Viaduct Construction on the Kansas City Terminal

A Discussion of the Conditions Governing the Design of the Many Structures on This Important Project

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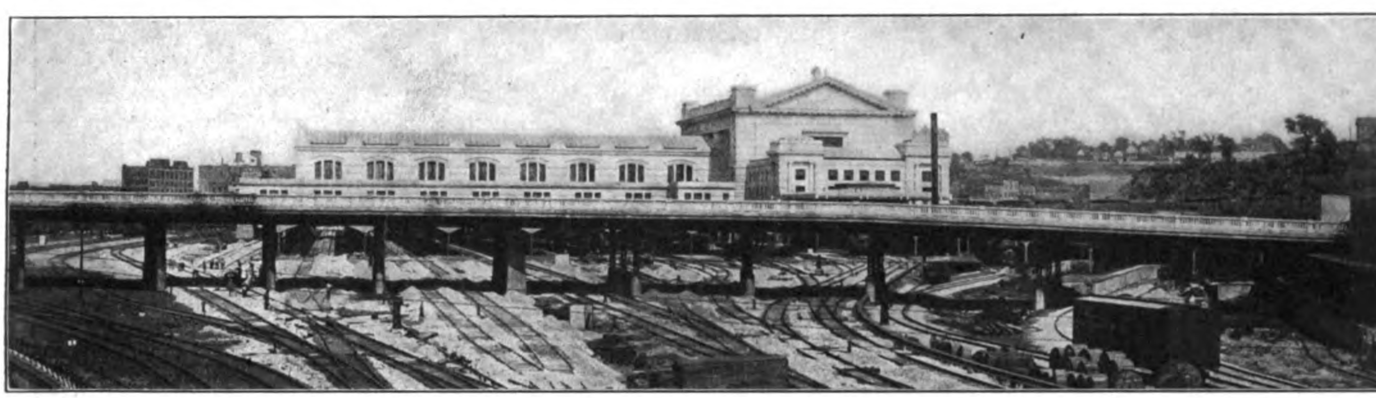
The construction work of the Kansas City Terminal included two distinct projects, the first, primarily for the benefit of the public, being the construction of a new union passenger station, and the second, to improve operating conditions, being the reduction of grades on all main line tracks east of the station and the elimination of the grade crossings over the entire system. A general description of the entire improvement at Kansas City was published in the *Railway Age Gazette* of May 23, 1913. The station which was recently completed was described in detail in the issue of October 30, 1914. A description of the design of the subways was published in the issue of December 13, 1912. The grade reduction and the grade elimination necessitated the building of 22,000 ft. of retaining walls, 21 viaducts and 12 subways, with approximately 181,000 cu. yd. of concrete and 8,500 tons of structural steel. A description of the general and detail designs of the viaducts in connection with this work is the purpose of this article.

The topography naturally divides the viaducts into two groups; the first comprising those which are isolated and which were designed independently of each other, as, for example, those crossing the tracks near the station; and the second comprising those in the big cut east of the station which were connected by walls and necessarily had to be considered together to obtain a harmonious result. The general design of the viaducts in the first group was simple, the entire problem being to have approaches of sufficient length at the specified grade to obtain the standard clearance of 22 ft. over the tracks. The spans over the tracks are of an inverted through girder type of steel construction; that is, a type involving stringers, floor beams and main girders, but giving a smooth floor with no girders projecting above it. The approach spans have been built either of steel of the same type or of reinforced concrete, depending on local conditions. A clause in the franchise ordinance requires the structure to be of open construction to a point where 7 ft. minimum clearance is obtained. Beyond this point to the end the structure is made up of earth fill between reinforced concrete retaining walls.

In the second group the viaducts are all comparatively short, the street grade being from 20 to 80 ft. above the main line tracks. Continuous walls were built on both sides of the main line to retain the slopes and to support bench tracks. These walls vary in type in accordance with local conditions. Wherever shale beds in natural formation and resting on limestone were found, facing walls were used. Where earth was found, lightly reinforced gravity walls were built for heights of 25 ft. or less, while above that height buttressed walls were used. In many cases facing walls were constructed for a part of the height with gravity walls above. The retained bench tracks serve industries along the line and either pass under the viaducts through box abutments or, as in two cases, cross the streets at grade.

The first preliminary designs for these structures contemplated a series of three hinged, reinforced concrete arch spans with supplementary spans for the bench tracks, but a detailed study of the borings showed that this type was not feasible owing to the uncertainty of the foundations. The same design was therefore adopted for the spans over the tracks as in the first group, the face walls of the box abutments supporting the spans, while the back walls, together with wing or tail walls, supporting the earth slopes. The building of a coping across the front face of the abutments on a line with the copings of the retaining walls joining them gave the appearance of continuous walls with the bridges rising from them.



Broadway Viaduct at West Entrance to Station

The first thing considered in the design of individual structures was their general appearance. The vast majority of people see or think little of the strength or construction of a bridge. They do usually notice, however, any obstructions of the roadway and sidewalks, the general outlines, and in addition the hand rails and lamp-posts. For this reason these points were given first consideration.

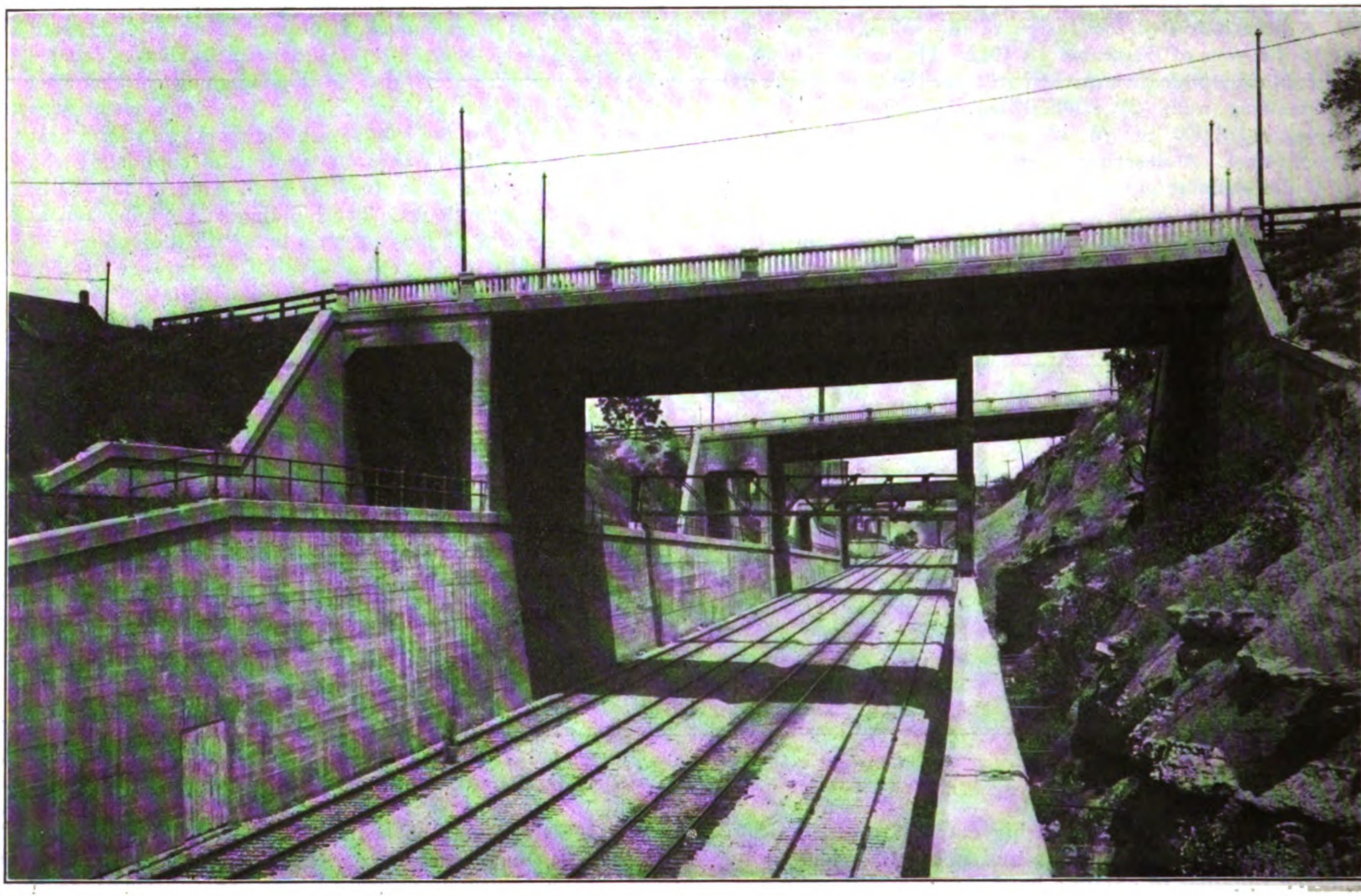
The grades for all structures were carefully studied with a view to securing an unobstructed roadway. In several instances the city was requested to allow changes of grade, which improved the connections with adjacent streets and at the same time allowed this type of construction to be used. The result was that out of 21 viaducts built, 16 have no projections above the street except hand rails and lamp-posts, 1 has trusses and 2 have girders along the curb separating the sidewalks from the roadway, while only 1 has a truss and another a girder in the center of the roadway in addition to those at the curbs. On the latter five structures, local conditions made it practically impossible to change the street grade or the grade of the tracks, the cost of the changes being far in excess of the additional cost of the through girder or through truss construction over the deck construction.

Special attention should, in this connection, be drawn to the Pennsylvania avenue viaduct. Some question may be raised as to the advisability of designing deck plate girders with a span of 127 ft. 5 in. out to out, especially with a depth of only 9 ft. 8 in. from clearance line to top of pavement. However, it may be said that this structure is at the west throat of the station and that it was impracticable to shorten the span without badly disarranging a complicated track layout. Furthermore, Pennsylvania avenue will shortly become the chief artery connecting the north and south boulevard systems of the city, and the additional expense of keeping the roadway clear and unobstructed was considered justifiable. Ruling grades of 4 per cent were already being used on the approaches and lócal conditions controlled the length so that greater depth could not be obtained. This structure as well as all others had to be erected without disturbance of railway traffic and in a number of cases temporary structures for highway traffic were also provided.

The next point considered was the best appearance, consistent with economy and simplicity of design, of the structures from adjacent ones or from the back platform of trains passing under them. As a first consideration vertical curves of a length sufficient to give a smooth contour were used at all breaks in grade; second, a heavy coping of a depth sufficient to mask the ends of the sidewalk brackets, but not heavy enough to be out of harmony with the rest of the structure, was made continuous from one end of the structure to the other; third, all girders on any one structure were made of the same depth as far as practicable to preserve parallel lines for the top of the structure, the coping and the bottom line of girders. For those structures adjacent to the station, the divergence of the tracks made necessary the location of column bents at all angles. At first it was thought that this would seriously detract from the general appearance, but it was found that if the girder lines, which are mentioned above, were kept smooth the location of bents had little effect.

The hand rails are of reinforced concrete unit construction and consist of posts 15 ft. to 20 ft. center to center, upper and lower rails, balusters and blocks. Dowels to anchor the hand rail posts were set when the floors of the viaduct were cast. The method of erection was as follows: First, small square blocks to support the ends and third points of the lower rails were placed; next, the lower rails were set in position; then the posts, which are hollow and also notched out for the rails, were set over them and all were accurately lined; the balusters and top rails were then placed in position; the posts filled with concrete to anchor them to the floor of the viaducts and the caps placed on the posts, the ⅛ in. joints left between balusters and rails and between rails and posts to give ease of erection were then carefully pointed. Expansion joints were left in one side of each post.

The lamp posts are of reinforced concrete surmounted by a single 100-watt lamp and 14 in. globe. They are arranged to be lighted by electricity but by removing the cables from the conduits and using a gas fixture and globe, gas may be used. A two-inch conduit is run in the curb on each side of the street to feed the lamps. At each post a pull box is inserted and a half-inch conduit carried from the pull box to the top of the post. Of course if gas is used the pipes must be connected through the pull boxes. A standard connection has been provided for this contingency. The lamp-posts are turned on a lathe, the method of manufacture being similar to that of making pottery. Lamp posts and hand rails have a sand finish, while the sidewalks have a float finish.



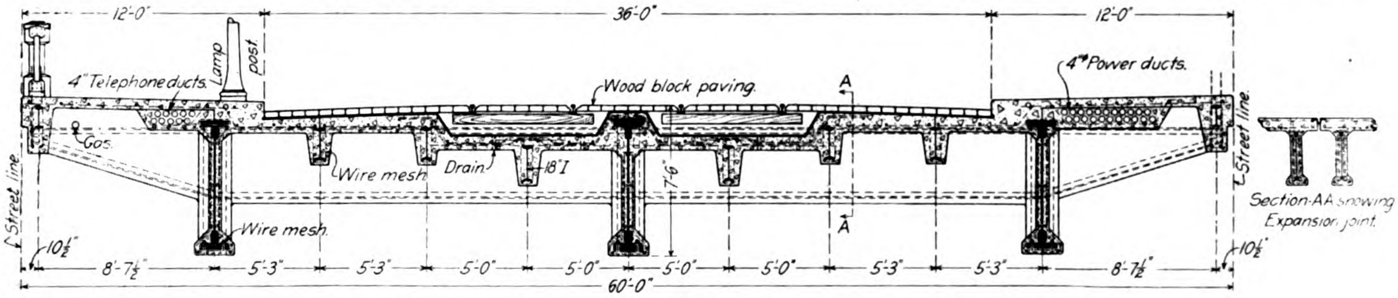
Typical Structures Built in Connection with Wall Construction

Provision was made for street car tracks on all structures as provided for in the franchise ordinance as well as conduits for the telephone and power companies and supports and protection for water and gas pipes. It may be mentioned in passing that proper provision for conduits and water and gas pipes is one of the most difficult parts of the design of city bridges. The conduits used were of 3½-in. fiber laid with a minimum of ¾ in. of grout between ducts. The only difficulty experienced in their use was an inclination to float when the concrete was poured. This was prevented by setting pieces of wire in the green concrete of the slab supporting the ducts and using these to fasten pieces of reinforcing bars over the ducts before grouting them in. Inserts were built into the floor on the lines of the water and gas pipes to support hangers from which the gas pipes and the slabs protecting the water pipes will be hung. The slabs supporting them are generally 2 ft. 2½ in. wide and reinforced with wire mesh. They will be built in units of about 5-ft. lengths and set in place on straps supported from hanger rods.

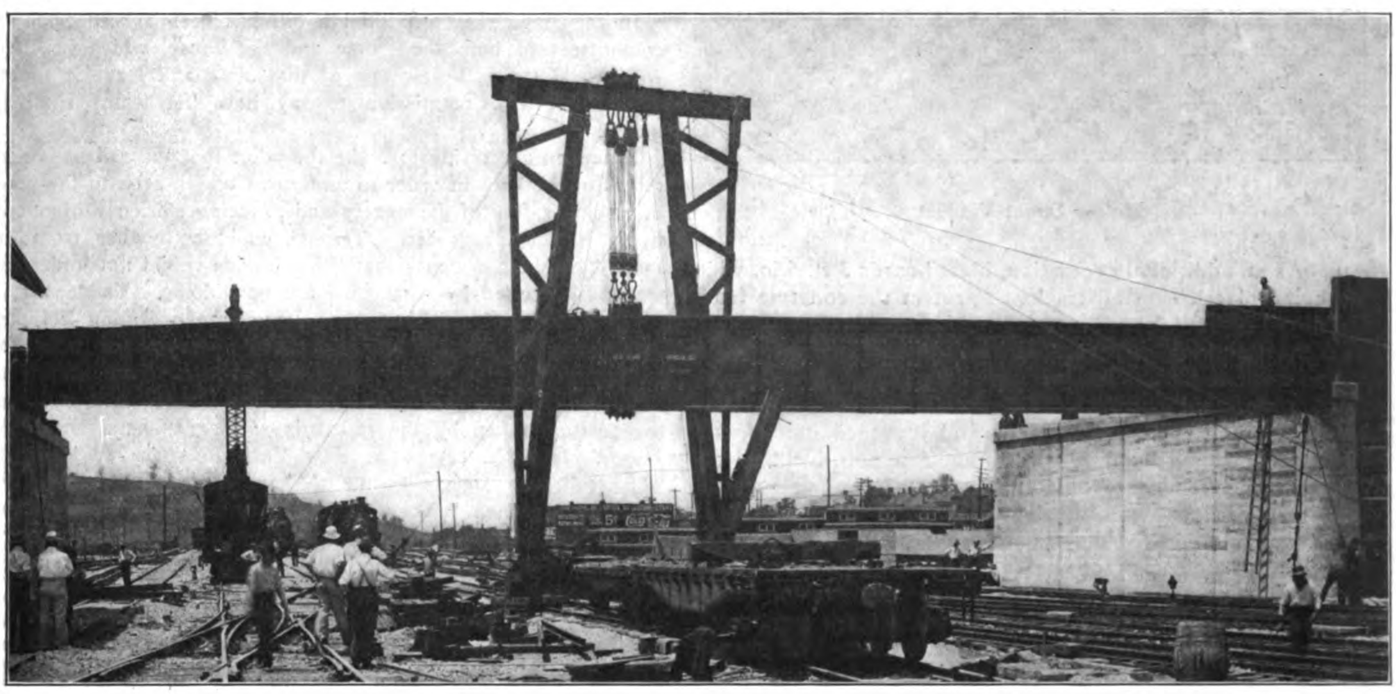
The viaduct span lengths were usually fixed by track conditions, although there was some latitude for some of the structures at the entrances to the station. The usual method of procedure adopted in the design was to first outline a tentative cross section so as to place conduits and pipes to the best advantage. Telephone and power cables were always placed on opposite sides of the structure. A detailed study of the arrangement was then made and the elevation of stringers adjusted so as to make the form work for the concrete floors as simple as possible, at the same time not losing sight of the fact that ease of erection of the steel work was very essential. These two points were very carefully watched throughout the work. From this it must not be inferred that design was neglected, for all elements of weakness were thoroughly investigated and complete shop details conforming to the latest modern shop practice were drawn up.

The specifications used for design, materials and workmanship were identical with the American Railway Engineering Association specifications for steel railway bridges, except for loads and a few minor points of design. The loads used were the dead loads already mentioned, a live load of two 100,000-lb. street cars on each track, the distance between end axles of adjacent cars being 10 ft., truck spacing 30 ft. and axle spacing 5 ft., the cars being assumed to occupy 10 ft. in width for each track; a uniform load of 100 lb. per sq. ft. on the roadway and 100 lb. per sq. ft. on the sidewalk. Impact allowance of 25 per cent was used for street car and roadway live loads. A 17-ton road roller was also used, assuming a spacing from center to center of axles of 10 ft. 9 in.; center to center of rear wheels, 5 ft.; load on front wheel, 11,000 lb., and load on each rear wheel, 11,500 lb. No allowance was made for impact on the roller, as this was assumed to be an occasional load. The distribution for road roller loads was assumed to be over a length of 8 in. at the point of contact and spreading longitudinally at a rate such that at any depth "D" below the pavement, the distribution would equal 8 in. plus D. Laterally the distribution was assumed equal to the width of the rollers.

Various types of construction were tried, but with the loadings used the best results were obtained by spacing the main girders either 15 or 20 ft. apart, with floor beams at intervals of 14 to 20 ft., supporting lines of longitudinal string-

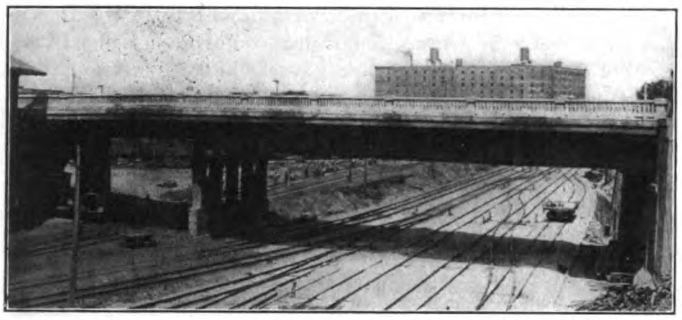


Cross Section of Charlotte Street Viaduct Showing Typical Construction



Erecting a 127 ft. 5 in. Girder at Pennsylvania Avenue ers 5 ft. apart center to center. The stringers were framed to outstanding legs of stiffeners on the floor beams. On account of the general direction of the tracks with reference to the streets, all structures were skew, but all stringers were framed square with the floor beams and all floor beams and brackets square with the girders except the end floor beams. At expansion points two sidewalk brackets and two end floor beams were always provided, one on the end of each span. The ease with which the expansion could be taken care of, especially in the concrete encased spans and in the concrete encased fascia beams of the non-encased spans, more than offset any additional weight involved, besides making the structures present a much neater appearance. Expansion joints were made by casting a piece of 3-lb. sheet lead bent into a semi-fold into adjacent spans, as shown in the accompanying drawing. The loop thus formed was then poured full of asphaltic mastic.

The concrete encased spans mentioned above probably require a word of explanation. At the time the Terminal Railway took over the old Belt Line property, there were a number of viaducts over the tracks. Nearly all of these were in serious condition due to the corrosive action of blast and smoke. A few of the later structures were concrete encased and were in much better condition. It was decided that in order to insure a long life to the structures all spans over the tracks with a clearance of 25 feet or less should be concrete encased. This work is now being done with a cement



McGee Street Viaduct

gun. As an additional protection, blast boards 3 ft. 6 in. wide are being placed over all tracks to protect the concrete from the direct blast.

In the wrecking of several of the concrete encased spans it was noticed that water had percolated through the pavement, penetrated between the concrete encasement of the beams and the steel, and cracked and loosened the encasement. For this reason it was thought imperative that all floors should be waterproofed. The waterproofing consists of three-ply fabric, two of burlap with a layer of felt between. Each coat was mopped down with asphaltic material in addition to a priming coat for the concrete. The pavement was laid directly on the waterproofing without any cushion intervening. For all grades, up to and including 6 per cent, creosoted wood block laid with lath joints was used. For steeper grades, brick was used. Along each curb two expansion joints, 1 in. and ½ in., respectively, filled with asphaltic filler, take care of lateral expansion, although it was found desirable to add additional longitudinal joints in several cases. Transverse expansion joints are placed at all expansion joints in the structure. As an additional safeguard, all street drainage was kept away from the structures as much as possible, and the drainage from the structures was conducted to catch basins at short intervals.

The wall, viaduct and subway designs were all made under the direction of George E. Tebbetts, bridge engineer, under the supervision of John V. Hanna, chief engineer. The construction work was executed under contract.

ANTI-FULL-CREW LAW CAMPAIGN

Samuel Rea, president of the Pennsylvania; Daniel Willard, president of the Baltimore & Ohio; Theodore Voorhees, president of the Philadelphia & Reading, and E. B. Thomas, president of the Lehigh Valley, have written letters to the stockholders of their respective companies, urging them to use their influence to have the full-crew law repealed.

R. L. O'Donnel, chairman of the committee representing the 21 associated roads of New Jersey and Pennsylvania, has issued a number of circulars during the past week dealing with certain local phases of the full-crew law question. To the people of a town where a new passenger station is needed, he observes that the $2,000,000, which now is being paid yearly to trainmen whose services are unnecessary, would build two hundred new stations at an average cost of $10,000 each. Mr. O'Donnel cites the stand taken against full-crew measures by the grangers of Texas, Missouri and New York. The farmers, he asserts, should help secure repeal of those laws in Pennsylvania and New Jersey, not only because they are fundamentally bad legislation, but "because of the higher prices for farm produce, making necessary increased plantings, and to meet the drawback of lack of labor." Farmers and business men of Kansas made such sharp protest that the bill which had been introduced in the legislature of that state was killed February 13 in the senate committee.

An effort to enact an excess crew law in West Virginia met with general opposition, and the bill was reported adversely by the legislative committee to which it was referred. In Alabama a legislative committee, after public hearings, concluded that the contentions of the trainmen's union were not well founded and that the measure would only compel employment of extra men not needed on the trains. The bill was consequently adversely reported.

In the state of Washington a bill has been agreed upon by committees of both the senate and the house, which in effect will repeal the full-crew law of that state and leave it to the Public Service Commission to say how the trains shall be manned.

Trainmen are trying to make the point that the railroads seek repeal of the laws in order to underman trains, even to the point of risking safety of passengers and reducing efficiency of operation. Nothing, says Mr. O'Donnel, could be further from the fact. "The best evidence that the railroads would not underman trains is afforded by what they are now doing. Thirteen railroads in Pennsylvania and New Jersey are operating 344 passenger and 446 freight trains manned in excess of what the law requires." He quotes Louis D. Brandeis, "best known of all critics of railroad affairs in the United States," who endorses the position taken by the railroads of Pennsylvania and New Jersey. In an interview at New York February 25 he says: "The railroads appear to me to have the better end of the full-crew argument. They seem to have made out a very good case. The full-crew laws are cumbersome and in an awkward way aim to accomplish something which a commission could do much better."

At last there promises to be a fair and open debate on the full crew question. Francis P. Boland, a brakeman of the Pennsylvania Railroad, who is also a member of the New Jersey legislature, sent a challenge to Mr. Rea, president of the Pennsylvania, asking that he, or such officers as he might designate, debate publicly the question how the law operates on the Pennsylvania in the State of New Jersey. Mr. Rea accepted, and the debate will take place at Elks' Hall, Jersey City, on the evening of Tuesday, March 9. Among several employees who asked the privilege of taking up the argument on the side of the company Mr. Rea has selected H. J. Fackenthall, an engineman who runs between New York and Philadelphia. Mr. Fackenthall has been prominent in the "safety first" work on the Pennsylvania, and is an experienced speaker.