THE COVINGTON AND CINCINNATI SUSPENSION BRIDGE.

Part 1.—The Original Structure. Features of Present Reconstruction. General Elevation and Section Details and Design of Anchorage and Saddle Girders.

The Covington and Cincinnati suspension bridge was designed and built by John A. Roebling, at a cost of $1,828,00. It was begun in 1857, and when finished in 1867 was the heaviest and the longest suspension bridge in the world. Its total length was 2,206 feet, width 36 feet, height of towers 200 feet, river span 1,057 feet long, and 103 feet above low water mark at the center and 91 feet at the towers. The clear width of carriage way was 20 feet and the maximum grade 5½ per cent.

There were two iron cables, each 1,700 feet long and 12½ inches in diameter, with an aggregate breaking strength of 8,400,000 pounds. Each cable contained 5,000 No. 9 B. W. G. wires of 1/60 square inch sectional area. The wires were laid in seven strands which were connected to the anchors by chains of iron eye bars in alternate sets of 16 and 17, which with the ends of the cable were bedded in cement masonry. The cables had a versed sine of 90 feet, and were cradled so as to lie in inclined planes 50 feet apart at the saddles, 36 feet at the anchorage and 24 feet at the center of the span.

The towers were built of masonry, each having a single pier, about 83 feet by 53 feet in extreme dimensions, resting on a timber platform which is sunk 12 feet below low water to hard gravel foundation. The piers were built solid, excepting a 19x30 foot well hole on the center up to the floor level. Above the floor they continue in separate portions on each side of the roadway. These pairs of towers are each about 40 by 22 feet, and were united by a masonry arch of 30 feet span and 20 feet length over the roadway, with the crown of its intrados 73 feet 6 inches above floor level. Above the arch the masonry was carried up to form a single tower, about 75 by 40 feet in extreme dimensions, with seats for the cable saddles at an elevation of 197 feet above low water, and an ornamental cornice and parapet around this platform.

In 1895 the traffic across the bridge had attained a volume averaging 1,200 electric cars, 1,000 trucks and wagons, and 6,000 foot passengers a day, and in order to increase its capacity, add to its strength and rigidity and permit an unlimited speed of vehicles upon it, the present reconstruction was undertaken. This involved the rebuilding of the approaches and extending them 557 feet, so that the total length of the bridge is now 2,763 feet, the rectification of the grade, the widening of the carriage way and foot walks, the addition of effective stiffening trusses, and the building of two new cables and anchorages that more than double the carrying strength of the structure. The new cables are each 1,970 feet long and 10½ inches in diameter, made up of 2,226 wires, No. 6 B. W. G., in 21 strands, and having a total breaking strength of 24,000,000 pounds for both cables. Between the towers these cables are exactly 6 feet above the old cables and parallel to them in the same planes as the old ones, which have been changed to suit the new construction. Beyond the towers the old and new cables diverge slightly, and the latter go to new anchorages, where they are secured by steel eye-bar chains with seven and eight members in alternate panels. The stiffening trusses are 31 feet 3 inches apart center to center and are ordinary pin-connected Pratt trusses, with intersecting diagonals in each panel and adjustment sleeve nuts in all the counters. The trusses are continuous from anchorages to the middle of the river span, where expansion is provided for by a telescopic joint. The channel span trusses are 13 feet 6 inches deep at the towers and 28 feet deep at the centers, all the top chords being curved, and all the bottom chords (which are also compression members) being straight, except as they conform to the camber, which is 10 feet 6 inches in the main span and approximately corresponds to the arc of a circle of 13,280 feet radius. In the reconstruction of the bridge the new anchorages were first built, and by the time they were finished the new approaches were completed. Then the new cables were laid and adjusted, the old and new cables were brought to the same planes, the new floor system was assembled, and finally the new stiffening trusses were erected.

The outline of the reconstructed bridge is shown in Figure 1, which gives a diagram of old and new cables and of the new stiffening trusses, but omits a portion of the Cincinnati approach, which is also in line of the bridge axis and comprises 177 feet of embankment with masonry retaining walls 52 feet wide from out to out of parapets, one 25 foot and two 66 foot plate girder street crossings, and a deck plate girder viaduct 49¾ feet wide with 33-foot spans

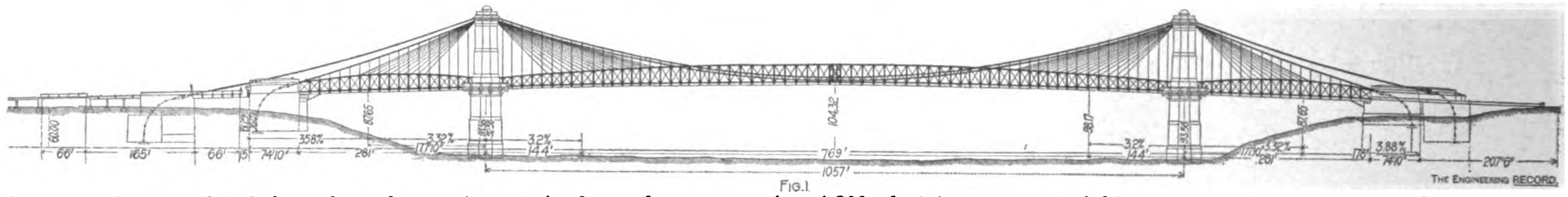

FIG. 1

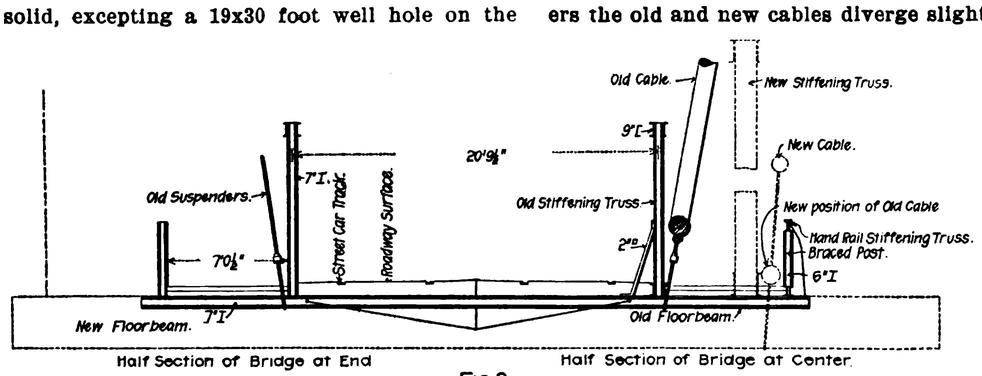

FIG. 2

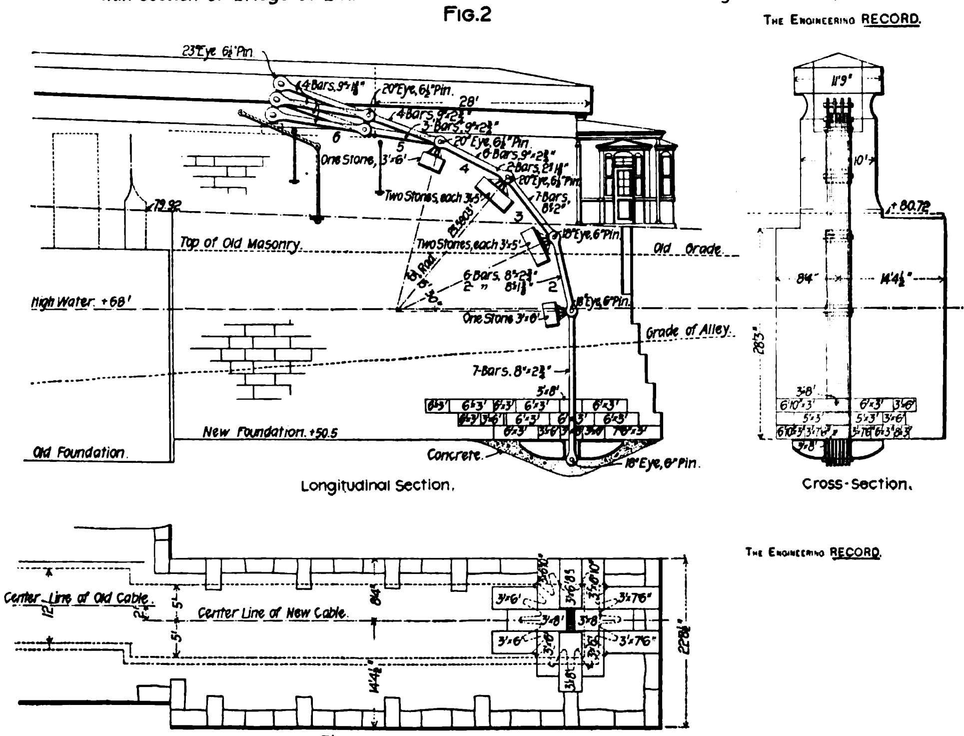

FIG. 3

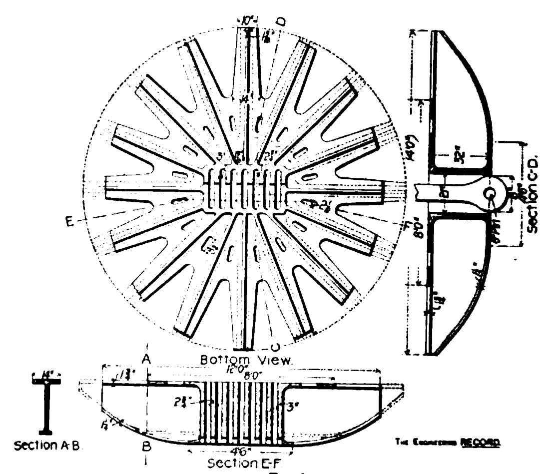

FIG. 4

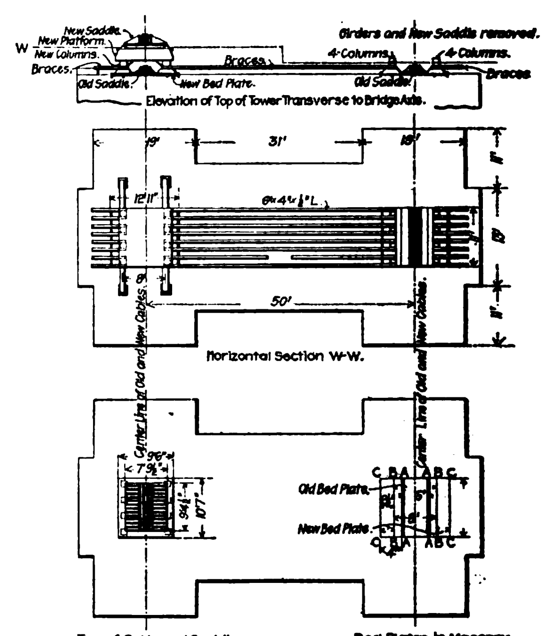

FIG. 6

THE COVINGTON AND CINCINNATI SUSPENSION BRIDGE.

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on steel columns, 200 feet long altogether, which is partly shown on the left of Figure 1. At the anchorage the roadway is 25 feet 10 inches wide between the walls of the eye-bar chain wells; elsewhere the roadway is everywhere 30 feet wide and has a 9-foot sidewalk cantilevered out each side and carried around the outside of the tower masonry. The old bridge had a roadway of 20 feet 9½ inches in the clear and two 7-foot side walks, as shown by the cross sectional diagram, Figure 2, which indicates in dotted lines the relative new positions of the old and new cables and the outline of new floor beam and stiffening truss. The old stiffening trusses were made with I-beam vertical posts, flat diagonal bars and pin connections at the bottom and a Howe truss screw connection at the top. The floor was of plank and the floor beams, which were spaced 5 feet apart, were simple 7-inch iron I-beams 38 feet long. These beams were reinforced by a 9-inch center longitudinal stiffening stringer on top, and a 12-inch I-beam at the bottom, which served as the king post for the support of a tie rod. In Figure 2 a half cross-section at the center of the span is shown at the right, and a half cross-section near the tower is shown at the left.

The approach viaduct consists essentially of five lines of longitudinal plate girders with 20-inch rolled transverse beams 8 feet apart for the roadway, and 10-inch ones under the sidewalks. The roadway floor is of concrete filled in 8 inches deep above the tops of longitudinal riveted steel troughs, and paved with brick between the 90-pound girder rails that rest on 6x7-inch cross ties laid on the troughs.

The new anchorages are arranged as shown in Figure 3, and are accessible for the upper two panels, the lower ones being built in solid in the ashlar masonry forming the pier, about 66x23x28 feet in principal dimensions and calculated to provide a reaction of 7,300 tons for the anchor shoe, to resist a maximum tension of 3,900 tons. The lower three courses are of dimension stones fitted in solid around the chain for about 18 feet around it. Each of these courses and the face walls was carefully laid out with headers and stretchers, and accurately cut and fitted. The rest of the pier is built of first class heavy rubble hearting and ashlar face stones, mostly 3x6x2 ft. The first two courses are each of 22 inches rise, and the remainder are 2 feet each. The cast-steel anchor plates, Figure 4, are 14 feet across, 32 inches deep, made of metal from 1¼ to 2½ inches thick, and weigh 23,700 pounds each. The arrangement and dimensions of the anchor chain where it is attached to the cable strands is shown in Figure 5. The lower panels are similar to panels 4 and 5.

The arrangement of cable supports on the tops of the towers is shown by half plans and elevation diagram in Figure 6. The old cables are supported on saddles rolling on two 8x11 feet cast-iron beds B B B B, each set in cement mortar in a depressed bed sunk in the surface of the masonry. These depressions were extended 2½x11 feet each side of each old bed, and in them were set new cast-iron bed plates B C C B, two at each saddle, eight in all, with their upper surfaces continuous with those of the old bed. A portion of the bed of the old saddle A B B A about 1½x11 feet extended clear of the vertical web, and this together with the new bed of the plate formed a surface A C C A about 4x11 feet each side of each table, upon which a new base plate was set to carry the new structure that supports the new cable above the old one. On each base plate were set four short heavy steel columns with their tops connected

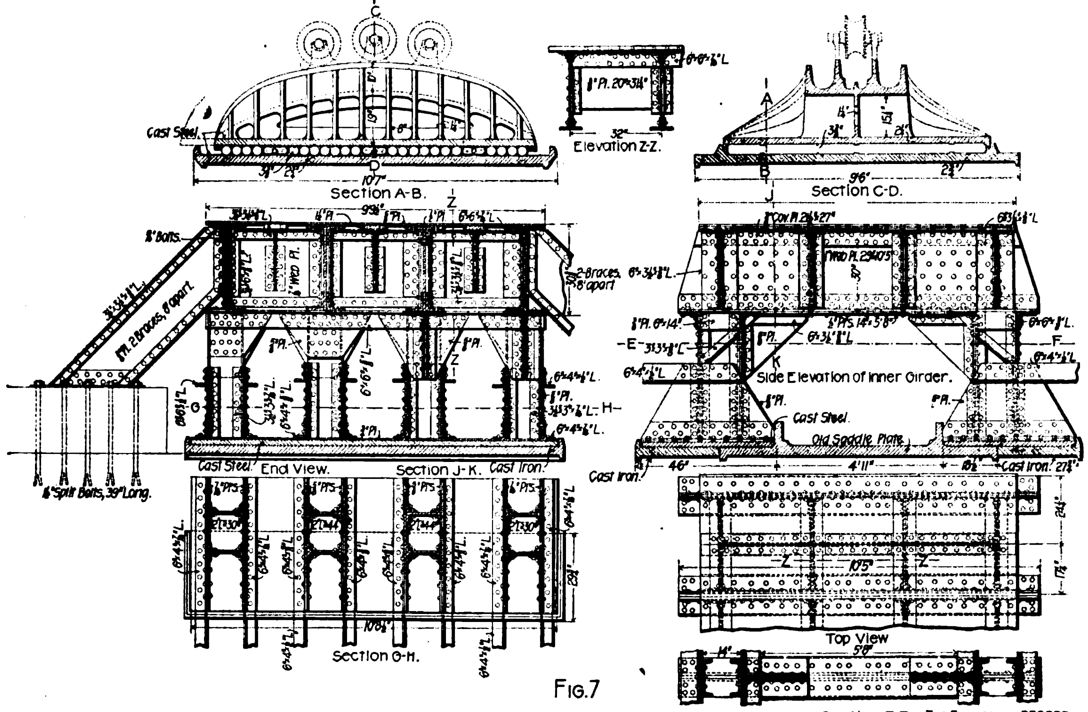

Fig. 7

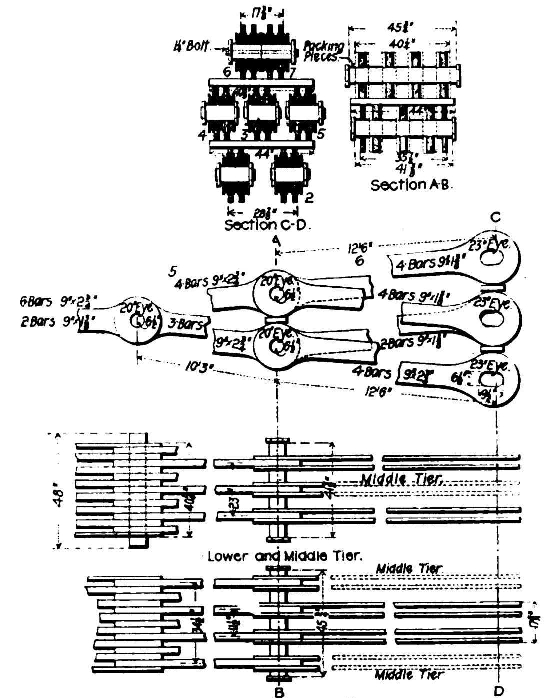

Fig. 5

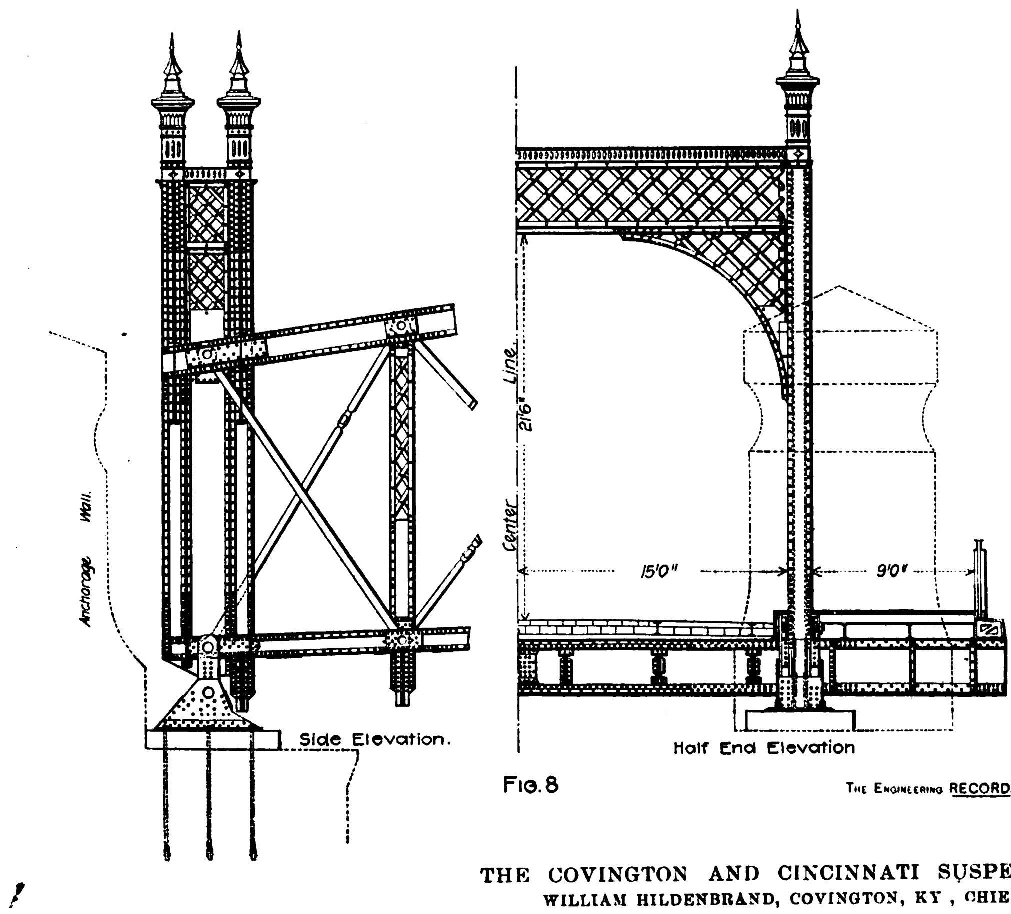

Fig. 8

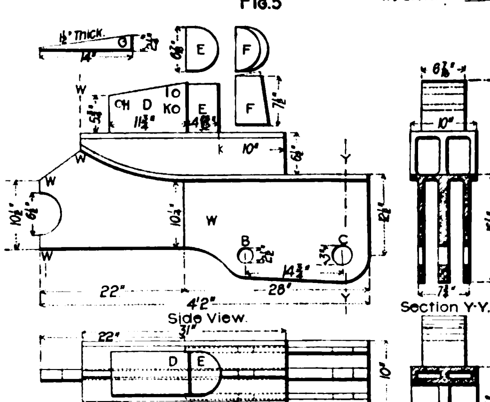

Fig. 9

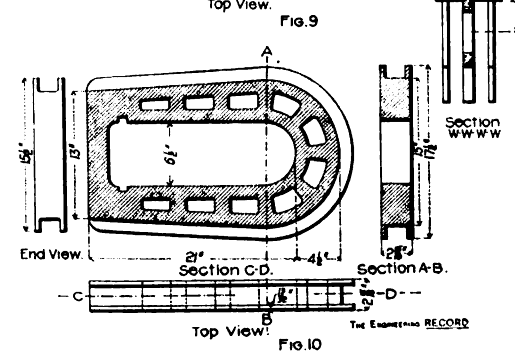

Fig. 10

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WILLIAM HILDENBRAND, COVINGTON, KY., CHIEF ENGINEER.

by a system of 30-inch plate girders, transverse to the bridge axis, riveted together with web connections, and to a thick horizontal top plate, so as to form an eight-legged platform 9 feet 2 inches by 9 feet 9½ inches on top and 6½ feet in extreme height above the top of the masonry that stands like a table above each of the four old saddles, clearing them and their cables, and providing a support above their centers, upon which in each case is set a cast-steel bed, rollers and saddles. The principal details and dimensions of the new saddles, platforms, etc., are shown by sectional plans and elevation in Figure 7. The general design of the stiffening truss and the features of its end portals at the anchorages are shown in Figure 8. The floor in the channel span roadway is of pine plank, 5½ inches thick with a 2½-inch oak wearing surface, and has been raised 3 feet above its former position at the center of the span, and 7 feet at the end abutments.

Mr. William Hildenbrand, who has been engaged previously on suspension bridge work for the Brooklyn bridge, the Sixth Street bridge, Pittsburg, the Wheeling bridge, and other places, is the engineer of the work, and has designed and prepared the plans and supervised the new structure with the aid of but one professional assistant for the field work and inspection, namely, Mr. Allan Cox at first and afterward Mr. S. W. Gunn. The data from which the structure is here described were received through Mr. Hildenbrand's courtesy and from the contractors.

The cost of reconstruction will be about $650,000 in all, including the acquisition of real estate for the extended Cincinnati approach and also all temporary work and constructions for maintaining traffic and for raising the grade. The work has been executed in day's labor by the employees of the bridge company, who built and adjusted the new cables, attached the suspenders and stays, laid the track and floor, raised the old bridge and did all the temporary work necessary for maintaining the traffic, which was never interrupted during the whole construction.

The Edge Moor Bridge Works, of Wilmington, Del., of which Mr. S. P. Mitchell is manager and Mr. C. W. Bryan is engineer, were the contractors for the general steel work. They built and erected the floor system and trusses of the suspension bridge and the plate-girder viaduct of the Ohio approach. The mill and shop inspection was done by Mr. G. C. Henning. Messrs. Kirchner & Folz, of Cincinnati, O., general contractors, built the anchorages, which were afterward increased by Contractor Thomas Malony, who also filled the well holes of the towers with concrete. Messrs. John Malloy & Son were contractors for the concrete piers, masonry, abutments and retaining walls of the Cincinnati approach, as well as for building the ornamental cupola-capped turrets over the saddles on top of the towers. The Phoenix Bridge Company, Phoenixville, Pa., John Sterling Deans, M. Am. Soc. C. E., chief engineer, furnished the anchor bars, and the Pennsylvania Steel Company, Steelton, Pa., J. V. W. Reynders, M. Am. Soc. C. E., engineer of bridge department, furnished the cast-steel saddles and built and erected the saddle bridges. The huge cast-steel anchor plates were furnished by the Pennsylvania Steel Casting & Machine Company, of Chester, Pa. All cable wire and wire rope was furnished by the John A. Roebling's Sons Company, of Trenton, N. J.

(To be Continued.)

NOTES ON SPIRIT LEVELING.

At the meeting on February 16 of the American Society of Civil Engineers Mr. Herbert M. Wilson, M. Am. Soc. C. E., presented a paper on "Spirit Leveling of the United States Geological Survey," giving a summary of the details of manipulation, the cost, the rate of speed and the accuracy with which the work was performed. In the correspondence on this paper which is printed in the "Transactions" a number of interesting points were brought out, drawn from experience in various localities. Mr. W. Carvel Hall, who had been running a line of spirit levels in the South for the past two seasons, considered a rod with a flat foot resting on a conical surface preferable to one which rests in a cup-shaped turning point, not only on account of the greater chance of dirt clogging the foot of the rod and point, but because the radius of the cup-shaped point must be larger than that of the rod shoe, and it is possible that there may be a change of height with the rod apparently in the same position. The wedge-shaped stripes on the faces of the targets gave a much better mark for setting than either a plain stripe or the line of division between two colors. The form of the vernier obviated any parallax in the rod readings, the effect of which had been very large for the first 30 miles of the work referred to. On some days the leveler and rodman had differed 20 times in their reading of the same rod, though the personal equation was slight, as sometimes one was too high and sometimes the other. The cross-section of the latest rods was cruciform, which will be much superior to the rectangular shape adopted for the second set of rods, as these warped badly, and when the rod-levels showed them to be plumb other parts of the rods were inclined, making it difficult to bisect the target. The "double targeted" rods save a great deal of time when it is required either to run in the reverse from the normal direction or to have the leveler check the rod reading before duplicating the lines in the same direction. As Mr. Wilson showed in his paper, a skin of paraffined wood is sufficient to prevent the rod from swelling on account of dampness and is much better than thorough saturation, because then the screws will not hold, and the rod, being so heavy, it is difficult to keep it from being badly scarred and splintered. The level used in this work was very rigid, kept its adjustments well and was remarkably steady in windy weather, as work had to be stopped on account of the rods before the instrument was much affected. The wind did not cause the level to vibrate, but made the bubble travel away from the wind, and that only in very bad gusts.

Mr. Wilson devoted some space in his paper to a consideration of spirit-level methods as distinguished from geodesic methods for such work, making reference to the lines run by Mr. C. H. Van Orden, assistant of the United States Coast and Geodetic Survey, from mean sea at Boston to the old Coast Survey "Gristmill" bench mark at Greenbush, N. Y., where the spirit level determination was nearly a mean between two geodesic determination. Professor T. C. Mendenhall, then superintendent of the Coast Survey, tested the instruments and methods used in this work and stated the result was such as to give him great confidence in the line referred to. Mr. Wilson expresses in his paper a preference for spirit leveling. It seems, he states, that, providing the instrument is well made and substantial, and the bubble sufficiently sensitive, precise spirit leveling should be more accurate than geodesic leveling, because the operation is simpler and more direct, while its results are at once evident and unencumbered by complicated and bulky computations. The primary argument against geodesic leveling, as compared with spirit leveling, rests, says Mr. Wilson, on the fact that in the former all the burden of exact observing and recording rests on the shoulders of one individual, the levelman; whereas, in spirit leveling the burden of these observations is distributed, resting not only on the levelman, but on two others, the rodmen, who, if they are fairly high grade and intelligent men, constitute a valuable check on this stage of the work. Again, no instrumental errors, that is, errors by instrument construction, need enter into the spirit leveling which cannot be readily eliminated by adjustment, repeated rod settings and equalized sights; whereas, in geodesic leveling every error in instrument construction affects the work seriously, through the fact that it is used as an angle-reading instrument as well as a spirit leveling instrument, and corrections must be made for errors of micrometer run, errors of collimation, etc. Mr. Hall points out a serious objection to geodesic leveling aside from those mentioned by Mr. Wilson, for the leveling instrument when in use in the field is always settling. There are very few cases where masonry can be used as a support, and as there is nothing whatever which tends to raise the level it must settle. The worst places are where the frozen ground, thawed by the tripod legs, lets the instrument down quicker than usual, and it is almost impossible to keep the bubble centered. In geodesic leveling, after recording the reading of the micrometer head at each station, which indicates the point at which the bubble is level, it is assumed that the reading remains constant during the time of observing at that station. Mr. Hall does not think this can be the case, but that the instrument settles, and the vertical angle computations, instead of being based on a level line as assumed, are really based on lines more or less inclined, which, if true, introduces a serious source of error. Records of a single day's work are quoted to show the relative differences in heights of adjacent turning points. The sights were all between 295 and 305 feet long and the total divergence between the two lines for that day was only 0.004 feet. Six times no difference was made; eight times there was a difference of 0.001 foot, ten times of 0.002 foot, six times of 0.003 foot and twice of 0.004 foot. All this difference cannot be charged to the incorrect centering of the bubble. Part goes to the settlement of turning points and instruments, part to "split thousandths" and part to the inaccurate bisection of the targets. Though the bubble may not be truly centered invariably, still the error, by careful manipulation, would be a balancing one and of slight effect on the work. Mr. Hall believes better work can be done with the 8-second bubble than with the very delicate bubbles generally used in precise leveling, for they are affected by outside influences and are not so integral a part of the instrument, consequently centering the bubble will frequently throw the instrument out of level. Though shorter sights must be taken with the coarser bubble, more work can be done with it in a day because of its easier manipulation. The speed attained in the work of the Geological Survey during the past season has apparently been about 7.5 miles per day, against 5.6 miles for that of geodesic leveling, which Mr. Hall considers not such a great difference after all.

Mr. C. H. Van Orden could not agree with Mr. Wilson as to the non-importance of a bubble-tender, as he considers it of the greatest importance to have a man to keep the bubble in the middle of the tube at all times; so important, in fact, that it is to him nearly the difference between good and ordinary work. Professor Boersch, in the "Zeitschrift für Vermessungswesen," after a discussion of the precise level states that it remains always preferable in field observation, where the tripod is used, to employ bubbles which come to rest. Mr. Van Orden considered the double simultaneous line of the highest value—for check, if for nothing else—and urged its use even if it were to be run both ways. With a height of instrument common to both lines one is enabled to pick up small errors, such as one rod not on the highest point of the bench, mud on the bottom of the rod, mistake of an even hundredth in reading, etc. It is also important in making observations where there is refraction. Results do not verify the stress which has been laid on the value of short sights and of sights of the same length at all times. In the double line between

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CONDUCTED BY HENRY C. MEYER.

VOLUME XXXIX.

DECEMBER, 1898–MAY, 1899

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100 WILLIAM STREET
NEW YORK.

Mr. Leffert L. Buck, M. Am. Soc. C. E., is chief engineer and designer of the new East River Bridge; Mr. O. F. Nichols, M. Am. Soc. C. E., is principal assistant engineer; Mr. Edwin Duryea, Jr., M. Am. Soc. C. E., is resident engineer in charge at the Brooklyn end, and Messrs.

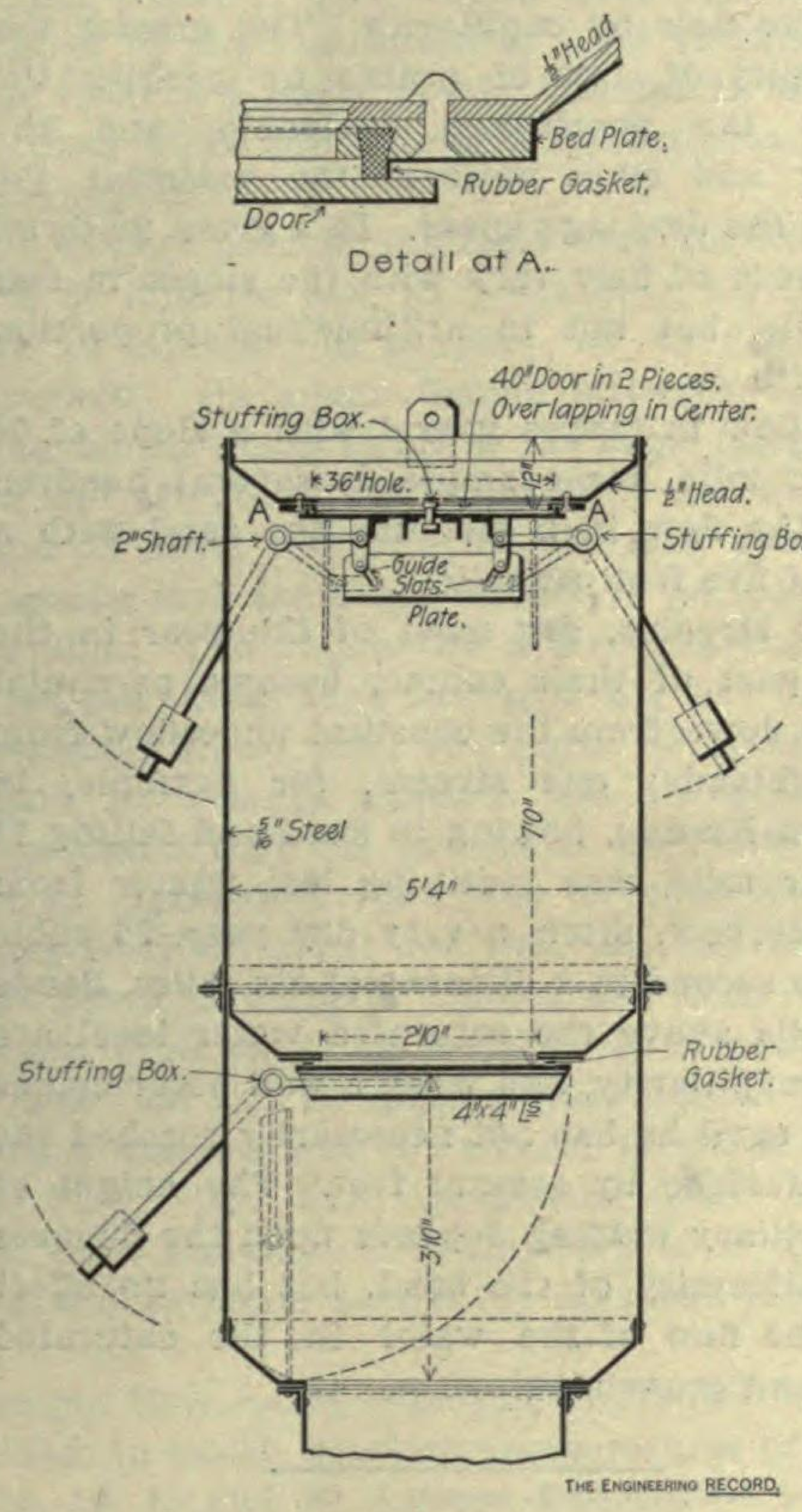

FIGURE 5.—MATERIAL LOCK.

F. L. Pruyn, C. E., and O. F. Kelly, C. E., are his assistants on the caissons. The contracts for the anchorage and foundation work are let to the Degnon-McLean Construction Co., of New York, Mr. A. A. Stuart, M. Am. Soc. C. E., chief engineer; Mr. W. O. Porter, general superintendent, and Mr. James E. Taber, superintendent of compressed air work.

THE COVINGTON AND CINCINNATI SUSPENSION BRIDGE.

Continuing from the issue of September 10 and November 26 the description of the Covington and Cincinnati suspension bridge, reference may be made to typical and special details characteristic of the connections throughout the stiffening trusses, and of their principal features, as shown in the accompanying Figures 16 and 17, and in Figure 8, page 315, Volume xxxviii. In Figures 16 and 17 the elevations are condensed and intermediate portions are omitted to save space, and in both cases the plans and transverse elevations are symmetrical about their center lines. The ends of the side elevation of the floor beam are omitted in the transverse elevations of both Figures 16 and 17, and the portions omitted are exactly the same as the corresponding elevations in Figure 8. A general view of the suspended structure of alternate panels is given in Figure 16. The adjacent panel points are similar except that the transverse top lateral strut and its four curved knee braces in the vertical and horizontal planes are omitted.

The slip joint in the center panel of the stiffening truss is shown in Figure 17. It was required to preserve the vertical and lateral continuity of the trusses and transmit all strains through them at this point, and yet provide for temperature variations in length at this point. This was accomplished by virtually making the two trusses four sides of a rectangular tube in this panel. The tube was practically in two sections, with a foot clearance between adjacent ends, and longitudinal members, A A, like sliding bolts, were fixed to one side, extended from it across the open space, and moved freely back and forth in rectangular cases, B B, etc., made in the other tube to receive them. Two transverse vertical and horizontal struts, S S, etc., were put in the center panel of each truss and in the horizontal plane of their top chords, and these, with the six intersecting longitudinal horizontal boxes B B, for the sliding connections, subdivided the three original panels into 27 sub-panels, each of which is braced with a pair of stiff riveted diagonal angles. The top and bottom chords themselves served as four of the boxes B, and the remaining six were made with similar cross-sections, except that their cover plates were very wide and extended beyond the flange angles. Channels and angles were riveted inside these boxes at one end of the tube, back to back with the web and flange plates, and extended inside the boxes of the adjacent tube, where they fitted closely and moved freely. The lower half of the main truss corresponds essentially to the upper half, and is therefore omitted in side elevation.

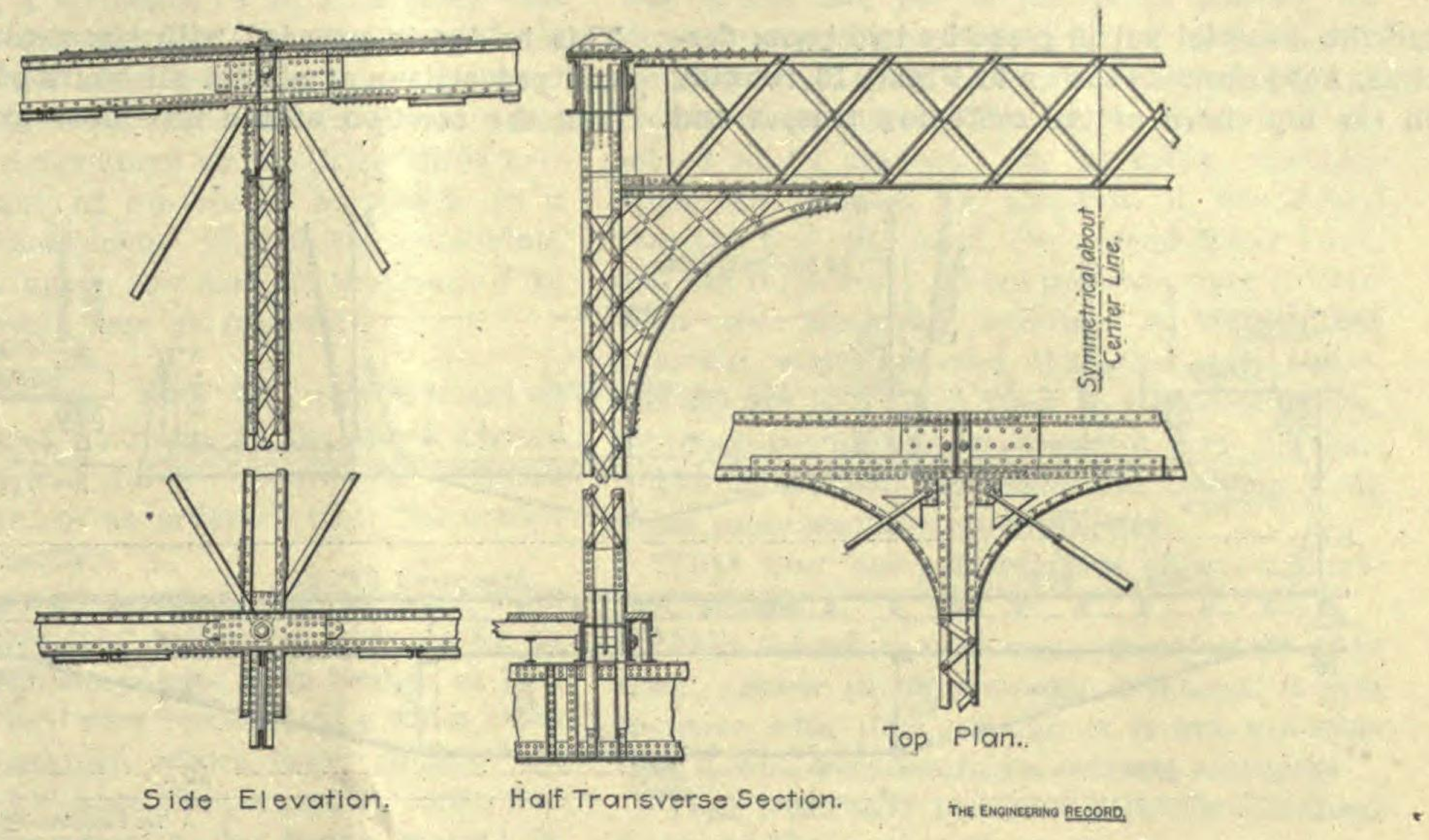

FIGURE 16.—CONNECTIONS OF THE STIFFENING TRUSS.

The work of erection of the bridge proper was begun by suspending from the cables the new floorbeams, which are 15 feet center to center. The permanent suspenders were used as far as possible for suspending these beams, but toward the center of the span temporary suspenders were provided. The attachment of the floorbeams in every case to the suspenders, however, was temporary, as it had to be shifted after the new stiffening trusses were erected. The floorbeams were lifted from a barge in the river below by balance beams projecting from and in front of the suspended traveler, Figure 18. As the floorbeams were put in place the 9-inch I-beams forming the sidewalk stringers were bolted on top of them at each end, thus making a track for the two trucks that carried the traveler and its platform underneath the old bridge and new floor. One sidewalk was abandoned, and the new stringers, etc., were run out on this abandoned walk, lowered upon the working platform, and put in place between the floorbeams panel by panel. As each panel of floor was in this way completed, the 7-inch I-beams forming the floorbeams of the old bridge were wedged up on the new longitudinal stringers, thus transferring the floor loads from the old suspenders to the new temporary suspenders which had been provided. The 7-inch floorbeams were left permanently in the new structure, and new 7-inch beams introduced between each of the old ones, thus making cross floorbeams on top of the longitudinal stringers 2½ feet from center to center, upon which was laid the floor-planking, girder rails, etc. After the floor system was hung from temporary suspenders and in place complete, as described above, the old suspenders were slacked off and the cables allowed to spread out to about their permanent position in the new structure, so that the new stiffening trusses, which are about 31 feet centers, could be erected in their final position between the cables.

During erection the stiffening trusses were supported on the floorbeams at each panel point

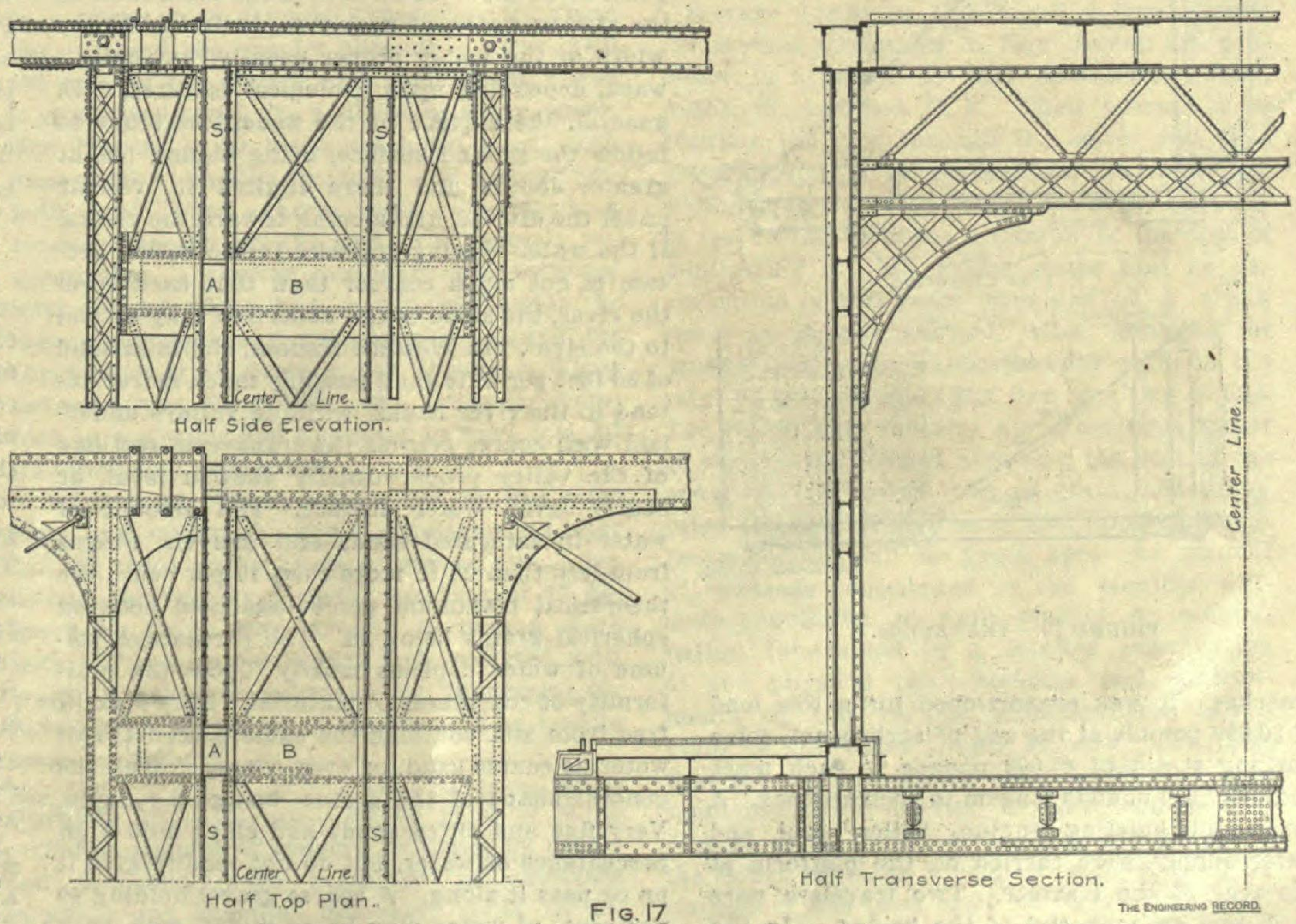

FIG. 17

THE COVINGTON AND CINCINNATI SUSPENSION BRIDGE.

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and the material put in place by two boom derricks, built about as shown by Figure 19, running on the top chord of the stiffening trusses and working out from both sides of the river simultaneously. When the new trusses were completed and the floorbeams pulled up to their proper position with relation to the stiffening trusses and the connections bolted, the old stiffening trusses were removed. After this the floorbeams were attached permanently to the suspenders, the new floor-planking laid, etc.

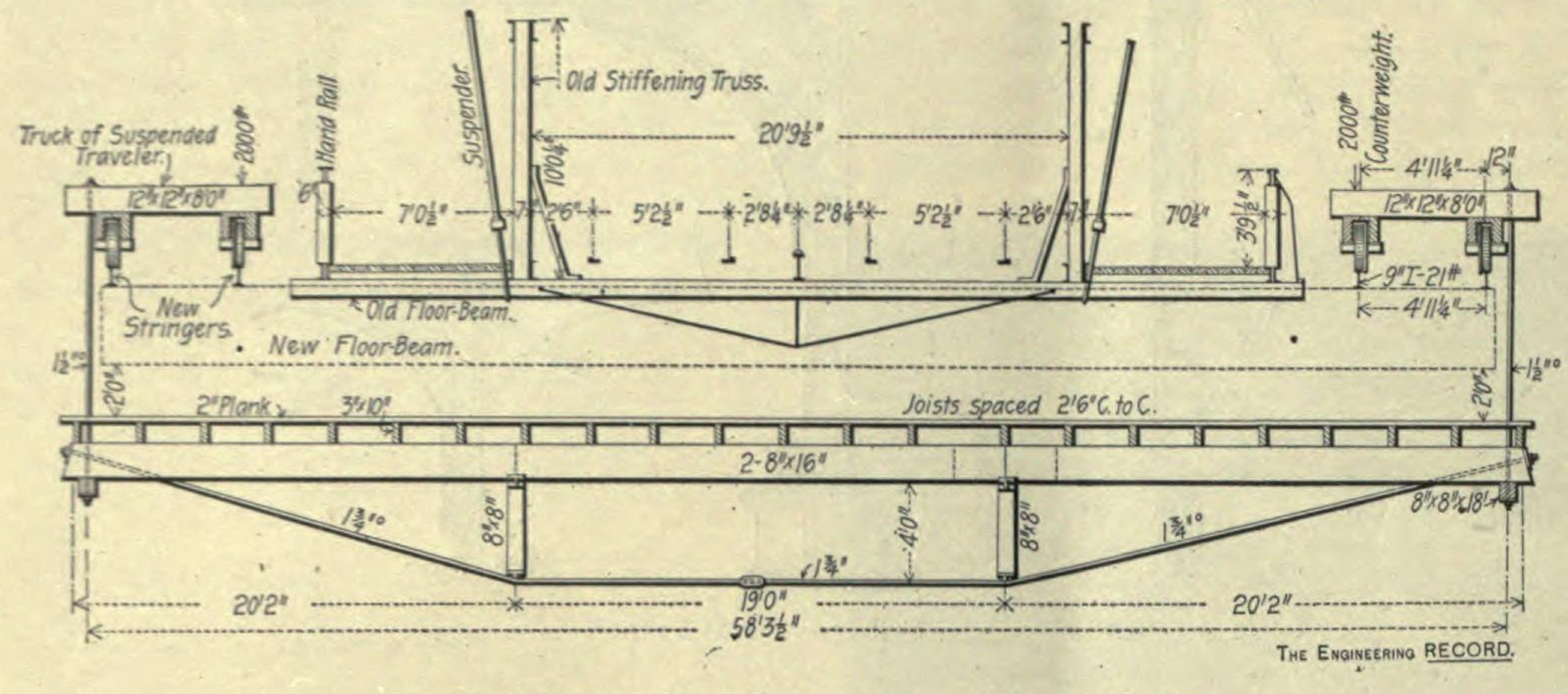

FIGURE 18.—METHOD OF ERECTING FLOOR BEAMS.

The same traveler was used for erecting the suspended superstructure and the viaduct approaches. It was proportioned for a live load of 30,000 pounds at the end of each boom, for a working strain of 45,000 pounds in each mast and of 47,800 pounds tension in each stiff leg. A four-spool hoisting engine, boiler, coal and water supply were carried on the platform at the rear of the traveler. Two travelers were used, one on each end of the bridge. In the plan, Figure 19, only one-half is drawn, as the figure is symmetrical about the center line.

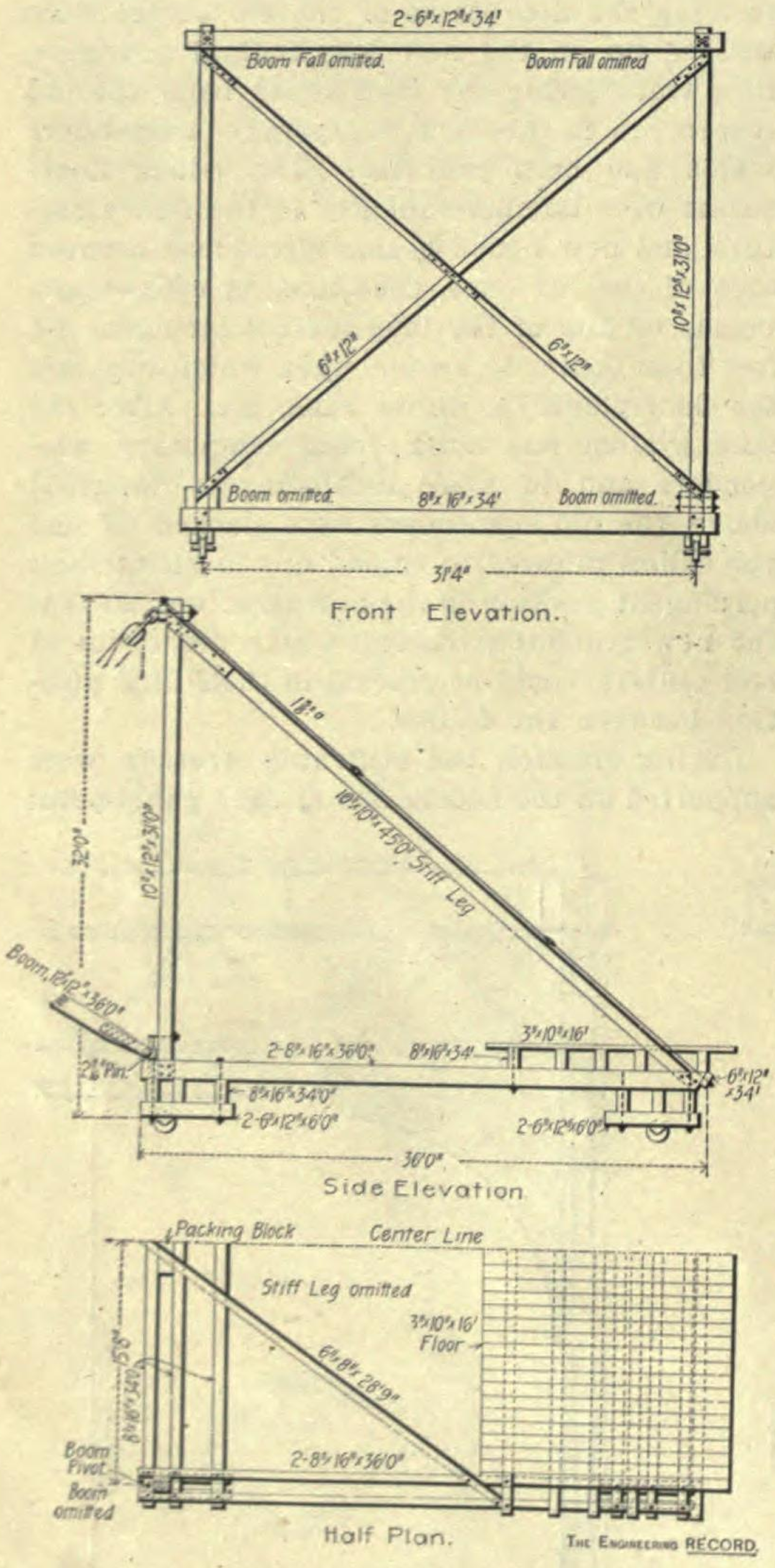

FIGURE 19.—TRAVELERS.

This bridge is crowded with street-cars, teams and pedestrians at almost all hours of the day, and the erection of the new floor system and stiffening trusses was done without interruption to traffic or without any one being hurt.

THE FLOW OF GROUND WATER.

The flow of ground water, or the underflow, as it is called west of the Mississippi, has been investigated for several years by Mr. H. V. Hinckley, M. Am. Soc. C. E., and at the twenty-fifth annual meeting of the Kansas State Board of Agriculture he described a number of the interesting results of his laboratory and field tests. The subject is an important one for both water-works and irrigation engineers, because the most reliable supply on the great plains, according to Mr. Hinckley, is afforded by the slow but reliable underflow, which can be drawn on when the Kansas, Arkansas, Rio Grande and other rivers of the country are apparently dry. The general conclusions drawn by this engineer from his studies are the following:

The only source of the underflow is the rainfall, though geological conditions may be such that rainfall in one drainage basin furnishes underflow in another. The bed of a mountain stream may have a continuous underflow from mountains to ocean; but the water that starts in the underflow at the mountains seldom traverses the entire distance to the ocean, generally reaching the surface of the stream by gravity, and then being evaporated, often at the rate of several inches per day when the river bed appears to be dry. Underflow of the same level as the stream water, or nearly so, is limited to the width of the valley proper usually, but not always, depending upon geological features. In general, the surface of the underflow tends to follow the ground surface, being higher, but at greater depths and more limited in volume under the divides, and sloping toward the rivers. If the water-bearing material in the valley bottom is not much coarser than that back from the river, the slope of the underflow may extend to the river. In Western Kansas, slopes in sand of 30 feet per mile (and possibly much more) extend to the river banks, while in valleys underlaid with coarse gravels the transverse sections of the valley proper usually show a level, or nearly level, water surface. The amount of water in saturated sands and gravels ranges from less than 20 to more than 40 per cent., the theoretical maximum percentage held between spherical grains being 48. The percentage volume of water depends mostly upon the uniformity of coarseness of material. Fine sand, if free from silt, contains the same percentage of water as coarse sand, or even coarse gravel, the general shape of the grains being the same. Very fine and silted sands and clays hold high percentages of water, but do not readily give it up or pass it along. A coarse gravel holding 40 per cent. of water may be so mixed with finer gravel and sands as to contain only 20 per cent. of water. The percentages of water that may be drawn off by gravity or by pumping from the sands or gravel are not proportional to the percentages held in them. The coarser the material the greater the percentage drainable, because fewer grains give less area of capillary surface; but a portion is invariably held back from the flow by capillarity. The greater the uniformity of sizes of grains or pebbles the greater the percentage drainable, and the coarser and more uniform the material the greater the drainage speed. In a given material the speeds of flow vary with the slopes in feet per mile, but not in arithmetical proportion therewith.

The flow in coarse gravel with a slope of 50 feet per mile, for example, is several hundred times the flow in a medium fine sand with a slope of five feet per mile.

Some streams, dry most of the year in the upper part of their course, become perennial further down from the constant underflow from the highlands; one stream, for example, in Western Kansas, flowing in sand and falling 13 feet per mile, was receiving last winter from the underflow, after a very dry year, 26 cubic feet per second in a distance of six miles. Sands and soils above the saturated water level are wet by capillarity, and when a well borer brings up wet sand he has not necessarily reached the water surface by several feet. The height of the capillary wetting depends upon the fineness and uniformity of the sand, but has no effect upon the flow of the water in the saturated sands and gravels below.

NOTES.

George Washington's Surveying Experiences were trying at times, as will be seen from the following quotation from one of his letters, reproduced by Mr. Ford in his "True George Washington." It describes his method of life during one trip while official surveyor of Culpepper County, an appointment he received in 1749, when 17 years old: "[Since] October Last I have not sleep'd above three Nights or four in a bed but after Walking a good deal all the Day lay down before the fire upon a little Hay Straw Fodder or bearskin whichever is to be had with Man Wife and Children like a Parcel of Dogs or Catts & happy's he that gets the Birth nearest the fire there's nothing would make it pass of tolerably but a good Reward a Dubbleloon is my constant gain every Day that the Weather will permit my going out and some time Six Pistoles the coldness of the Weather will not allow my making a long stay as the Lodging is rather too cold for the time of the Year I have never had my Cloths of but lay and sleep in them like a Negro except the few Nights I have lay'n in Frederick Town."

A Test of a Pumping Engine of 10,000,000 gallons capacity, built by the E. P. Allis Company for the city of St. Paul, Minn., was recently made by the Robert W. Hunt Company of Chicago, and a duty of over 144,000,000 foot pounds of work per 1,000 pounds of steam supplied to the engine was realized, thus earning a bonus for the builders of $6,000 for exceeding the duty guaranteed, which was 130,000,000 foot pounds. The cylinders of the engine are 21½, 38 and 56 inches in diameter, the three water plungers 24¾ inches in diameter, all with a stroke of 42 inches. The test was of 72 hours' duration, and from a report furnished by City Engineer L. W. Rundlett the following data have been taken:

Steam pressure, lbs.	128.
Average first receiver press. by gauge, lbs.	31.8
Average second receiver press. by gauge, lbs.	.28
Average vacuum by gauge, lbs. absolute	12.83
Total head on pumps, feet	146.586
Average rev. per minute	27.
Actual water pumped for 24 hours, gals. (by weir)	10,159,000.
Loss by slip and leakage, per cent.	.44
Total dry steam supplied to engine, lbs.	258,045.
Duty per 1,000 pounds steam	144,463,000.