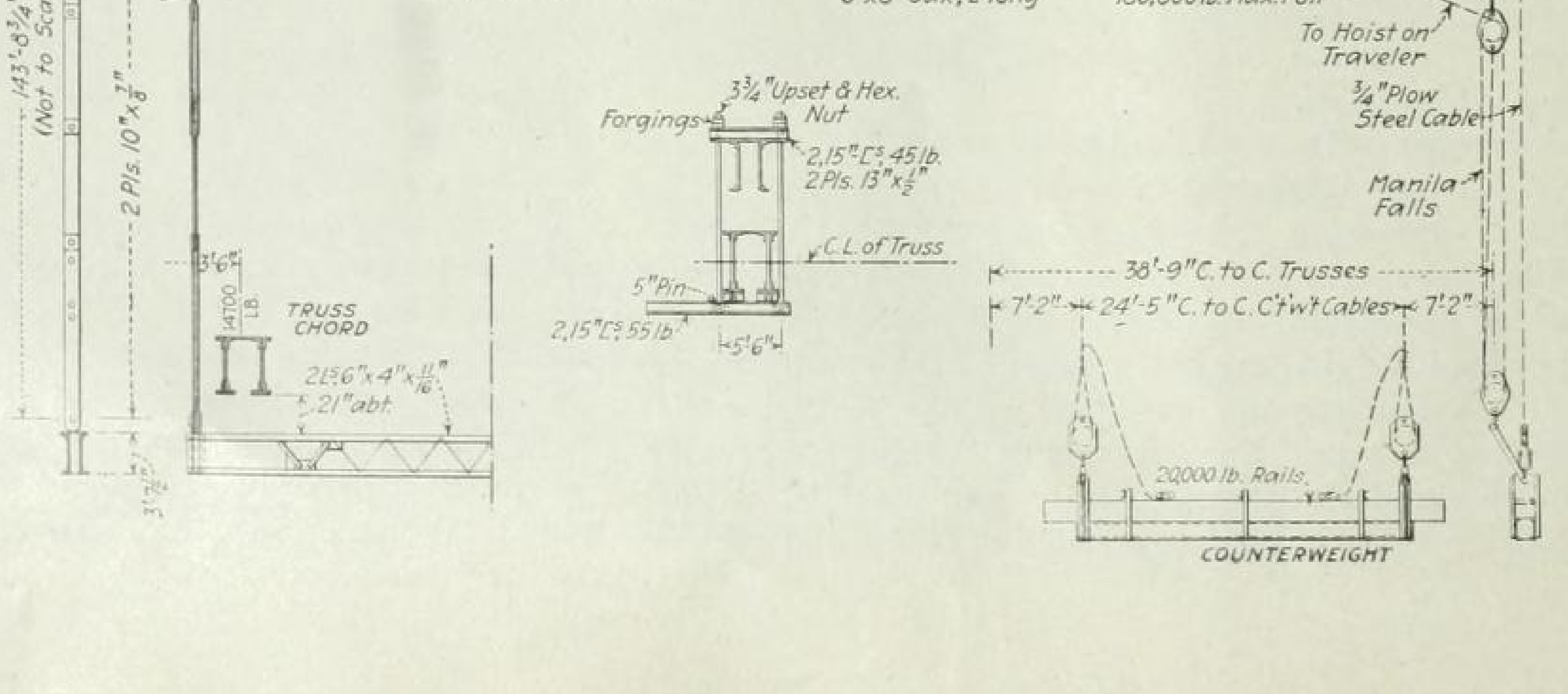


FIG. 5. TWO-BOOM CREEPER TRAVELER HANDLED MEMBERS OF BOTH TRUSSES; ADJUSTABLE PEAK CONNECTION TO SUIT HORIZONTAL AND INCLINED CHORD; MATERIAL BROUGHT OUT ON JIGGER BRIDGE; SUPPORT FOR JACKING UP TRUSS MEMBERS SUSPENDED FROM OUTRIGGERS OF TRAVELER; REAR OF TRAVELER ANCHORED AND COUNTERWEIGHTED.

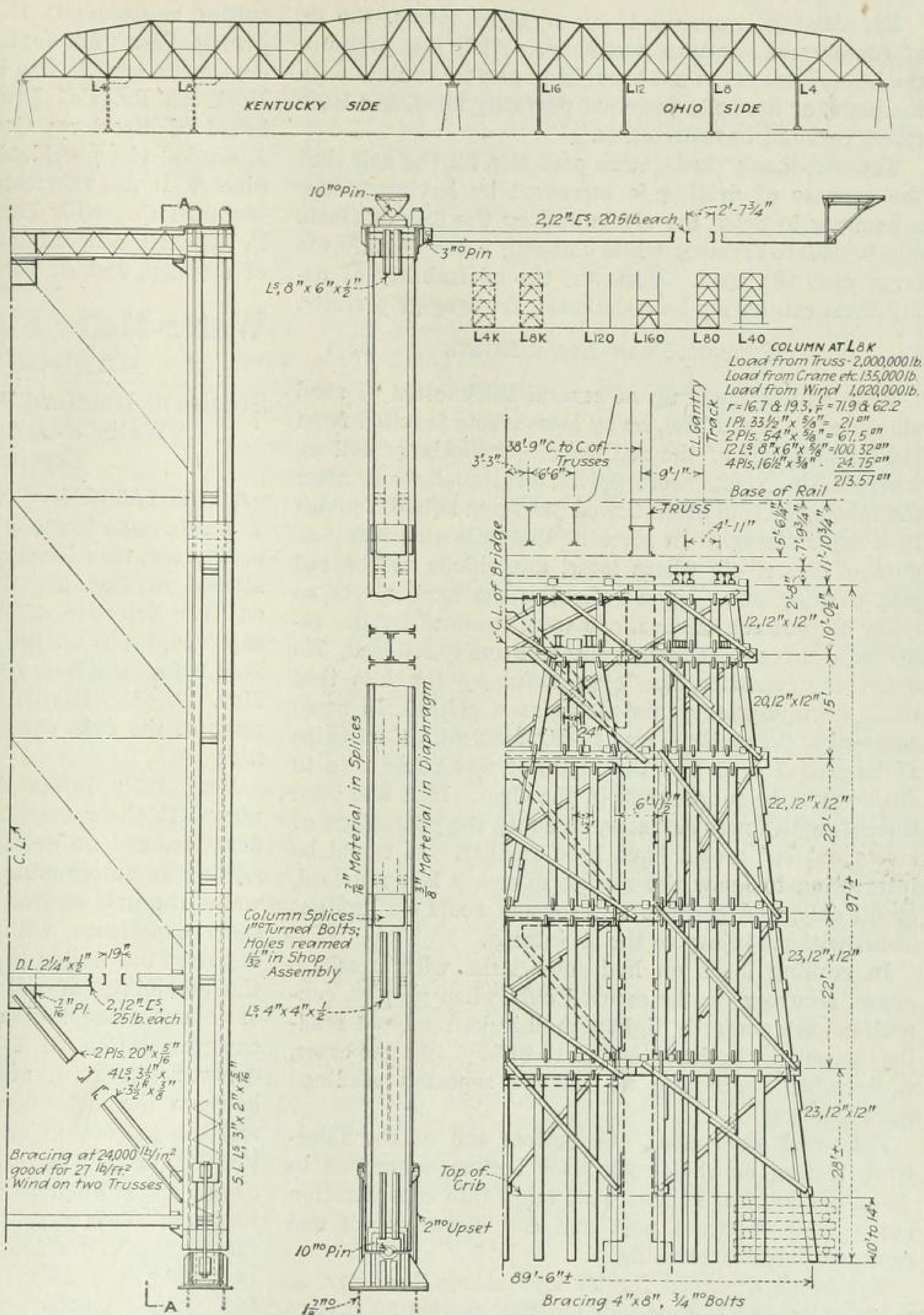
these outriggers, gave the riveting gangs easy access to the bottom-chord splices and laterals. Smaller scaffolds similarly supported were used for the top-chord riveting. These were in correct position for their service, in every panel.

Two portals were embodied in the traveler structure for lateral bracing. One of these was in a plane just back of the derrick masts or A-frames, while the other was in the plane of the backstays. These portals also served as trusses for taking the pull of the derrick A-frames and transferring it to the main triangles of the creeper frame on either side.

As the creeper had to work both on the sloping part of the top chord and on the horizontal, provision had to be made for keeping the A-frames vertical. This consisted of an adjustable link at the top of each A-frame, tying it back to the portals. Three pin-holes in the link made it equivalent to a long and a short link.

As explained in *Engineering News-Record* of Jan. 31, 1918, the stresses in a long continuous bridge are not greatly changed by slight variations in the elevations of the supports. Therefore, the use of this type of bridge is to be encouraged, since considerable metal is saved.

It is not necessary to leave a chord splice bolted for adjusting in case the end deflection is ot exactly equal to the computed amount, through the effects of inaccurate reaming done in the shop.



Half Rocker Bent at L8K

Elevation A-A

Half Bent of Timber Falsework at Main Panel-Point 4

FIG. 6. TIMBER AND STEEL FALSEWORK OF OHIO SPAN; STEEL BENTS LATER USED AS SUPPORTS OF KENTUCKY SPAN

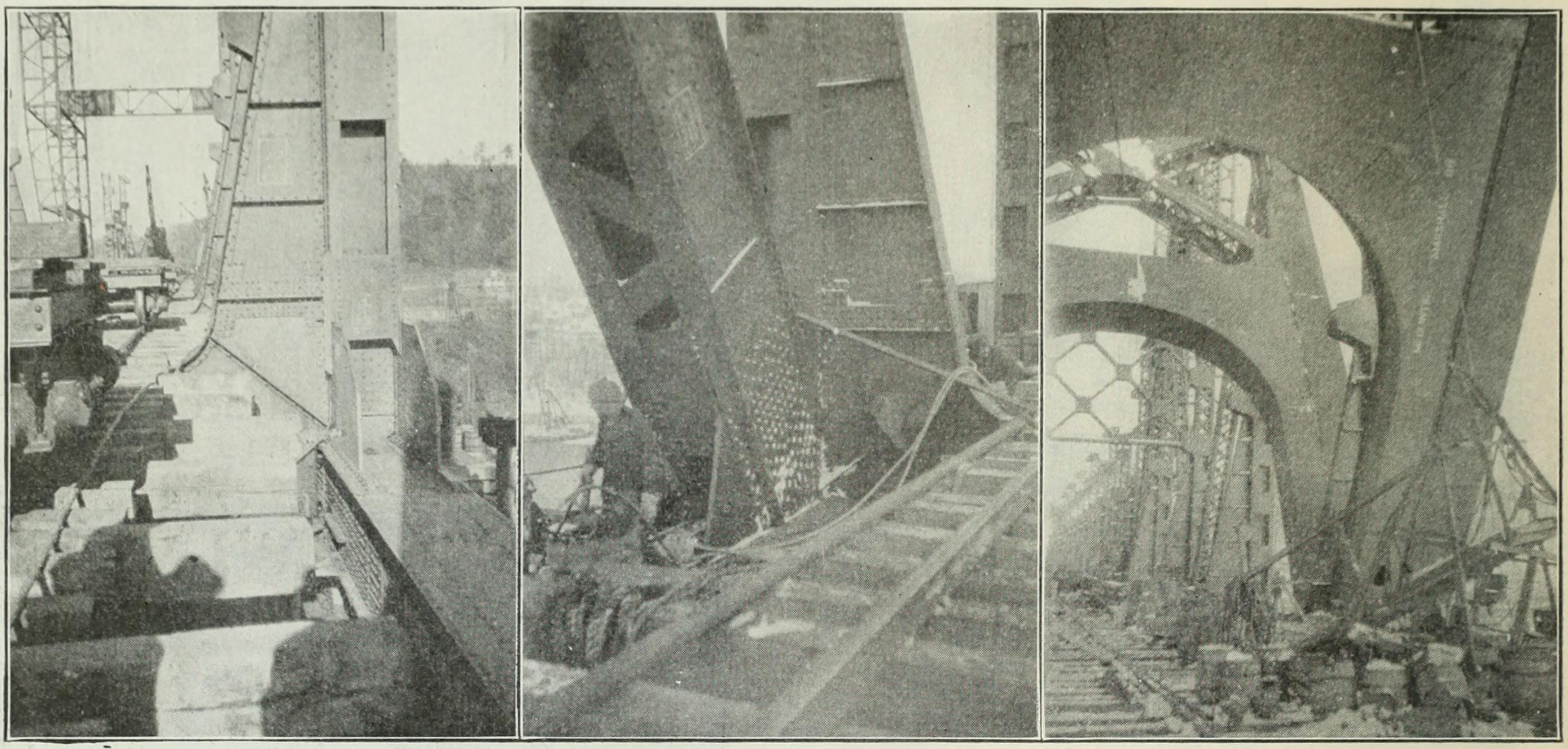
Secondary stresses can be eliminated from the completed structure as was done in this riveted bridge. This requires reaming the trusses point by point instead of entirely fitting together. The extra work involves some expense and some loss of time in erection.

Computed deflections agree exactly with the actual. In the deflections of the Sciotoville bridge acting as a truss this was the case for computed values which considered the sections of members increased 10% on the average for the influence of details on deflection. Bending of individual members as simple beams, cantilever beams, or beams fixed and hinged at one or more points, corresponded exactly with computed values. In computing bending of individual members the effect of details was taken into account as accurately as possible for each member. Computations of deflections of the structure as a whole and of the bending of members while erecting them, which were made for the entire bridge, proved invaluable. Serious difficulty in the field was thereby entirely avoided.

If the two members meeting at a joint were not tangent, thereby making the holes at the ends of the splice and top and bottom of chord a little out of match (after a few pins had been driven near the center of the splice), some pins driven simultaneously in scattered holes brought the whole connection near enough to match for easy entrance of the rivets. However, even a large number of pins never seemed to bring all the holes to absolute match.

Sciotoville Bridge Erection Is Well Started

An unusual bridge-erection problem is being handled in the construction of the Sciotoville Bridge over the Ohio River for the Chesapeake & Ohio Northern R.R., which has been designed and is being executed under the direction of Gustav Lindenthal, Consulting Engineer, the McClintic-Marshall Co., of Pittsburgh, being the contractors. The unusual feature is the bending of the truss members during erection in such direction and amount as to bring all members into precisely straight condition when the completed bridge is loaded to half its live-load capacity. The object is to eliminate secondary stresses, not only in the chords but also in the web members.



FIGS. 1 TO 3. ERECTION VIEWS OF THE SCIOTOVILLE BRIDGE

Fig. 1—Floor-beams and lower post sections set; gantry being raised for truss erection, Nov. 1. Fig. 2—Main panel point (L 16). Fig. 3—Portals over the center pier.

Something similar was done in the new Quebec Bridge, but in simpler manner on account of the numerous pin connections. The Sciotoville Bridge has riveted joints throughout.

The erection program is based on full and precise calculations covering the deflections in every stage of erection, the stresses in all members, the influence of raising or lowering any point of support, the angular relations of the triangle members, and the forces that must be applied to bring the members together.

The bridge comprises two 775-ft. spans continuous over the middle pier—a structure virtually of new type for America, and the largest structure of its type ever attempted. It was shown by general drawings in *Engineering News* of July 8, 1915, p. 64. The original feature of U-shaped floor-beams, whose upward-extending legs are held at the top by the sway-bracing strut, thus securing both stiffness and reduced floor-beam moment, was there shown by a drawing. These floor-beams in erected position are seen in the view, Fig. 1, herewith. They are field-spliced a short distance above floor level, the upper parts being built integral with the posts. This splice was drilled to templet in the shop, except for the splice cover on the inner flange, which was drilled in the field.

The views show the Ohio span, which is erected on falsework; the Kentucky span is to be cantilevered out from it for a length of 465 ft., will there land on a steel temporary bent, and 155 ft. farther will land on a second bent, 155 ft. north of the Kentucky end pier. On account of the deflections of the trusses as the erection progresses, and the necessity of avoiding both undue stress in the truss members and excessive concentrations of load on the falsework posts, the truss will be jacked up several inches at these temporary bents as soon as it reaches them.

Similar jacking is done on the Ohio span previously, the truss being jacked up successively at three points, as it reaches them, in order to free the falsework on which it rested up to that time and thereby allow this falsework to be pulled, which will eliminate a large part of the danger from drift in an unexpected flood.

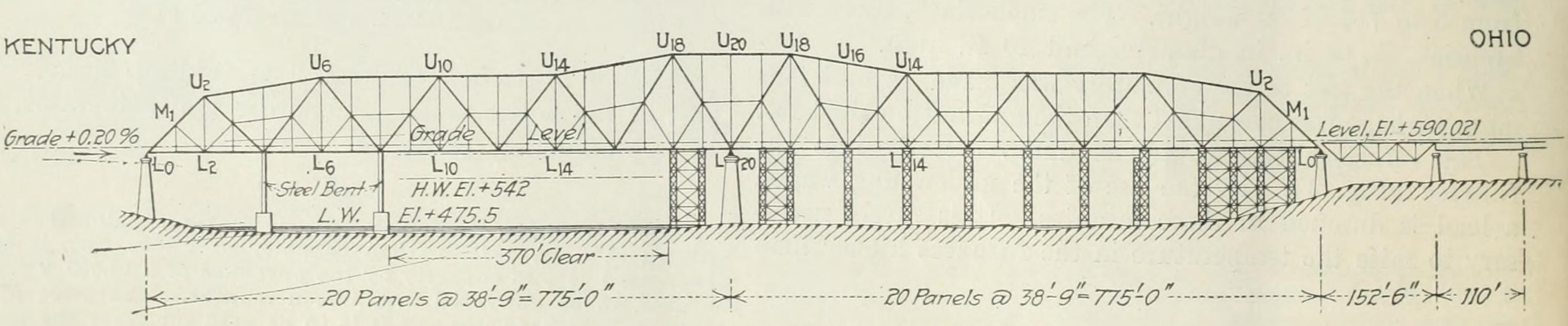


FIG. 4. SKETCH OF ERECTION FALSEWORK

The diagram Fig. 4 is reproduced from an erection sketch. The description of the erection procedure is based in part on a statement prepared by Paul L. Wolfel, Chief Engineer of the McClintic-Marshall Co.

Timber falsework is used to support the floor at every second panel point of the Ohio span, and plate girders from the approaches are used to span between them to carry the intermediate joints. At every second falsework bent (that is, every main triangle point) steel columns are built in, on separate footings, to carry the truss load. Screw-wedge jacks of 250 tons capacity on the timber bents (Fig. 7) allow for adjustment of height. Pin bearings are placed on the steel columns, allowing space for jacking up the truss by hydraulic jacks (Fig. 6).

The Ohio-span floor was first laid, by gantry traveler proceeding from L 0 Ohio, to L 20, the center pier, and on to L 18 Kentucky. Then working back, the traveler placed the lower chord. Immediately the splices of the chord were riveted. Then the chord was jacked and lowered at its various bearings, to deflect it into a curve of such shape as to allow the web-member connections to be made most easily. This curve is at its maximum about 1½ in. above the true level line, and at L 0 Ohio is about 8 in. below level.

The gantry being now built to the height necessary for truss erection, and the lower sections of the posts placed and spliced to the floor beams and chord, the work on the trusses was started at the great triangle over the center pier, and is progressing toward the Ohio bank. To erect the cantilever work of the Kentucky span, a creeper traveler was erected on the top chord of the L 20, U 18 O, U 18 K triangle in the latter part of December.

In the erection of the web members and top chord, none of the joints will go together without forcing, as they were laid out to fit the true truss diagram when stressed under full dead- and half live-load (3,000 lb. per lin.ft. per truss, full live-load being equivalent to about 6,000 lb. per ft. per truss). The web diagonals in general require to be bent by upward pulling with the tackle of the traveler, until drift pins can be entered in the joint, and then the connection must be forced into full matching position by drifting of a kind that will tend to put a slight reverse bend into the member.

To connect the posts, large vertical forces are required, for which purposes a special jacking rig has been built, to be clamped around the post near the top.

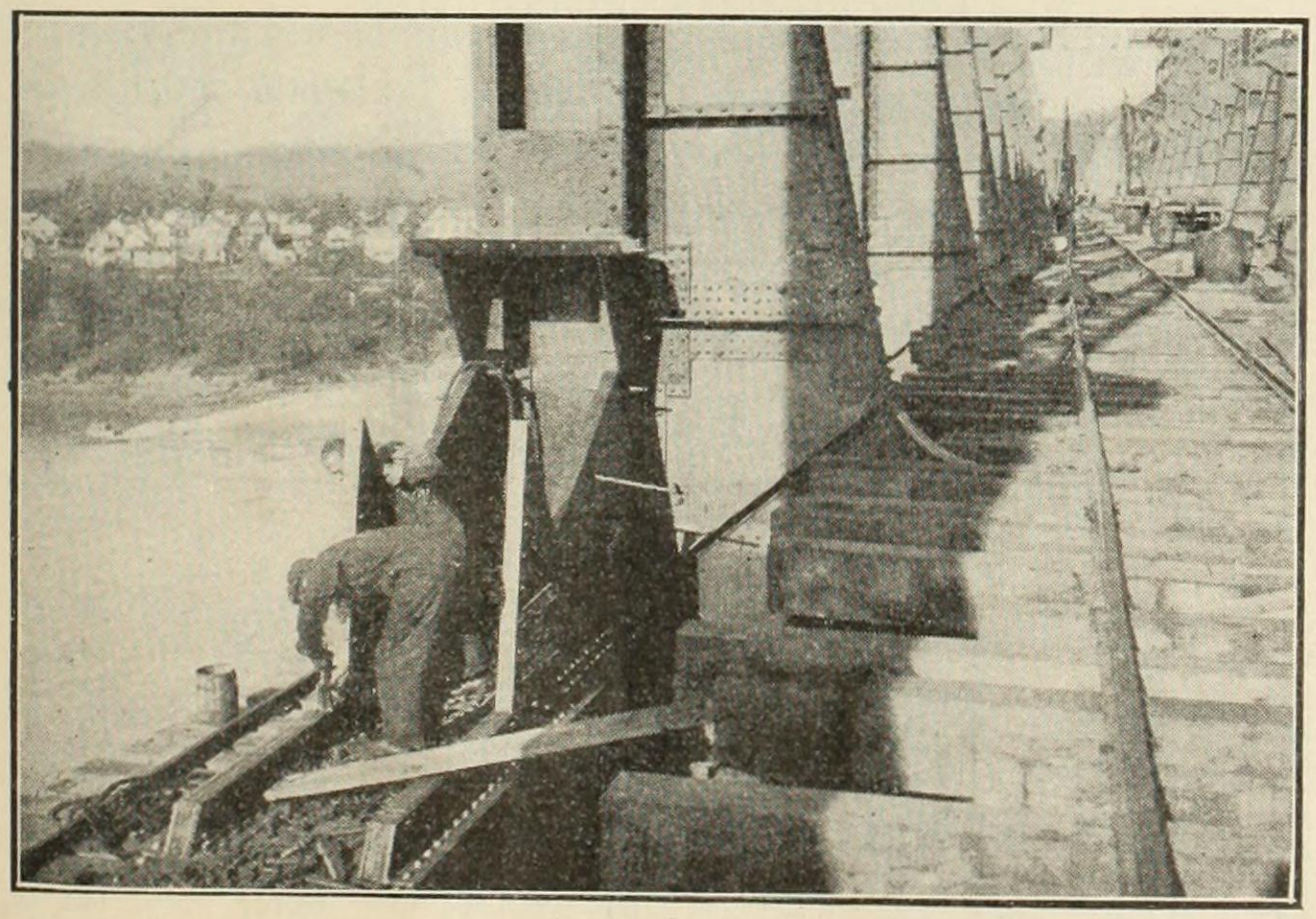
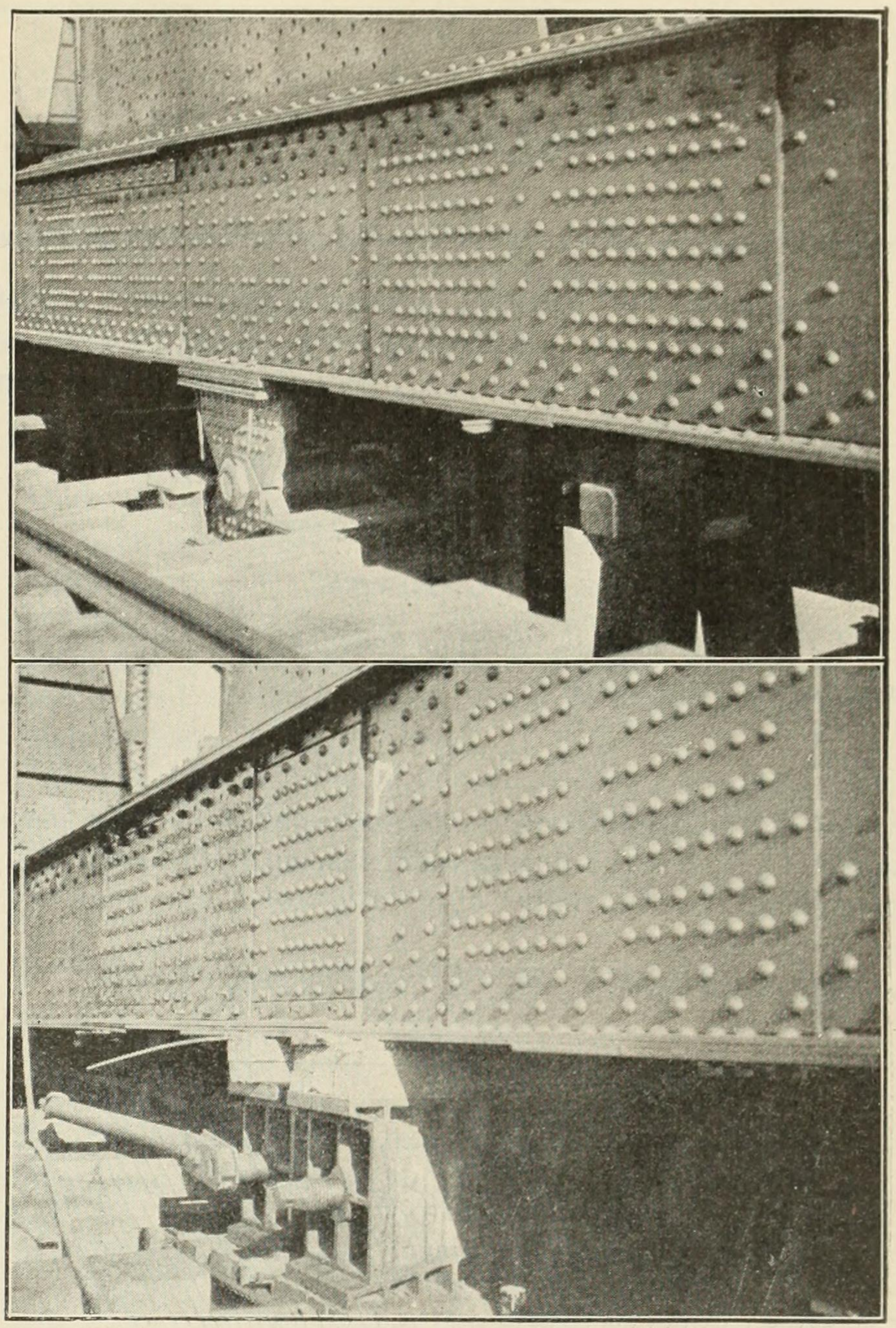


FIG. 5. THE U-FLOOR BEAMS SEEN FROM THE CENTER PIER; GUSSETS OF L 20 AT LEFT



FIGS. 6 AND 7. PIER SUPPORT AT MAIN PANEL POINT AND WEDGE JACK AT INTERMEDIATE PANEL POINT

A steel post is built in the falsework under each truss at the four main panel points

The Ohio span will be jacked up at L 12, L 8 and L 4 successively, to free the falsework. The jacking loads range to 400,000 lb.; the greatest load on the falsework columns will be about 1,300,000 lb. Finally, the Ohio end will still be 8.1 in. low and will have to be jacked up with 1,926,000 lb. to proper level, which will allow the 16-in. end rollers to be inserted and will free the last of the falsework columns.

Hydraulic jacks of 200 and 500 tons capacity are provided for the jacking; they will utilize pressures up to 4,000 lb. per sq.in.

Jacking the Kentucky span on the bents at L 8 and L 4 will require somewhat larger forces than above noted, and the final jacking at L 0 Kentucky will require a force of 2,337,000 lb. and a 16-in. raise.

At the end of December the trusses are erected from L 18 Kentucky to L 16 Ohio. The creeper traveler is in place on the Kentucky top chord and is taking down the falsework at 18 and 19 Kentucky. The gantry is proceeding with erection of the Ohio span. When L 12 Ohio is reached, the truss will be jacked. Shortage of labor has caused some delay, especially in riveting. The chord splices and large connections have 1¼-in. rivets, which demand skilled riveters.

R. T. Robinson is Resident Engineer for the consulting engineer. A. Toohey is superintendent in charge of erection for the contractor.

Field and Office

Building Concrete Piers for Sciotoville Bridge

The plant layout for the substructure work on the Chesapeake & Ohio Northern Ry. bridge over the Ohio River at Sciotoville, Ohio, was dictated by the necessity of getting sand and gravel in by river. A total of some 27,000 cu.yd. concrete and 850,000 lb. reinforcing steel was involved. The work comprised three river piers and twenty-four land piers.

On each bank an incline with narrow-gage track was erected, leading from low water to 40 ft. above the top of the bank (see layout plan, Fig. 2). The Ohio incline, the longer of the two, led up from a crib supporting a revolving or "whirler" derrick.[1] The Kentucky incline was served by a derrick boat. The engines of the inclines were of the direct-hoist type with large drums. All parts of both inclines worked satisfactorily throughout the season and a half that the work required.

The sand and gravel for concrete were obtained from a river bar a few miles below the site by means of a ladder dredge on which the sand and gravel were washed and screened. Flatboats delivered the material to the inclines, where it was unloaded with clamshell buckets.

At the top of the incline the skip dumped just below the head pulley and directly over a partition separating the sand and the gravel, there being a tilting apron on top of the partition, under the skip. The gravel used ran from ¾ to 3 in., undersize and oversize being wasted.

Materials for 8,000 cu.yd. of concrete were delivered to each bank, including that for the Ohio shore pier. All cement came in via the Norfolk & Western Ry. on the Ohio side. Cement for the Kentucky (south) viaduct, the Kentucky shore pier and the center pier was sent down the Ohio incline to flatboats, that for the Kentucky viaduct going up the Kentucky incline and that for the two larger piers going to the floating mixer plant.

The work was simplified by unusually good foundation conditions. In the river, rock was within easy reach. This was an important advantage, as on account of the structural type of the river span—two 775-ft. continuous truss-spans resting on three piers—it was necessary that there be no settlement of these piers.

The middle, or river, pier, which is the largest pier of this bridge, measuring 18x63 ft. under the coping and rising 96 ft. above low water, was built by means of a cofferdam. Work on this pier started late in October, 1914. A double-wall box coffer-dam was built, 79x127 ft. outside and 14 ft. high. At this spot the elevation of the river bottom, of practically bare rock and fairly level, was at low-water level. The 10-ft. space between the walls of the coffer-dam was filled with sand and small gravel, dredged from the river near-by, and decked over with 2-in. plank.

On account of the great rises of the river it was known from the beginning that the coffer-dam would be sub-

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[1] See "Engineering News," Sept. 9, 1915, p. 506, for description and drawing of the Dravo "whirler" derrick.

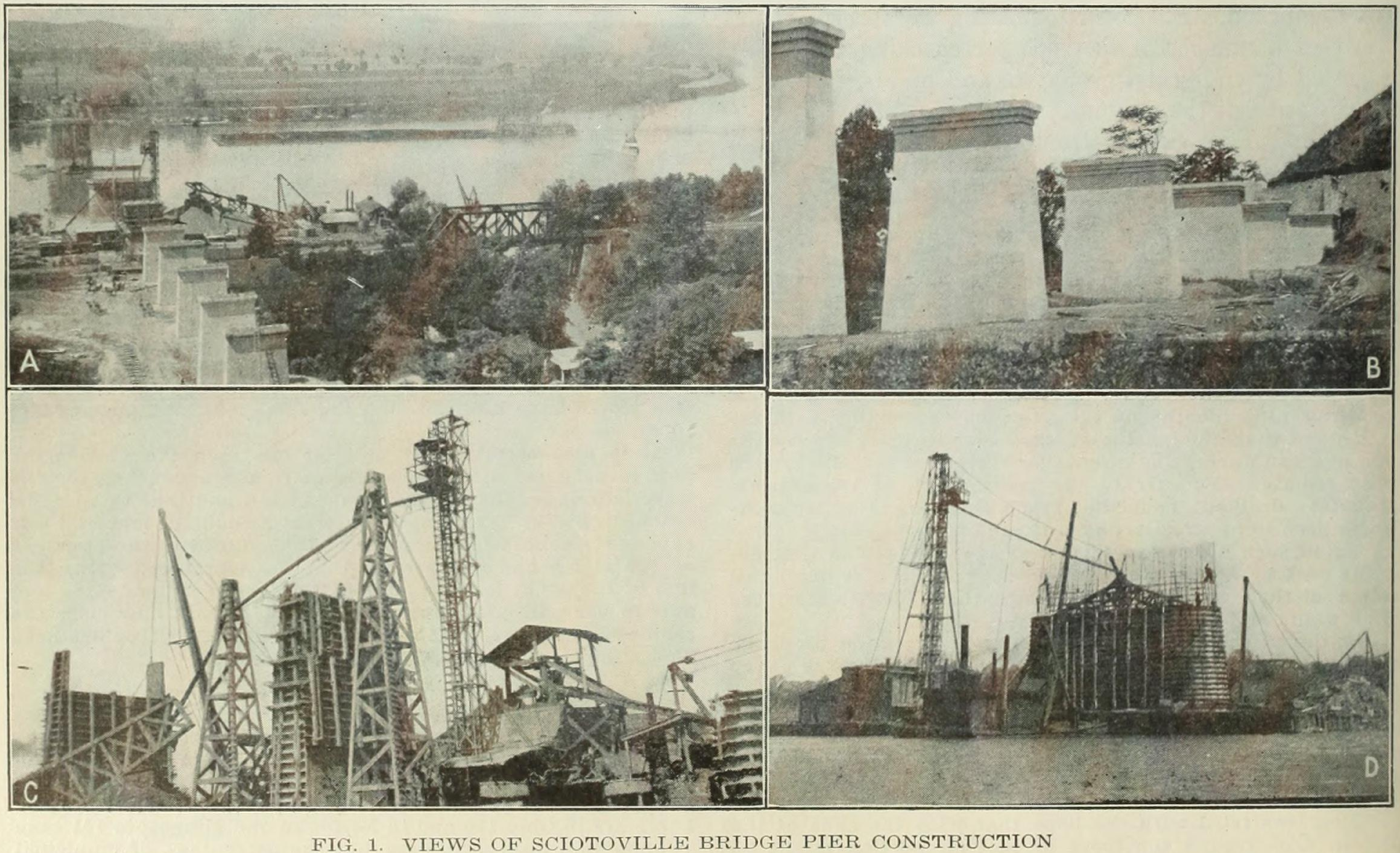


FIG. 1. VIEWS OF SCIOTOVILLE BRIDGE PIER CONSTRUCTION

A—Looking south along line of bridge; Ohio viaduct, north shore pier and center pier in place. B—Piers of Ohio viaduct. C—Spouting concrete to pier of Kentucky viaduct. D—Floating plant spouting to center pier merged at all stages above a moderately high river. It was in fact submerged continuously for four months, but in the spring was found not to have moved, and practically no fill was washed out.

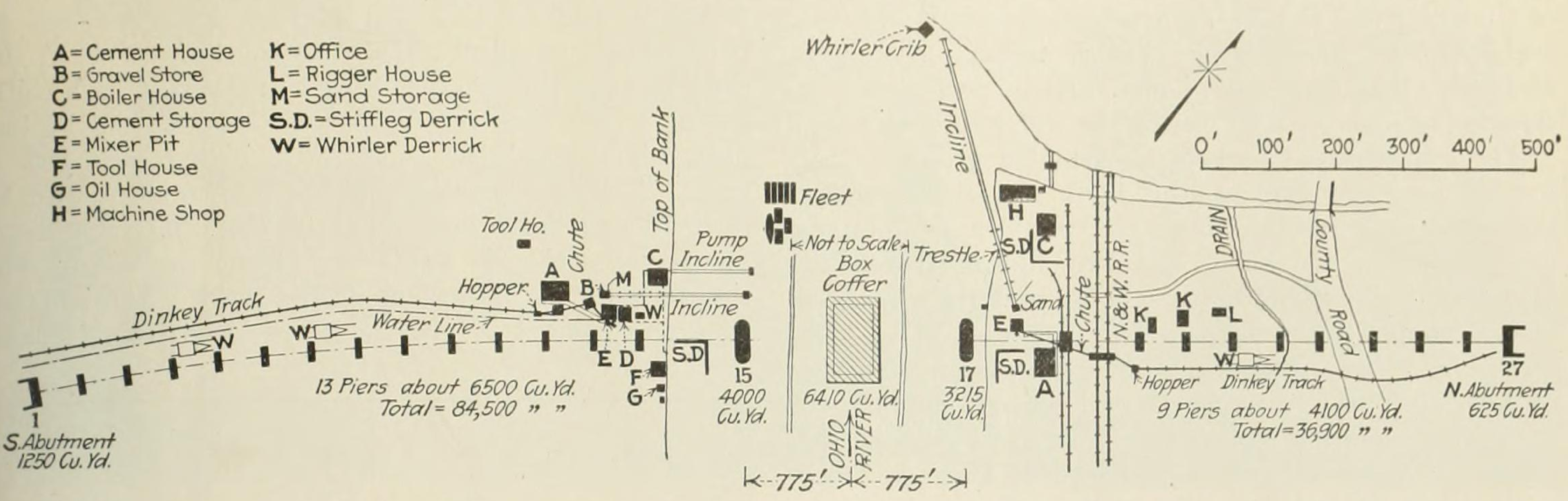


FIG. 2. DRAVO CONTRACTING CO.'S PLANT LAYOUT FOR SUBSTRUCTURE WORK ON SCIOTOVILLE BRIDGES

Inside the coffer-dam, open excavation was carried on by means of derrick boats to a depth of 10 ft. into the rock all over. The size of the footing is 40x85 ft. One No. 4 Emerson pump was used to keep the coffer-dam dry; it did not run at full capacity. Excavation was 30% completed on Dec. 4, 1914, when work stopped for the season on this pier. Work was resumed Mar. 29, 1915, the river being unusually low for this time of the year. The footing course was poured April 8.

The Ohio shore pier was built in open excavation 24x70 ft., extending 8 ft. into the rock and high enough up the bank to be dry at ordinary river stages.

The Kentucky shore pier was sunk by open dredging through wells. It was so designed that it could have been converted into a pneumatic caisson at any time if it had become necessary. The pier cylinder is 24x70 ft., with semicircular ends. Excavation with orangepeel bucket, through four wells, was carried on with working chamber and wells flooded, after the first 5 ft. until gravel was reached. The pier went through 25 ft. of fine sand and 2 ft. of coarse gravel, and the final excavation (in the dry) was carried an average of 2 ft. into the rock. The sinking was successfully done in 16 working days for excavating only. The cutting edge was sealed and the working chamber kept dry while filling with concrete. The river was up around this pier during practically the whole period of its construction. The top of the pier cylinder was 28 ft. above the cutting edge, the working chamber was 6 ft. high, and the wells were 7 ft. 3 in. in diameter.

Both shore piers are 12x67 ft. under the coping. The Kentucky viaduct piers and abutment, with an average load of only 2½ tons per sq.ft., rest on a clean sand with depth of excavation averaging 8 ft., except the pier at the top of the bank, which goes down 25 ft. on account of possible scour of the bank.

Of the Ohio viaduct piers five rest on shale, while five are on rock, as is also the abutment. The second pier south of the county road was rather deep, on account of a gully. The abutment had to be stepped into the face of a hard shale cliff. Otherwise the excavation was very simple. The rock bottoms needed but little pointing to give level beds for the foundations.

The excavation for both viaducts was handled by whirler derricks on a track parallel to the line of piers. There were a 5-ton and a 10-ton whirler on the Kentucky side and a 5-ton on the Ohio side. Work at both shore piers was handled by a stiffleg derrick.

There were three concrete-mixing plants—a floating plant, and two fixed plants, one at the shore end of each incline. All these plants had 1-yd. mixer, 100-ft. tower, and chutes. The floating plant was served by a derrick boat which transferred cement and aggregate from flatboats direct to the mixer bins. With the aid of chutes this floating mixer poured all of the center pier and all except the coping of the Kentucky shore pier.

The chutes from the fixed plants were able to deliver concrete direct to the Ohio shore pier and to one pier of the Ohio viaduct and several of the Kentucky viaduct. For the remaining piers and abutments of the two viaducts the chutes spouted the concrete into hoppers, and from there it was carried by bottom-dump buckets on a dinkey track along the line of the piers (between them and the whirlers) to the pier where needed. On the Ohio side the hopper sat on the north side of the Norfolk & Western Ry. tracks, the chute from the mixer tower running over the tracks on a temporary bridge.

The viaduct piers are all rectangular in plan; all except two are 5x26 ft. under the coping and average 40 ft. in height. Slab forms were used in sections 16 ft. high and, for the sides, long enough to extend by the ends. These slabs were very substantial; they as well as the end bulkheads were made with vertical ¾-in. sheeting, 2x10-in. horizontal studding and 8x8 rangers. The tie-rods were fitted with a sleeve-nut 1 to 2 in. back of the face. The coping is somewhat complicated, but a well-made form of two sides and end bulkheads was built. Only two of these forms with minor repairs lasted throughout the job.

On the large river piers some of the slabs and a few of the round end forms were used more than once, but most of the forms for these three piers, including all of the three copings, were built new for each pier. Below the coping the forms were in 16-ft. lifts.

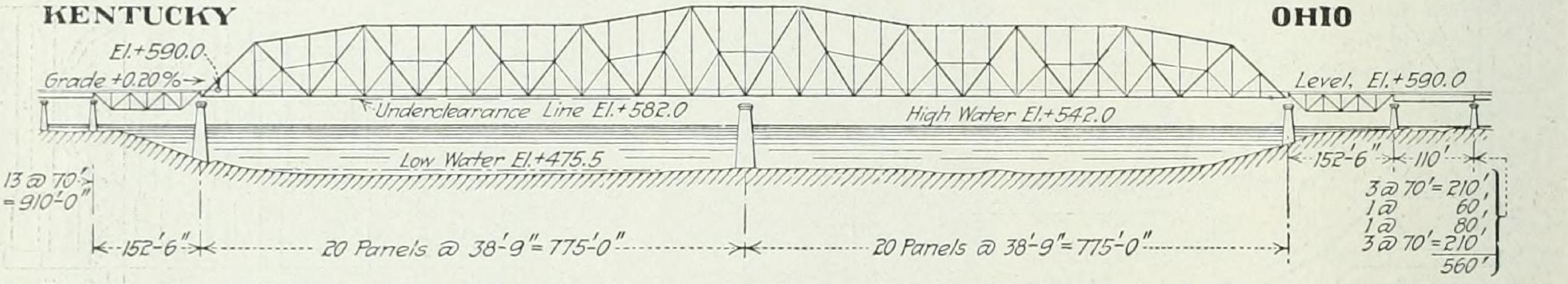
About 150 cu.yd. of concrete was usually poured in 10 hr., but on several occasions 300 to 350 cu.yd. was poured in 10 hr.

The bridge and approaches were designed and are being built under the direction of Gustav Lindenthal, Consulting Engineer, for whom O. H. Ammann acts as Principal Assistant Engineer and R. T. Robinson as Resident Engineer. The Dravo Contracting Co., Pittsburgh, Penn., was the contractor for the substructure. The plant layout was made by J. J. Nolan and the subsequent work was under J. Smith Miller as superintendent.

Long-Span Continuous-Truss Bridge over the Ohio

SYNOPSIS—Requirement of two 750-ft. openings led to adoption of two-span continuous truss; first large bridge of continuous type in America; piers on rock, eliminating the question of settlement; triangular web system with all joints riveted; enormous gussets required; floor-beams of U-shape, sides extending up the posts to the bottom of the swaybracing, which reduces the bending-moment in the floor-beam nearly one-half; traction truss in every panel; no expansion joints in floor

Striking departure from conventional practice in bridge design is found in the Chesapeake & Ohio Northern Ry.* bridge which is now under construction over the Ohio River at Sciotoville, Ohio. The consulting engineer, Gustav Lindenthal, of New York, who worked out the design of the bridge and viaduct approaches and is directing the construction, decided upon a two-span continuous-truss bridge as best suited to the conditions. The bridge has two equal spans of the extraordinary length of 775 ft. each, continuous over the center pier. Since the continuous truss is practically unknown in American bridge practice except for its use in swing bridges, the radical character of the Sciotoville design is evident.



New Double-Track Bridge Over Ohio River for Chesapeake & Ohio Northern Ry. at Sciotoville, Ohio

Continuous Spans

The river is about 1500 ft. wide at the bridge site, and makes a sharp curve with the channel near the inner, or Kentucky, side. At high water, however, the river traffic shifts over to the Ohio side. These circumstances made it desirable to have two large openings, fixed by the War Department at 750 ft. This called for two spans of about 775 ft. between centers of piers. A comparison among various designs consisting of successive simple spans, cantilever trusses and continuous trusses showed a decisive economy for the adopted design, in addition to which it has the advantage of symmetrical appearance.

Foundation conditions for the river spans are excellent. Rock was found in the middle of the river at an elevation of about 10 ft. below low-water level, and it extends nearly horizontally across the river. Since the concrete piers will rest on solid rock, settlements are not to be expected, so that one of the common objections to the continuous type of bridge is not present in this case.

The principal dimensions of the river spans are as follows:

Total length c. to c. end piers	1550	ft.
Span length c. to c. of piers	775	ft.
Clear height above low water	106½	ft.
Clear height above high water	40	ft.
Height of trusses at center pier	129	ft. 2 in.
Height of trusses at ends	77	ft. 6 in.
Width between centers of trusses	38	ft. 9 in.
Panel length	38	ft. 9 in.

The two large channel-spans are being built double-track. The approach viaducts, on the other hand—consisting largely of plate-girder spans 67½ to 110 ft. long—are being built for the present with steelwork for one track, while the masonry is built to accommodate a future second track.

Triangular Web System, Riveted Joints

A Warren web system was applied to the adopted truss outline, with main-panel length 155 ft., subdivided by verticals and by a substrut system.

Most chord and web members being subject to both tension and compression, on account of the continuous design and the web system employed, it was decided to make them stiff throughout. It appeared also that no saving could be effected by the use of eye-bars for the few members taking tension only.

Pin connections being considered undesirable for members subject to reversal of stress, it was decided to use riveted connections throughout and thereby secure greatest possible rigidity. These spans will be the longest and heaviest of the fully riveted type built in America.

The riveted connections involve tremendous gusset-plates, larger, in fact, than those of the Hell Gate arch and of the same thickness—1⅝ in. The facilities of mills and bridge shops will be taxed to the utmost in providing these gussets.

Even so, it was not possible to provide gusset connections of the ordinary type at panel-points U18 and L20 (that is, at both ends of the main-pier diagonal). The stresses in the members that connect at these points are so great that it was found impracticable to make the connection to the gussets with rivets in double shear without exceeding the obtainable size of plates. Therefore, each web-plate of the top chord and diagonal members, as well as the gussets at U18 and L20, was made of four 13/16-in. plates so arranged that the rivets can transmit the stress in shearing in four planes. The aggregate thickness of each gusset at these two points is 3¼ in.

Sizes and weights of individual parts in the bridge are given by the following tabulation:

Heaviest chord member, 4x4½x77½ ft.; cross-section, 596 sq.in.; weight, 228,000 lb.

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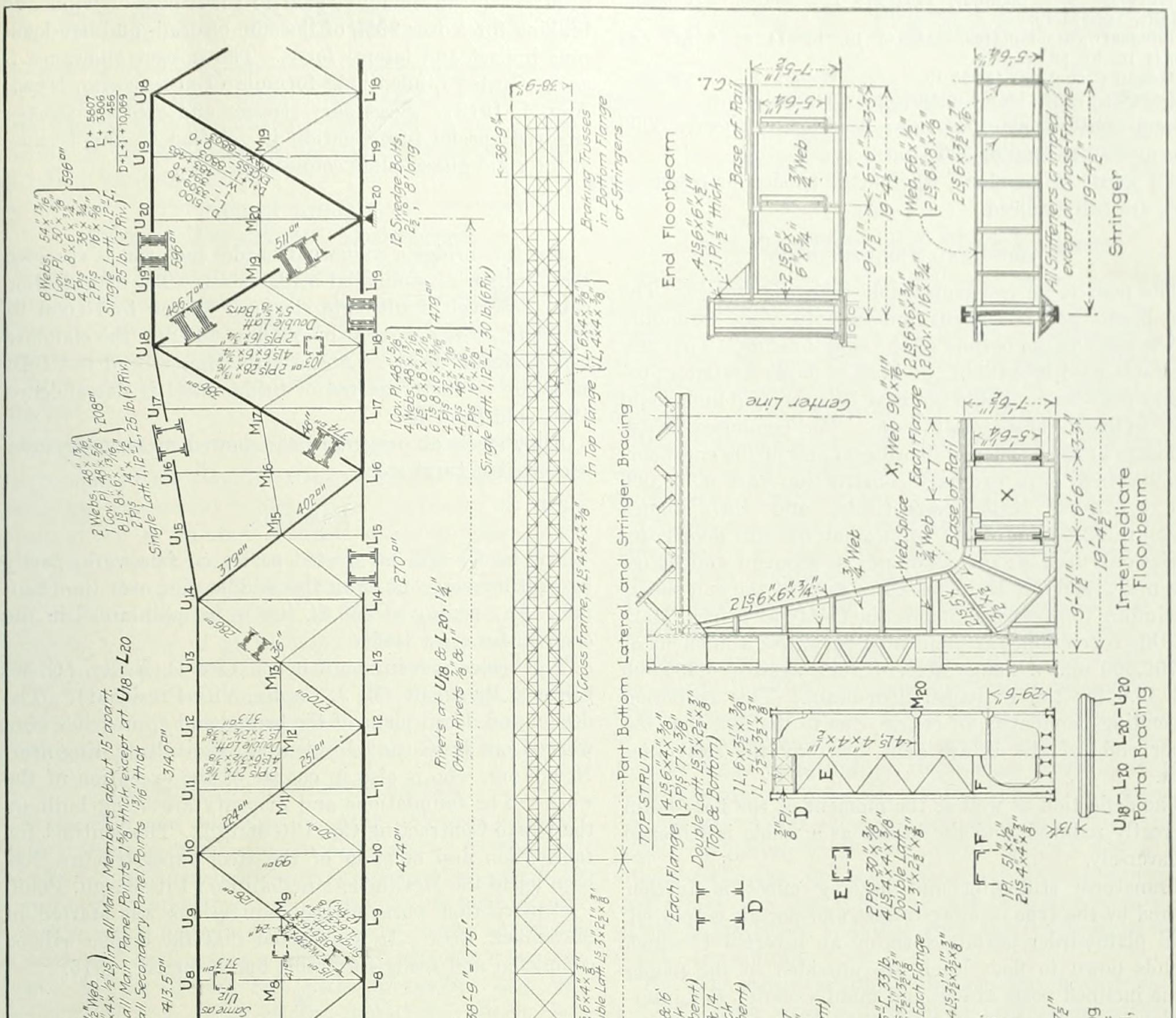
*The Chesapeake & Ohio Northern is a new branch line of the Chesapeake & Ohio Ry., to connect the main line of the latter on the Kentucky side of the Ohio River with the Hocking Valley R.R. at Columbus, Ohio. It crosses the Ohio at Sciotoville, about 120 mi. above Cincinnati. The new line is projected for heavy freight traffic, principally coal trains, for which reason the grade has been limited to 0.2%, compensated on curves.



Stress Sheet and Details of Chesapeake & Ohio Northern Ry. at Sciotoville, Ohio

EXCESS LOAD PROVISIONS IN SCIOTOVILLE BRIDGE

Wind load, top chord, 800 lb. per lin.ft. bridge.
Wind load, bottom chord, 700 lb. per lin.ft. bridge.
Wind load, train, 500 lb. per lin.ft. bridge.
Lateral force, 10% of live-load of one track.
Braking, 670 lb. per lin.ft. truss.
Excess = (W. + Br.) — 20% (D + L + I + Lat.)

Field connections of stringers to floor-beams not riveted up until span is completely erected and self-supporting. Field connection of diagonal M19 — L20 to bottom-chord gusset not reamed to full size or riveted up until span is self-supporting.

Heaviest web member, 4x4½x75 ft.; section, 511 sq.in.; weight, 166,000 lb.

Largest gusset-plates, 135x1⅝ in. by 14 ft. 9 in., and 140x13/16 in. by 18 ft. 2 in.

Heaviest casting, 45,000 lb.

Largest rivets, 1¼-in. diameter by 7⅜-in. grip.

Each center bearing carries a dead-load of nearly 5000 tons and a live-load of 3000 tons.

All joints of members, whether in tension or compression, are fully spliced.

FLOOR-BEAM CONSTRUCTION

The floor is no less remarkable than the trusses. The floor-beams are U-shaped frames, with sides extending up the posts to the bottom of the sway-bracing. This new form was used because of the shallow depth available; ordinary floor-beams would not have been as rigid and would have weighed considerably more. The computed center moments of the U-shaped floor-beam and of the end floor-beam—which is of ordinary construction—are 6,300,000 and 8,197,000 ft.-lb. respectively, and their flange areas are 42.63 and 55.17 sq.in.; but the end floor-beam carries only half a panel-load, and its moment and flange area must therefore be increased in ratio of the end shears (including impact) to compare the two types fairly. Making this correction, the plain floor-beam has a moment of 11,700,000 and a flange area of 78.8, against 6,300,000 and 42.6 for the U-shaped floor-beam. This reduction of bending moment is, of course, due to the fact that the upper ends of the U are held apart by the swaybrace strut.

The deflection as well as the moment of the floor-beam is greatly reduced, and the bridge as a whole is stiffened transversely.

Transverse stiffening and bracing effect is further secured by the type of sway-frames and portals employed. Solid plate-girder portals, forming an inverted U which extends down to floor level, are provided in the planes of the inclined posts at end and middle piers. For intermediate sway bracing, in place of the diagonal sway bracing ordinarily employed, deep lattice-girders and curved knee-brackets are used.

TRACTION TRUSS IN EVERY PANEL

In each panel in the plane of the bottom lateral bracing a truss is provided to transmit the longitudinal "traction" due to braking of trains directly to the trusses without bending the floor-beams. The arrangement is shown by sketch in the drawing.

No expansion joints are provided in the floor system. However, to prevent setting up chord tension in the stringers, the stringer connections are not riveted up until the spans are swung.

DESIGN LOADING

The design and details were worked out with a view to obtaining a strong, rigid structure that would meet the demands of the heaviest immediate and future traffic. The live-load is E60 on each track. The dead-load (weight of steel 13,500 tons) amounts to 18,800 lb. per lin.ft. of bridge. A lateral force equal to 10% of single-track live-load is counted. The braking force amounts to 670 lb. per lin.ft. per truss. Wind was figured as 800 lb. per lin.ft. of bridge on the top chord, 700 lb. on the bottom chord, and 500 lb. on the train. An excess stress was taken into account in all members subjected to various kinds of stress, of an amount equal to the excess of wind and braking force over 20% of the sum of dead- and live-loads plus impact and lateral force. The impact allowance is as per Gustav Lindenthal's formula (ENGINEERING NEWS, Aug. 1, 1912). Secondary stresses and erection stresses received special investigation in relation to and because of the rigid gusset-plate connections.

MEDIUM STEEL

For this bridge a somewhat harder material is specified than ordinary commercial bridge steel. The specification calls for steel of ultimate strength 62,000 to 70,000 lb. per sq.in., which exceeds by 5000 or 6000 lb. the standard bridge steel of today. At the same time a bend test fully as severe as that required of bridge steel is demanded—180° cold bend flat.

Alloy steels at present prices showed no economy over carbon structural steel.

ERECTION

The bridge will be erected partly on falsework, partly by cantilevering out from the middle pier over the channel. An opening of 350 ft. has to be maintained in the channel for river traffic.

The bridge is being built by the C. & O. N. Ry. (G. W. Stevens, President; M. J. Caples, Vice-President). The design and detail plans of the bridge and approaches were worked out by Gustav Lindenthal, Consulting Engineer, New York, who is also in charge of the execution of the work. The foundations and masonry are being built by the Dravo Contracting Co., Pittsburgh. The contract for fabrication and erection of the steel superstructure has been let to the McClintic-Marshall Co., Pittsburgh, Penn.

Construction work on the foundations was started in November, 1914. It is expected that the bridge will be completed and ready for traffic by November, 1916.

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Increasing Ontario Hydro-Electric Power—The total revenue from the Niagara hydro-electric system for the six months ending Apr. 30 was $710,324, according to returns just received by the Ontario Hydro-electric Commission from 84 municipalities, railways and large users of power in the Niagara district. Of this sum $353,508 was expended for power. $155,120 for interest charges, $49,696 for maintenance, $30,815 for operating expense and $1156 for engineering and auditing. Of the balance, $69,808 was devoted to the sinking fund and $50,221 to the depreciation reserve. At the end of April the total consumption of power under commission control was approximately 88,000 hp., of which Niagara contributed 75,281 hp., the Ottawa, Port Arthur, Big Chute and Wasdels Falls developing the rest. At the present rate of increase the remainder of the 100,000 hp. contracted for with the Ontario Power Co. will be required before the end of the year. Having in view the early exhaustion of the supply now under contract, the commission is preparing plans for submission to the Ontario government for the development of new power. It is understood that these plans will provide for an ultimate total development of 250,000 hp. and that the bulk of this will probably be derived from developments upon the Welland Canal and a proposed public development on the Niagara River. New schemes, however, are under consideration. Contracts for the construction of the distributing stations and connecting line of the Eugenia Falls development were recently let. Adam Beck, chairman of the Ontario Hydro-electric Commission, states that the territory covered by the operation of the system is being rapidly extended. During the last two months the commission has concluded contracts with 17 additional municipalities for supplying electricity, and 14 others have made application for it and will submit by-laws to their citizens for authorization to make contracts. The system is now operating 2200 mi. of transmission lines, outside of the local distribution systems of the municipalities, and an additional 200 mi. is under construction.

Field and Office

Sinking a Cylinder Pier by Open Dredging

The south shore pier of the continuous-span channel crossing of the new Chesapeake & Ohio Northern Ry. bridge over the Ohio, at Sciotoville, Ohio, was put down by open dredging through wells—the only foundation on this work put down by other than ordinary methods. The sinking went on quite according to expectations and encountered no difficulties.

The most successful feature of the work was that, although sunk in a sharply sloping bank at the edge of the river, the pier was landed almost precisely in correct position; this is to be credited to the well-judged allowance for downhill shift which was made by the contractor at the start of the sinking.

The Dravo Contracting Co., of Pittsburgh, Penn., did the work under the direction of Gustav Lindenthal, Consulting Engineer, who designed the bridge and foundations.

The south shore pier has a base 70x24 ft., with parallel sides and semicircular ends. Four wells, 7 ft. 3 in. in diameter, spaced 14 ft. 8 in. c. to c., were cored in the concrete for doing the dredging. The lower ends of the wells flare outward sharply for a height of 6 ft.

The pier is located some 30 ft. back from the water's edge, somewhat below the middle of the sloping bank. The bank is mainly clay, although farther back the soil is sand practically from the surface down. Rock was expected to be found within 10 ft. below low-water level, the latter being El. 475. It was actually encountered at El. 462.5.

The shoe of the pier was set June 22, 1915, on an excavated bench at El. 487. Forms for the chamber, built on the shoe, were then concreted to a level 6 ft. above the cutting edge, which formed the chamber and roof. Two further 6-ft. lifts were concreted, the pier being allowed to settle during this time with a small amount of hand excavation inside to level it up. On July 17 excavation through the shaft by orangepeel was begun.

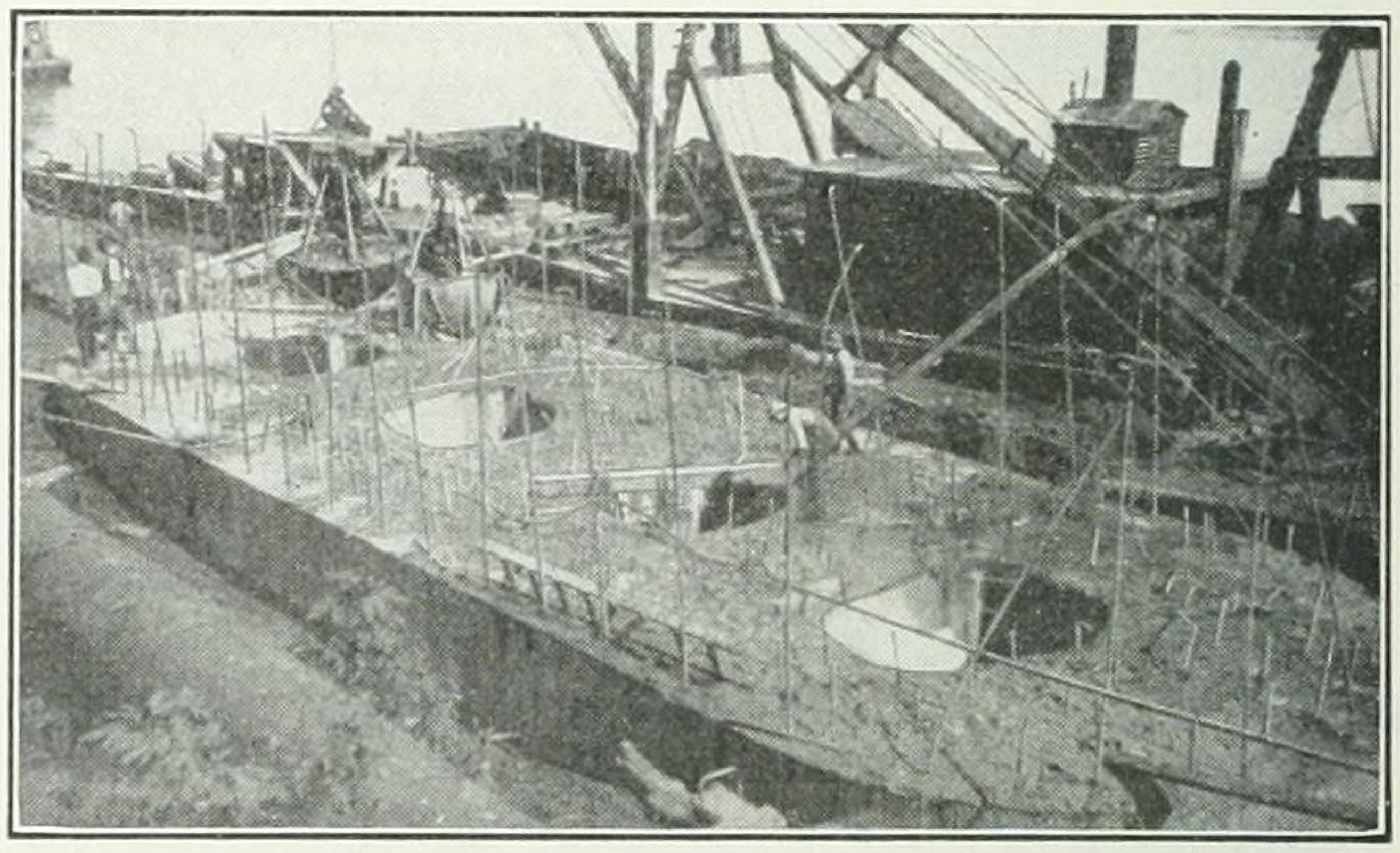
On account of the slope of the bank the contractor set the shoe 7½ in. landward of true position in order to allow for the riverward shift due to the greater earth pressure on the land side.

Shortly after excavation started, masses of old leaves and much clay were encountered on the river side of the pier. The excavation through this material had to be done by hand, the water being held by pumping. When clear soil was reached the chamber was allowed to flood, and thereafter the entire sinking proceeded by orangepeel buckets through the wells to within 18 in. of rock. Two buckets were used, one handled by a stiff-leg derrick set on the bank above the pier and one handled by a derrick boat working close against the bank.

Sinking went on at the rate of ½ to 2 ft. a day in the early stages. After the cutting was through the clay it was in fine sand, and here it made 2 to 3 ft. in 10 hr., the cutting edge being continually buried about 18 in.

Practically all seepage into the pier chamber came from the inshore side and end, there being numerous springs in the bank. Excavated material on the river bank was probably a factor in holding down the inflow from the river.

On July 28 the final 9-ft. lift of concrete was poured, and with this the pier went down to rock, bringing up Aug. 7. The rock was overlain by a layer of gravel on the downstream half of the pier, ranging from 2 to 3 in. at the middle line to 2 ft. at the downstream end. The pier brought up on this gravel. The chamber was then pumped out and the remaining excavation and a 2-ft. cut into the rock to get good bearing were done by hand.



TOP OF CHAMBER, KENTUCKY SHORE PIER OF SCIOTOVILLE BRIDGE

In this work a single No. 4 Emerson pump was sufficient to keep the chamber clear of water. As the shoe was lowered down during the rock excavation, empty cement sacks were packed under, which rolled up behind the cutting edge and shut off most of the water.

In preparing to concrete the chamber on Aug. 18, the bottom (El. 459.3) having reached sound rock, a drain of short lengths of 3-in. pipe covered with concrete in bags was laid around the cutting edge and carried to a sump under one of the shafts. Two 2-in. siphons not worked to their full capacity took the water from this sump. Two grout pipes down each of the four shafts leading to the cutting-edge drain were put in, and then the working chamber was sealed and the shafts filled. After this, grout was forced down one of the grout pipes, using compressed air as the forcing pressure, until it showed at all other pipes.

The pier as finally landed is within 1 in. of true position, departing a little toward the river, and stands practically plumb, is correct in alignment and at a true right angle to the bridge center line. Thus its total lateral shift was 8½ in. from shore toward river.

The total working period was 62 days. Of this period 19 days of 10 hr. were used in excavation.

The above data were supplied largely by R. T. Robinson, resident engineer. He gives credit for the success of the sinking operations to J. Smith Miller, the contractor's superintendent in charge of the work.