THE ERECTION OF THE ST. PAUL'S MISSOURI RIVER BRIDGE.

BY J. H. PRIOR.*

The Chicago, Milwaukee & St. Paul recently completed the construction of a new bridge over the Missouri river at Mobridge, S. Dak., where this road connects with its Pacific coast extension, the Chicago, Milwaukee & Puget Sound. The bridge was designed and constructed by the bridges and building department of the road, under the direction of C. F. Loweth, engineer and superintendent of bridges and buildings.

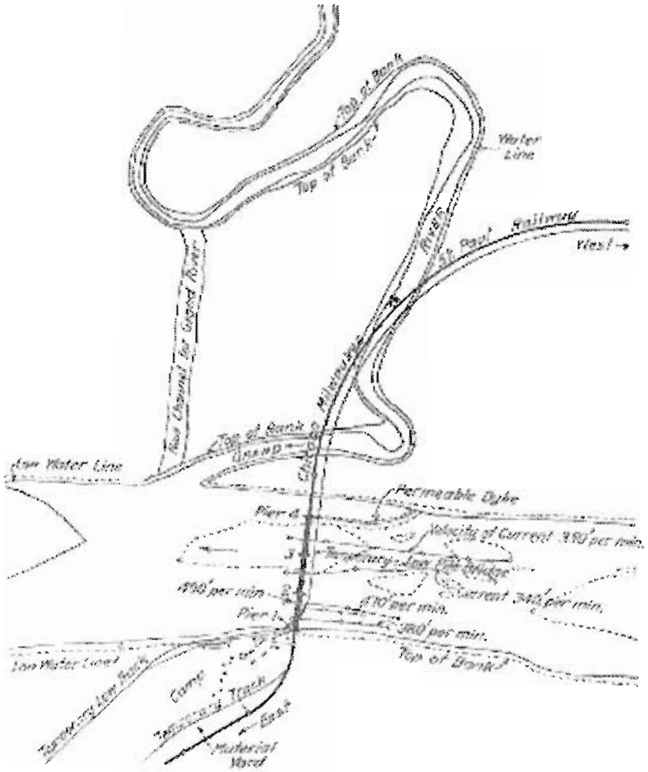

Fig. 1.

At the site of this bridge the low water channel has a width of 1,450 ft., which increases 100 ft. at times of high water. As an act of Congress required a clear headroom of 50 ft. above ordinary high water, the grade of the track on the bridge was placed at an elevation of 65 ft. 6 in. above low water. The bridge was designed for Cooper's E-55 loading per rail, and consists of three 420-ft. through pin-connected truss spans over the main channel, approached from the east by one 125-ft. deck span, and from the west by 283 ft. of steel trestle. A long wood frame trestle approach has since been partially, and will ultimately be wholly, replaced by an earth embankment.

In Fig. 1 the location of the bridge is shown and in Fig. 2 it is shown in outline. The abutment forming the east end is set back a safe distance from the water's edge, and the trestle at the west end is protected by a permeable dyke and woven willow mattress and stone riprap.

ERECTION.

The 125-ft. deck truss at the east end and the 420-ft. main channel spans were erected on falsework by means of an ordinary bridge traveler, but no falsework was used for the erection of the steel trestle at the west end. A temporary pile bridge 90 ft. upstream from the permanent bridge, as shown in Fig. 1, was used to get material across the river for construction of the railway and to serve the construction work on the permanent bridge, although not most conveniently located for this second purpose. This pile bridge was in continuous use from the time the foundations were started until the main channel spans were swung clear of the falsework.

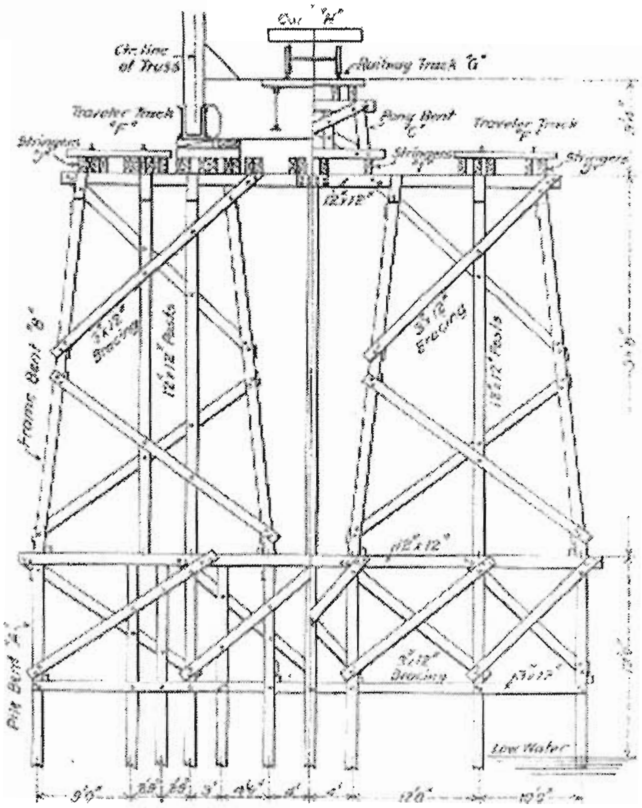

Fig. 3. (See Also Page 1410.)

The falsework for the main channel spans (Fig. 3) consisted of pile bents A, extending 19½ ft. above low water and supporting frame bents B, 36 ft. 8 in. in height, which in turn support the stringers carrying the traveler track and also the stringers carrying the pony bents which support the railway main track. Main bent E, located midway between panel points, carries the traveler and railway track only, and is of somewhat lighter construction, but consists of three stories similar to bent D.

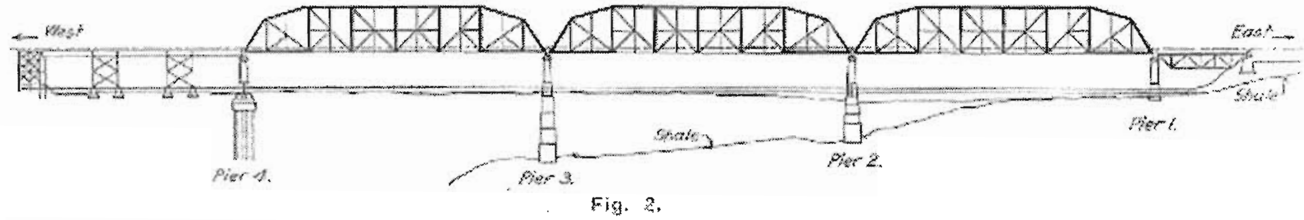

Fig. 2.

Such of the pile bents A, which formed the lower story of the falsework, as were driven in the ground, which was above water and dry during their construction were driven by a track driver running on a temporary track which was

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laid on the bents already driven, the track driver driving one bent in advance, piles being cut off and capped, and stringers and ties placed on the cap to permit the pile driver to move forward.

The piles for the falsework were carried out on the temporary pile bridge (Fig. 1) on push cars and rolled off into the stream at a point opposite where they were to be driven. The pile bents A (Fig. 3) were driven by a pile driver mounted on a scow, as shown in Fig. 4. On one side of the scow a longitudinal timber, A, was attached at a distance from the center of the leads which would give the correct

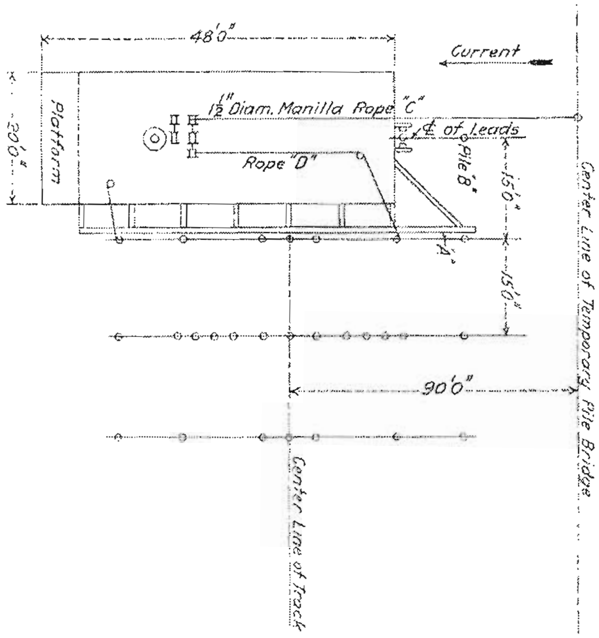


Fig. 4.

spacing of the piles from center to center of the pile bents. The scow was placed with this timber bearing against the piles in the last bent driven, and the pile, B, in the new bent driven. The driving of the remaining piles in the new bent followed, the scow being allowed to float down stream each time a distance equal to the spacing of the piles.

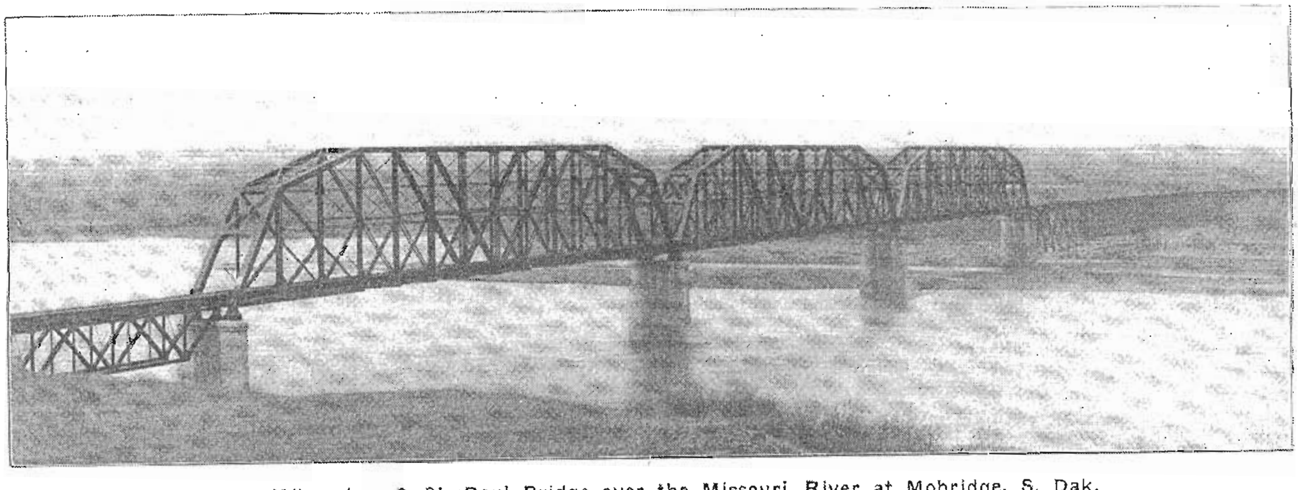
The frame bent B (Fig. 3) consists of nine 12 x 12 posts, the four outer posts on each side being braced as a unit and in such a manner that these four posts could be lowered from the track on the completed bents, A, with a derrick car and braced back to the finished portion of the falsework so as to support the stringers and track, thus completing a panel of falsework. The half-bents mentioned, consisting of four outer posts together with their bracing, were assembled to a template on a platform on shore, the platform being near enough to the track to be within reach of the derrick car, and were then picked up by the derrick car and carried out and put into place.

The piles for the falsework bents were driven from a scow in the manner just described, but the frame bents B for this portion of the falsework were assembled in a horizontal position on top of the pile bents and then erected into position by the derrick car, one panel at a time in advance of the completed portion of the falsework, the derrick car operating from the railway track which rested on the steel floor beams and stringers. In order to permit the derrick car to operate from the railway track it was necessary to carry on the erection of the steel floor fast enough to place the floor beams and stringers next to the end of the falsework structure as soon as the bents upon which they rested were erected. As soon as erected the bracing of Fig. 3 was placed, giving stability to the bent. The pony bents C were not used in this portion of the falsework, the derrick car being carried by the steel floor beams and stringers, each panel of which was placed as soon as the frame bents were raised into position. Although Fig. 3 is not a sketch of this portion of the falsework, it shows at D how the steel floor was placed from which the derrick car was operated. The material for this portion of the falsework was that which had been previously used in span I, and was now available, as span I had been erected and swung clear of the falsework.

The traveler which spanned the truss (Fig. 5) moved longitudinally on the traveler track F, Fig. 3 and Fig. 5. The railway main track G was supported by the pony bents C, Fig. 3 and Fig. 5, until the erection had proceeded to a point where the pony bents C, together with the stringers which they support, were removed, and the track placed with the steel stringers and floor beams of the permanent bridge, as shown at D and D1, Fig. 3.

As shown in Fig. 3, the bents are placed 15-ft. centers. This permitted of the use of the railway company's standard bridge material to a great extent without cutting, and made the second-hand timbers from the bridge only slightly less valuable than new material. It was possible to make the intermediate bents E of lighter construction than the bents D, at the panel points, as they carry only the traveler and the railway track, the dead load of the trusses being carried by bents D.

The traveler used in erecting the 420-ft. spans is shown in Fig. 5, and consists of three bents 85 ft. high, made long enough to erect one full truss panel of 60 ft., or two sub panels of 30 ft. each, without moving, and extending 3 ft. beyond the panel point at each end, in order to afford a plat-


Chicago, Milwaukee & St. Paul Bridge over the Missouri River at Mobridge, S. Dak.

form for the men while making the connections at three separate panel points.

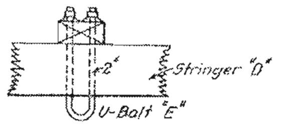
The traveler was supported by a runway on each side consisting of two rails marked "Traveler Track F," shown in Fig. 5. A runway of two rails instead of one gave a wider platform for the engines, increased the stability of the traveler, and afforded a place for the men to stand while driving the pins, and a place for them to work when the main track G was loaded with cars. Fig. 5 shows an outline of the traveler, the detail drawings from which the material was ordered and the traveler was framed, being made in advance. The maximum load for which the traveler was designed was a top chord section which weighed 52,000 lbs.

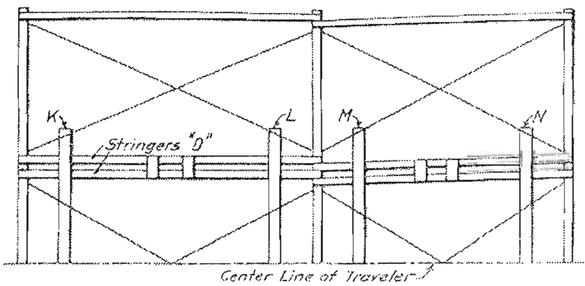
The general arrangement of the traveler lines is shown on Fig. 5. Power was furnished by four 30-h.p. hoisting engines on the platform, two on each side. Each engine had two drums and three spools, as shown in Fig. 5 in a diagrammatic manner. Tie beams L, M and N are similar to the tie beam K. Tie beam K is carried by the stringers D, and has passed through it a U bolt E, which carries the blocks a and b, which are rove with six parts of $\frac{5}{8}$-in. diameter steel cable, the lead line a, b, of which passes through a snatch block d at the top of the traveler, thence to the snatch block e at the bottom of the traveler and thence to the forward hoisting drum q of the engine. From the tie beams L and M (Fig. 5) are suspended four part tackles, a3-b3 and a2-b2, and are suspended in a similar manner to the tackles from the tie beam K, the lead lines a3-b3 and a2-b2, of which pass through the snatch blocks d and f respectively, at the top of the traveler, thence to the snatch blocks e and h, respectively, at the bottom of the traveler, and thence to the rear hoisting drums p and r of the engines, respectively. The blocks b1 and a1, suspended from tie beam N, have similar lines arranged, Fig. 5.

The tie beam K, in addition to transmitting the load in the tackle to the stringer D, acts also as a strut and prevents the lateral pull of the tackle when hanging at an angle with the vertical from overturning the stringer D, or pulling it laterally from its true position.

There are two runner lines from each engine which were used to raise some of the lighter members; such as the line m-n at T (Fig 5), which passes from the load which it is supporting to a sheave m, through a sheave n, through a sheave t, and thence to the winch head X on the engine.

In making the drawing Fig. 5, some minor details of the traveler were slightly changed to simplify the drawing, one 2-sheave block being shown at points D and N instead of the two 1-sheave blocks used at these points on the traveler.





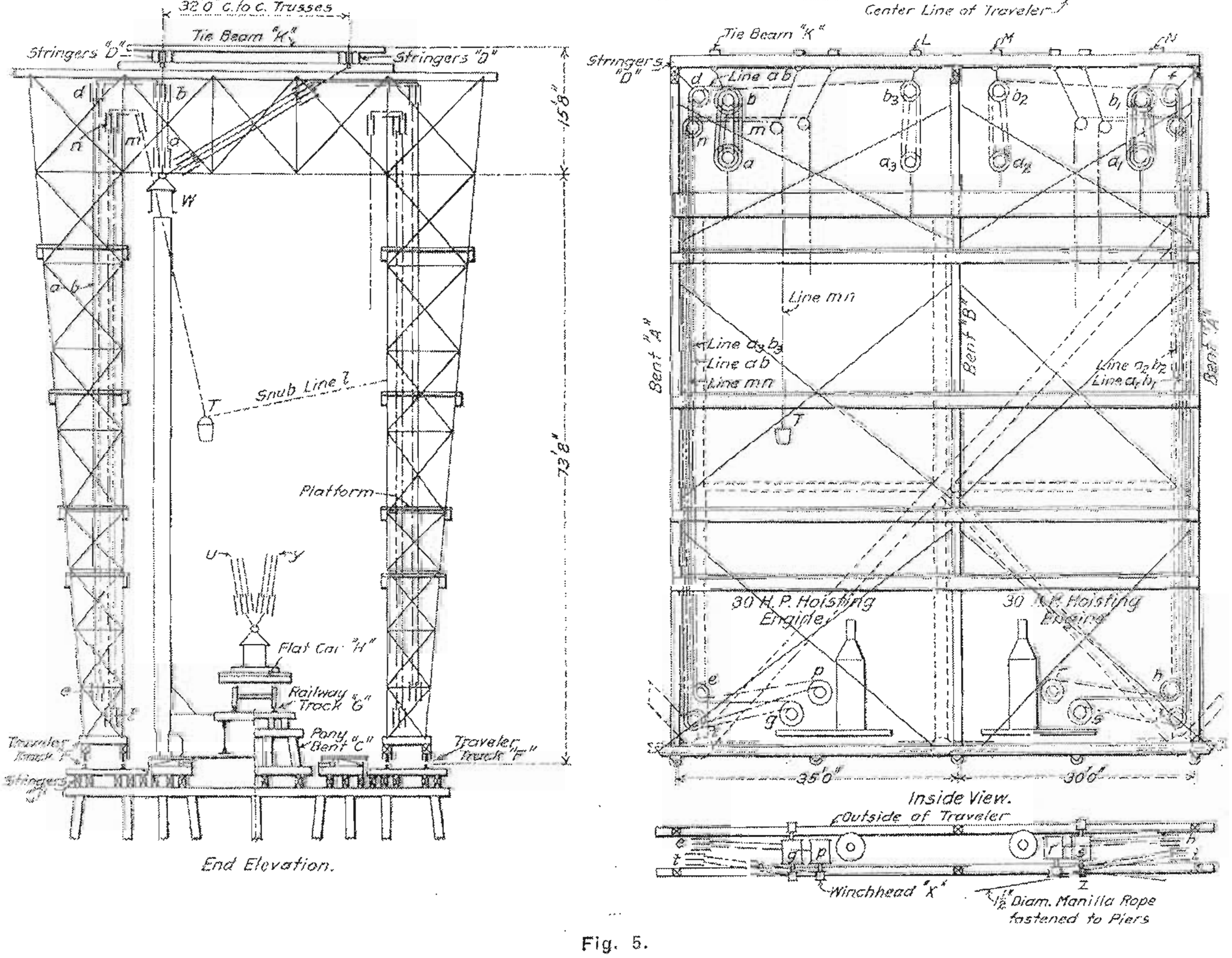


Fig. 5.

The traveler was only used for the erection of trusses, the floor system and bottom laterals having been put in with a derrick car. Fig. 5 shows the heavy top chord section being placed in its final position. The chord was run out on a flat car, H, to a point opposite its position in the truss. The tackles a-b to a3-b3 from the tie beams K, L, M, etc., were attached to the chord by a chain sling. The lead lines on all tackles were hauled in until the chord was lifted clear of the car. By increasing the velocity of haul of the lead lines of the tackles in position u over those in position y, the load is given a considerable lateral movement, bringing it to the position W at a low velocity, but remaining under control of the tackle y.

The lighter members were raised, as shown at T, Fig. 5, by means of a tackle from one side of the traveler only, and when raised from the car were prevented from swinging laterally with any great amount of force by the snub-line 1.

The traveler received its motion longitudinally by means of a line fastened to the piers at the ends of the span and containing enough slack to permit its being wound when required three or four times around one of the spools of the hoisting engine, as shown at Z.

Each bent of the traveler was framed in six sections on a platform on shore. These sections were carried out to a point on the falsework where the sills of the traveler had been previously placed and bolted together. The three bents were placed partly one above the other, as shown in Fig. 6, the feet of the bents being chained in their true position to the sills of the traveler, which in turn were fastened to the falsework. The first bent was raised by means of auxiliary bent, Z, 42 ft. high (Fig. 6), by means of the seven part block and tackle, one end of which was fastened to the top of the traveler bent and the other end of which rested on the top of the auxiliary bent, the lead line of which passed over the top of the auxiliary bent, thence down to a snatch block fastened to the falsework, and thence to a spool on the engine of the derrick car. The end of the tackle nearest the auxiliary bent was a three sheave block held by a double 2-in. manila pendant rope passing over the top of the auxiliary bent and fastened to the falsework. The bent was raised into position by hauling on the lead line, which caused the tackle to pull on the top of the traveler bent until it was revolved through the angle A to a vertical position. The second and third bents were raised in a similar manner except that the traveler bents already erected were used instead of the auxiliary bents.

The material yard was located, as shown in Fig. 1, about one-quarter mile from the east end of the bridge. The steel was shipped to the material yard from the shops in gondola cars as fabricated and unloaded by a derrick car. It was sorted and piled in the material yard as it was unloaded. The heavy material was unloaded on the temporary track at C, Fig. 1, and the lighter material was strung through a distance of a mile from A to B and beyond on both sides of the main track.

The 420-ft. spans were erected on the bents shown in Fig. 3, on which the pony bent C was used. First, on account of their great weight, the shoes, built up bottom chord sections, and posts L2 M2, were erected with the traveler, the material being carried out on flat cars running on the railway track G, Fig. 3, which rested on the pony bents C, then lifted from the flat cars and placed in their proper location by the traveler tackles a-b to a3-b3, Fig. 5, in the manner previously described for the top chord. Following this the floor system and bottom laterals were put in by a derrick car. In order to place bottom laterals and floor beams, the pony bents C and stringers L of Fig. 3, just in advance of the portion of the floor already placed and occupying approximately the position of the steel floor beams and stringers about to be erected, were removed by derrick car, No. 1, Fig. 3, which had been backing away from the por-

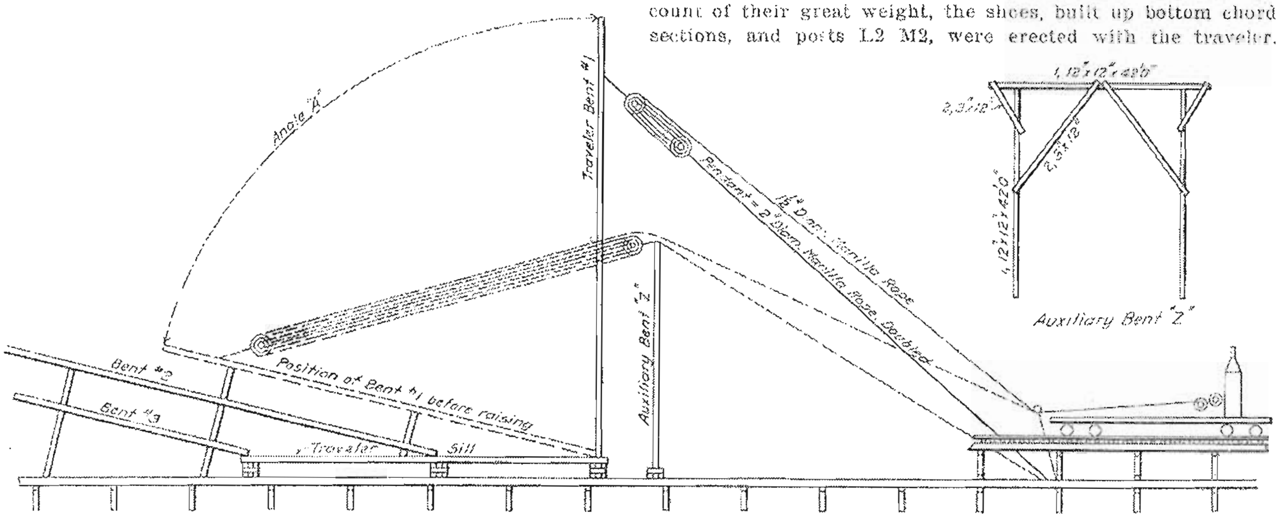


Fig. 6.

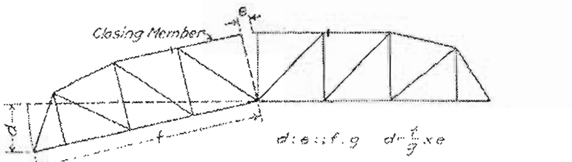


Fig. 7

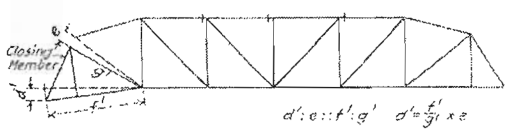


Fig. 8.

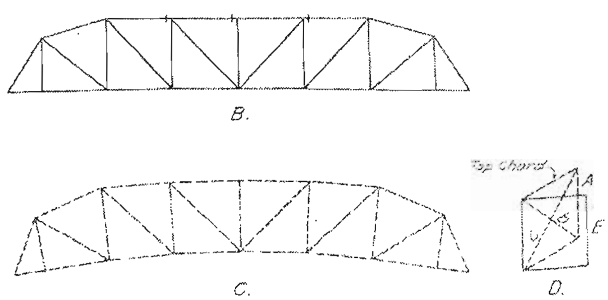


Fig. 9.

tion of the structure already erected. This derrick car No. 1 removed the temporary floor in advance of the portion of the steel work about to be erected and placed the material from the temporary floor upon the falsework alongside, where it could be picked up and carried off the structure when the floor was connected. After derrick car No. 1 had removed the panel of temporary floor immediately in front of it, it moved backward and picked up the next panel of floor to the west. Simultaneously with this, derrick car No. 2, Fig. 3, had been operating as follows: A load of floor beams and stringers were pushed out on a flat car in front of the derrick car and unloaded on the falsework alongside of the track as near as possible to their final position longitudinally. The flat car in front of the derrick car was then pulled out and the derrick car returned and placed the floor beams and stringers, which it had just unloaded, in their final position. the center of the span putting in the top laterals and completing the sway bracing of the span which it has just erected. The movement of the traveler continued past the center of the span to the west end, erecting the remainder of the top chord, batter posts and bracing. The pins were driven with a steel ram 6 in. in diameter by 16 ft. long, and weighing 1,600 lbs., suspended from the top of the traveler and operated by men working from whichever platform in Fig. 5 was just below the pin to be driven. All bottom chord splices were riveted before the span was swung, and all other connections were riveted after the span was swung. Two crews of nine men each were used on this traveler, one crew on each side. An average of about 14 days was required to erect each span, counting from the time that the first work was done in placing the shoes until the span was swung clear of the falsework.

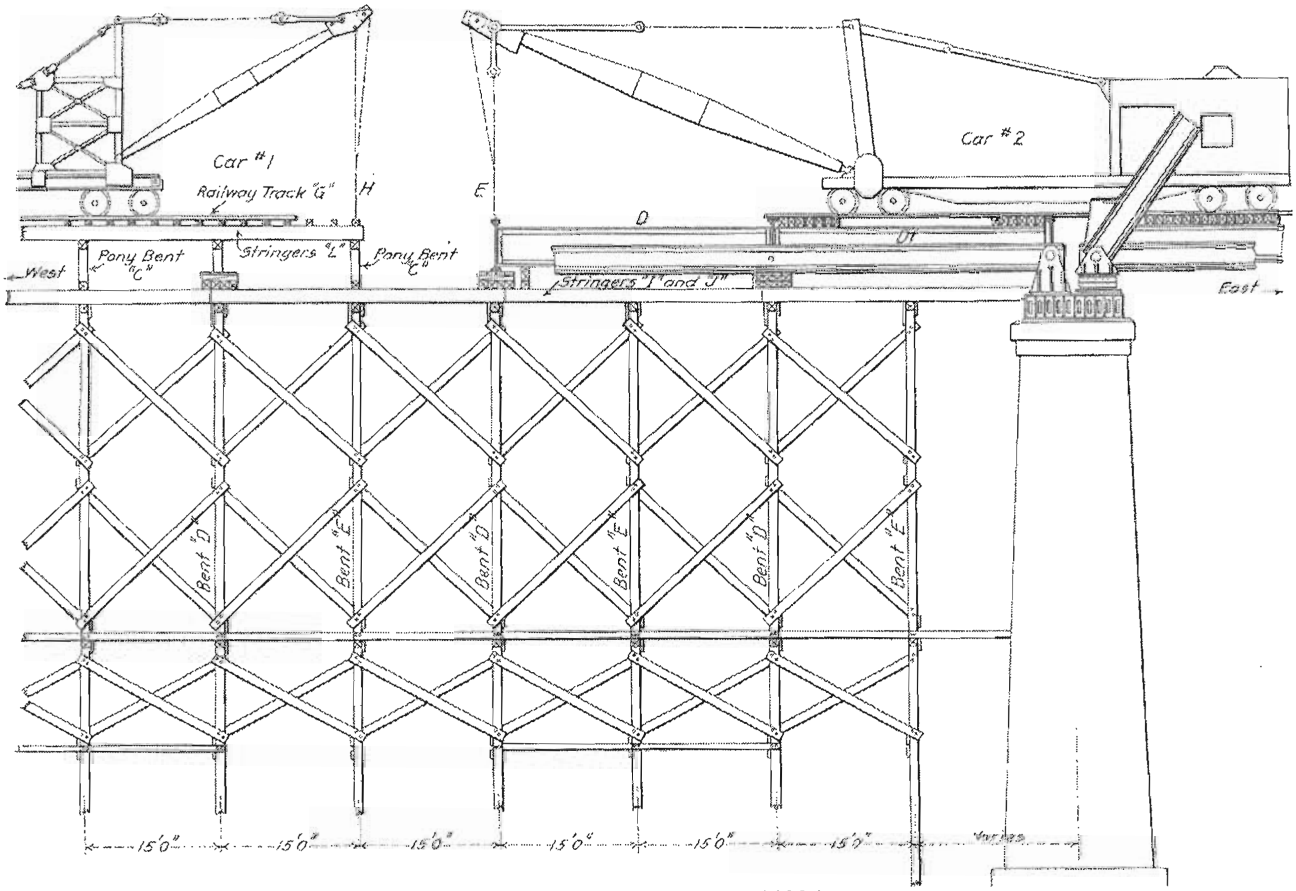


Fig. 3. (See Also Page 1406.)

During the entire time that the floor system and bottom laterals were put in by a derrick car, the gap or the break in the track between points H and E, Fig. 3, was open. After the floor beams, stringers and bottom laterals were placed, the track was restored and all material erected from this stage onward was brought out under the traveler on cars.

The steel floor having been placed, the end connections of the floor beams formed a convenient support to which all vertical posts could be fastened and be made secure without much guying. These posts, together with the other web members and the remainder of the bottom chord, were next erected in the following manner: Enough material for one full panel of bottom chord and web members was run out at one time on flat cars on the railway track G, Fig. 3 and Fig. 5, and erected by the traveler. Pins were then driven, except top chord pins.

Starting with the center of the span and working to the east end, the top chord section, batter posts and top struts were put in, the pins being driven as the several panel points were reached. The traveler was then started back to

On account of the danger of the approaching high water, the erection of the steel followed closely on top of the erection of the falsework. One derrick was either employed in upending the frame bents B, Fig. 3, which were assembled on tops of the pile bents A below or else was employed in placing the stringers. As soon as the panel of falsework had been completed this car moved back to pick up and place the steel floor beams and stringers necessary to complete the panel. In this way the erection of the falsework and the erection of the steel upon it were carried on practically simultaneously.

The end posts on the end top chord section at one end were the last members of the truss to be erected as previously described. This was due to some features of camber blocking shown in Figs. 7, 8 and 9. In Fig. 9, in full lines at B, is shown an outline of the truss when subjected to the dead load of its own weight. In dotted lines at C is shown to an exaggerated scale an outline of this truss when resting on the camber blocking, each panel being distorted, as is shown in dotted lines, and to an exaggerated scale at D in such a manner as to make the diagonal distance b less than the diagonal distance c and less than the true fabricated length of the member which will be located in the diagonal b. It is a simple matter to give each panel the shape shown at A by means of camber blocking, as the rectangle, the top and bottom of which are formed by the top and bottom chords respectively and the sides of which are formed by posts, approximate a four-sided figure each side of which consists of a stiff member but which is hinged at the corners. As the length of the diagonal distance b is less than the member occupying this position, by decreasing the amount of camber blocking, the panel at A can be brought toward a position shown by light lines E in which the distance center to center of end pins on diagonal b is exactly equal to the distance center to center of end pins of the member which occupies this position in the structure. Allowance is, of course, made for the conditions of sag, temperature, etc., under which the member is being erected.

This use of the camber blocking permits making the necessary adjustments so that all members of the truss can be erected except the closing side. If the center section of top chord, Fig. 7, is chosen for the closing member any error between the fabricated length of the top chord and the space left for it in the truss in amount equal to e would make it necessary to alter the elevation of truss by the amount d equal to $\frac{f \times e}{g}$, but if the end post is chosen as a closing member the total amount of vertical movement required for a similar error of like amount is shown in Fig. 8 to be $\frac{f' \times e}{g}$ or about 3/5 of the foregoing. An advantage is also obtained through the pin connection at either end of the end posts which permits of the use of the large force available from a pilot nut driven by a ram to force the last member into position. The steel trestle approach at the west end, for which no falsework was built, was erected as follows:

As the bridge was erected from the east toward the west, it was necessary to carry the material for the steel trestle through the 420-ft. spans. As the portals and the transverse bracing for these spans limited the clear head room, it was impossible to bring out columns for the steel trestle suspended from the boom of the derrick car, without fouling the transverse bracing of the trusses. Two columns, therefore, were loaded on a flat car which was pushed out ahead of the derrick car to a point near the west end of span III, adjoining the trestle approach. The columns were then lifted from the car by the derrick car boom, one column being placed each side of the track resting on the floor beams, as there was sufficient room to store these in this position for a few hours. Following this, two panels of transverse bracing for one bent and laterals for one girder span were loaded on a flat car in the same manner, pushed out and unloaded on a few temporary timbers laid from the top flange of the stringers to the bottom chord of the truss. The lateral bracing for one girder span which had been placed on the same car with the transverse bracing for the bents was unloaded by being merely thrown from the car onto the track between the rails. The members being light and containing no large projecting gusset plates, their position between the rails did not effect the clearance for cars moving over them.

The flat car was then pulled in the clear, the derrick car returned and picked from its position one column, to the top of which had been fastened longitudinal and transverse guy lines. The derrick car moved forward with the column at the end of the boom on the portion of the structure already completed, the length of the boom, 80 ft., permitting it to place the column a full span in advance of the completed portion of the structure. The remaining column of the same bent was placed in a similar manner and the two upper panels of transverse bracing were placed by being carried out on the boom of the derrick car and lowered by runner line into place.

THE SUCCESSFUL LOCOMOTIVE MECHANICAL STOKER: PENNSYLVANIA LINES WEST OF PITTSBURGH.

For the past ten years or more it has been generally recognized that a mechanical stoker for locomotives was desirable, because of the increasing demands made on the strength and endurance of the fireman by the growing proportions of the motive power. With the advent of the Mallet locomotive, what was desirable before becomes an absolute necessity, if this type of power is to be used in road service. For, as was recently pointed out in the *Railway Age Gazette* in a note on the performance of the Mallets on the Erie Railroad, no human being has the strength to fire one of those machines over a long division, if it is worked to capacity.

With this incentive a number of stokers have been developed and put on the market. They have succeeded in doing the main thing for which they were designed; that is, maintain the steam pressure on a run where the engine was worked with the usual trains and speeds. But they have failed, so far as any data that has been made public indicate, in two other essentials of prime importance. They have not only failed to show any economy in comparison with hand firing, but they have developed an excess of coal consumption. Then, they have failed to suppress smoke. In fact, no hand firing would be permitted that could not do the work with less.

With these general conditions and results before him, D. F. Crawford, general superintendent of motive power of the Pennsylvania Lines West of Pittsburg, attacked the problem. His first step was to analyze the conditions obtaining in hand firing. The coal is spread or laid on the top of the incandescent mass beneath, with the result that the volatile gases are immediately driven off, and a cloud of black smoke is emitted from the stack. If the same system is followed with a mechanical stoker the trouble with smoke is simply exaggerated. The machine, not possessing the intelligence of the man, will simply persist in scattering the coal, and green coal must necessarily fall upon that which is still unignited, increasing the density of the smoke and the corresponding waste of heat units in the unconsumed gases.

It therefore seemed desirable in the development of a new type of stoker to so arrange the distribution of the coal upon the grates that this excessive development of smoke, with the resultant waste of heat, would be avoided. In short, it was planned to have the stoker utilize the contained heat of the coal to the utmost and, to do this, it must work under practically smokeless conditions.

In addition to these theoretical or chemical requirements, as they might be called, it was decided that the stoker must do all of the work, from the tender to the firebox. And as it was to do this, it was laid down as an essential requisite that it should be built in so as to form an integral part of the locomotive itself and not be a mere appendage that could be detached and thrown to the ground in case of failure or breakage; while at the same time it should in no way obstruct the regular firedoor, but the latter could be used at once, as usual, in case hand firing became necessary for any reason.

Further, the development of design must be such that it can be readily applied to existing locomotive equipment without radical and expensive changes, not only to facilitate the application, but also to obtain immediate results in case the design meets the exacting requirement.

Starting in with the chemical aspects of the case, the only available means of distilling the gases and raising them to the ignition temperature before they could escape into the tubes was along the lines of the underfed stoker. This was a revolutionary innovation, but as it offered the surest solution of the smoke difficulty as well as giving promise of economical results, it was chosen and work started along these lines.

The problem as laid out, then, was to produce a mechanical stoker that should maintain the desired steam pressure under