As will be noted, the head pumped against, and also the water delivered, were somewhat greater than those specified in the contract. For purposes of comparison with this test, therefore, both the third and the fourth tests on the De Laval centrifugal pump have been taken. Table 2 compares the leading facts in regard to the two units and their performances.

To make a further comparison of these two units it would be necessary to consider installation at the same location, as the cost of buildings and foundations depends largely on local circumstances. The total weight of the reciprocating engine is over fifteen times that of the turbine-driven centrifugal pump, while the cubical space occupied is about ten times as great. In view of this, it may be assumed for comparison of economic results that the buildings and foundations for the reciprocating unit would in general cost four times as much as for the centrifugal unit, although they might be even more.

The cost of bituminous coal (13,000 B.t.u. per lb.) to the City of Cleveland is $1.64 per ton, whereas in St. Louis washed coal showing 11,000 B.t.u. per lb. is purchased for $1.69 per ton. For the purpose of comparison it has been assumed that both units are supplied with steam generated from the coal costing $1.69, which, if burned under boilers of 65% efficiency, would give a fuel cost of 13c. per 1,000,000 B.t.u. It has further been assumed that the nominal horsepower capacity of boilers installed will be the same as the boiler horsepower of steam used. Operation at 200% above nominal rating is now common, so that this gives ample spare boiler capacity. The interest rate upon money has been taken at 4%, maintenance and supplies for pumping engines and buildings at 2%, with 30 years as the probable life. This gives a total annual charge against engines and buildings, including depreciation or amortization, of 7.6%. For boilers the same rate of interest has been assumed, while maintenance and supplies have been put at 4% and the probable life at 20 years, making the total 11.3%. These assumptions give the following figures for comparison, using the results of the fourth test upon the centrifugal pump:

	Centrifugal Unit	Reciprocating Unit
Cost of buildings and foundations, assumed	$20,000	$80,000
Cost of boilers, settings and stack, assumed as $30 per nominal boiler horsepower	16,371	10,503
Annual interest, maintenance and depreciation charges on pumps and buildings	5,130	21,310
Annual interest, maintenance and depreciation charges on boilers	1,849	1,188
Total interest, repairs, maintenance and depreciation charges	6,979	22,498
Annual fuel cost of steam, at 13c. per 1,000,000 B.t.u., based on full load 24 hr. per day, 365 days per year	22,030	14,540
Total annual cost per water horsepower, exclusive of attendance and supplies, assuming 100% load factor	23.11	34.45

As will be seen, the annual cost per water horsepower is $23.11 for the steam-turbine-driven centrifugal pump and $34.45 for the vertical triple-expansion reciprocating pumping engine. In neither case has any charge been made for supervision and attendance, although there can be no question that in view of the great complexity and great number of valves, packings and other parts connected with a reciprocating pump, its cost for attendance will be greater, both because more men will be required and because they will need to possess a greater degree of skill and intelligence. For the same reasons, and also because of the rapid wear of valves and packings, the probabilities of falling off in duty are greater for the reciprocating unit.

Further, full-load operation 24 hr. per day and 365 days has been assumed—an improbable condition. If the load factor is put at 66.6%, the comparison is still more favorable to the centrifugal pump. The annual fuel costs become $14,690 and $9,690 for the centrifugal and reciprocating units respectively and the annual costs per water horsepower-year become $25.90 and $44.90.

For average operations, therefore, and with fuel prices such as are generally found in the Middle West, a modern steam-turbine-driven centrifugal pump will deliver water at about half the cost for pumping as compared with the highest development of the reciprocating type of pumping engine.

Track Elevation on the Nickel Plate Railroad at Chicago

SYNOPSIS—The piece of work described in this article is peculiar in that conditions necessitated abandoning the original line and building an elevated line on a new location. The line has to rise to cross one railway, then descend to pass under two railways and then rise again to connect with one of the latter. There is a large amount of concrete work for the length of the line, and a notable structure is a steel skew bridge with plate girders of from 125½ to 132 ft. in length.

The track elevation at Grand Crossing, Chicago, includes the elimination of railway crossings of both streets and railways at grade, and has involved special problems for the New York, Chicago & St. Louis Ry. (Nickel Plate), which is one of the four railways concerned. The situation is shown by the sketch plan and profile, Fig. 1.

Originally all the railways were at the street level. The two parallel lines of the Lake Shore & Michigan Southern Ry. (now New York Central Lines) and the Pennsylvania Lines crossed the Illinois Central R.R. at grade, and the New York, Chicago & St. Louis Ry. (parallel with the Illinois Central R.R.) crossed the Pennsylvania Lines at grade (by a 14° curve) to connect with the Lake Shore tracks. To eliminate the street grade crossings the Illinois Central was elevated sufficiently to clear the streets, which were depressed at the intersection, and the parallel lines of the Lake Shore and Pennsylvania were elevated still higher in order to pass over the Illinois Central R.R. Each road has numerous tracks and heavy traffic at this point.

To eliminate the grade crossing of the Nickel Plate with the Pennsylvania Lines, the old connection was abandoned and a new one located as shown on the plan. Beginning at 87th St., this connection rises on a grade of 0.6% and swings with 10° curves so as to cross over the Illinois Central. It then swings north on a long curve of 1° 36″ and descends at 1% grade to pass under the other two lines in a skew subway (on a 10° curve), and then, running parallel with the latter, it rises on a grade of 0.638% till it is on a level with the Lake Shore

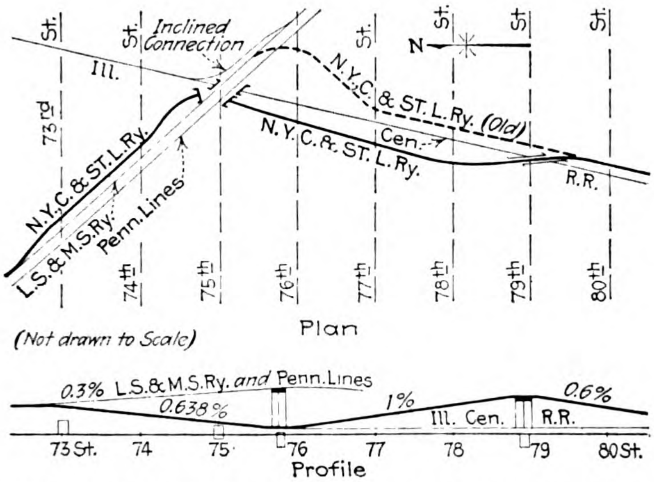

FIG. 1. TRACK ELEVATION AND GRADE-CROSSING ELIMINATION AT GRAND CROSSING (CHICAGO)

Ry., with which it connects a little north of 73rd St. Only two tracks have been built as yet, but the plans provide for four tracks.

The elimination of the Nickel Plate grade crossing in 1909 closed the original connection with the Lake Shore Ry. As the new connection had not been built it was necessary to divert the Nickel Plate trains to some other route, and since November, 1909, they have been detoured from 95th St. over the Rock Island Line, which brings them into the same terminal station (the La Salle Station). The new connection is expected to be put in service by December, 1915. Unlike most of the track-elevation work in Chicago, this line has been built without the complications involved in doing the work while the line is carrying traffic.

Concrete Retaining Walls

From 87th St. the new line is on an ordinary embankment as far as the bridge over the Illinois Central R.R., the fill being made by dumping from a temporary trestle. At the approach to the bridge, however, long retaining walls are required in order to keep the slopes of the fill clear of street lines and property lines on the east side and clear of the Illinois Central R.R. right-of-way on the west side of the tracks. This is shown in Fig. 2, and the sections of walls are given in Fig. 3.

The east wall is 600 ft. long, with a height of about 35 ft. for 200 ft. at the middle, the ends then sloping down on grades of from 12 to 18%. It is built in sections 50 ft. long (with expansion boards at the center of each section), except that at the north end, where the wall is low, there are sections 35 and 45 ft. long. Two layers of tar paper were placed between the sections.

The wall has a vertical face, with no coping, and the back is stepped. It was originally proposed to put a line of concrete piles under the face of the wall, but this was abandoned and the footings were made somewhat deeper, being carried 1 ft. into the solid clay subsoil. The width of base of wall as built is 50% of the height plus 1 ft. The west retaining wall is an extension of the bridge abutment.

West of the Illinois Central R.R. the line is mainly a fill between concrete retaining walls. At 78th St. an incline has to be provided for an industry track on a

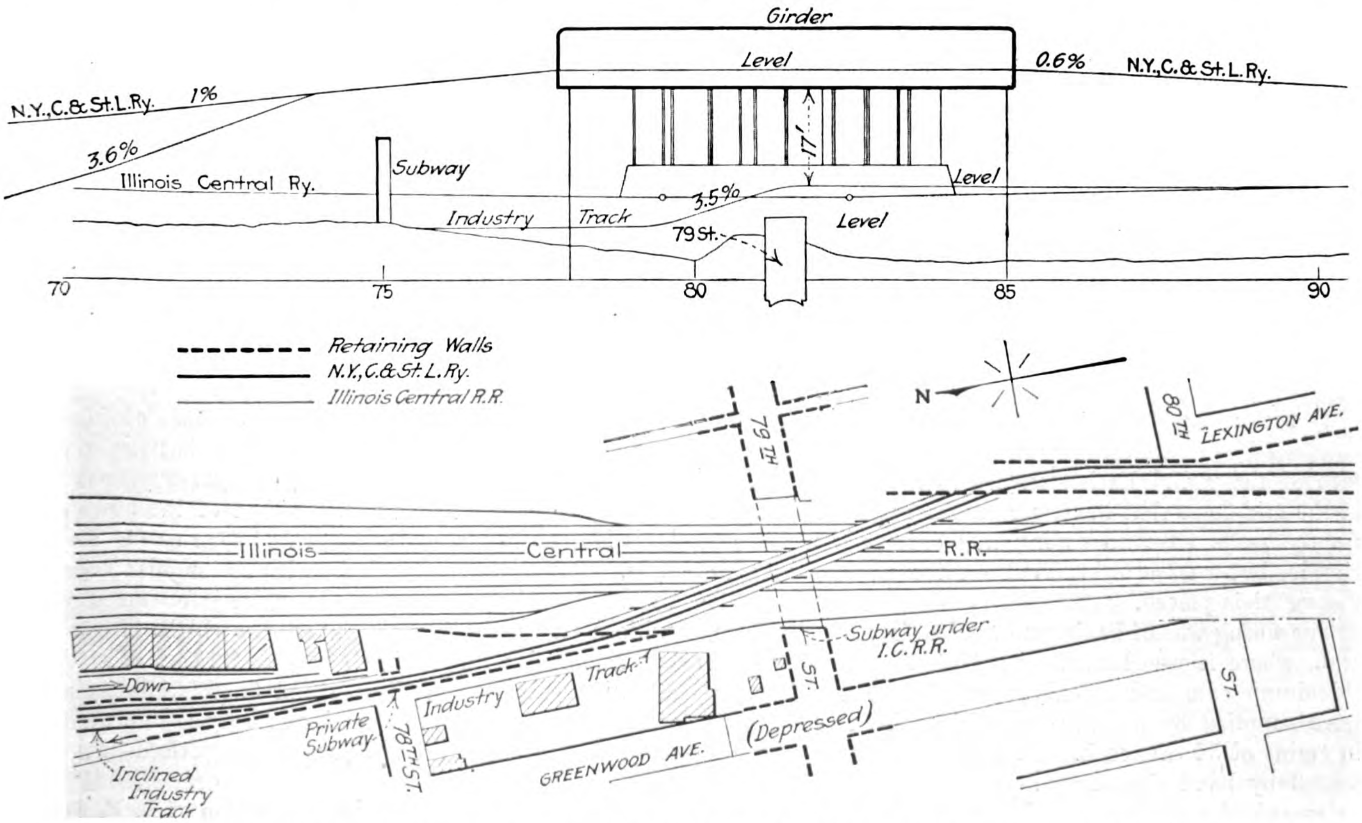

FIG. 2. SKEW CROSSING OF THE NEW YORK, CHICAGO & ST. LOUIS R.R. OVER THE ILLINOIS CENTRAL R.R. AT GRAND COSSING (CHICAGO)

grade of 3.6%, with a subway beneath this to give access to the railway company's property. This necessitates the triple-wall arrangement shown at the left in Fig. 2. At the 79th St. bridge over the Illinois Central R.R. the retaining wall and abutment meet in a sharp angle, as shown on the plan. The sections are given in Fig. 3. Fig. 5 is a view at this angle, with the wall at the left and the bridge abutment on the right. The tie bars are pieces of old rails which anchor the walls together.

All concreting was done by means of a train having a mixer and elevator tower on the first car and material cars behind, as described in *Engineering News*, Aug. 12, 1915. The walls are surmounted by pipe hand railings carried in standards, which are secured to the outer

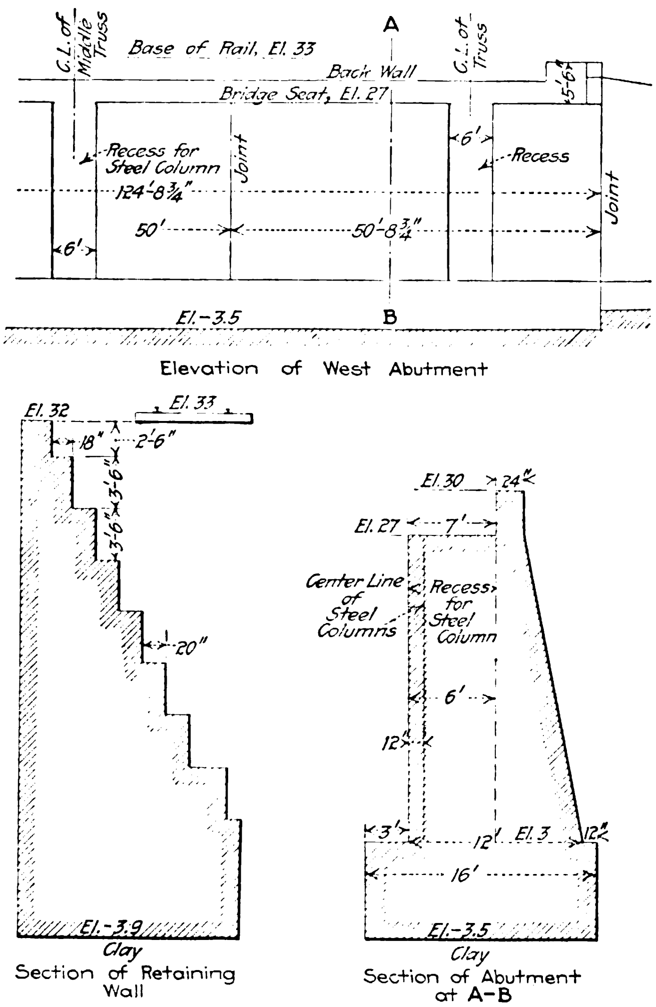

FIG. 3. ABUTMENTS AND RETAINING WALLS

face of the wall. Each standard is a flat bar, twisted at the middle so that the lower part lies against the wall. As the walls have no coping this construction is very simple, but rust streaks occur on the wall as soon as the metal is placed.

The filling was of bank sand hauled from South Gary, Ind., where it was loaded by a 70-ton steam shovel on side-dump cars and side-door gondola cars. The cars were supplied by the railway, which also hauled them in trains of 30 cars each. Most of the material was unloaded by hand shoveling, and was spread and leveled by means of a Jordan spreader car. Part of the filling was deposited from a temporary trestle, but on a considerable part of the work it was necessary to jack up the track as the filling progressed. The work required only about 42,500 cu.yd. of material and was done between July 1 and Aug. 3, 1915.

Bridges and Subways

The private subway at 78th St. is 12 ft. wide and 13 ft. high, with a roof of 15-in. I-beams embedded in a concrete slab, as shown in Fig. 5. The end walls are carried up to hold the fill for the main tracks and wing walls provide for the slope of the fill on the inner side. Streets are crossed by steel bridges having four spans, with bents on the curb lines and in the middle of the roadway. The steelwork of girders and bents is all incased in concrete. The roadway spans have through plate-girders, while the sidewalk spans are of I-beams. Some of the bridges are built as two parallel single-track bridges, with a narrow space between them, giving light in the street. Over the sidewalks this space is covered by concrete slabs. The bridge floor is a concrete slab on transverse I-beams.

The 78th St. crossing is shown in Fig. 6, with three structures. On the higher level is the Lake Shore & Michigan Southern Ry. and on the lower is the Nickel Plate railroad. At the left the latter passes under the

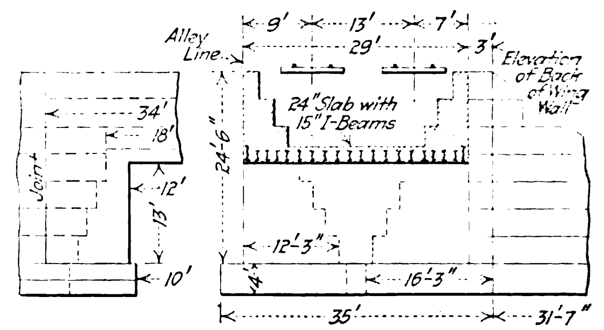

FIG. 4. SMALL SUBWAY UNDER TRACK ELEVATION AT 78TH ST.

former by a long skew subway on a curve and then runs parallel with it on an ascending grade (to the right) until it comes to the same elevation and makes a junction with it. It will be noted that the wing wall of the bridge at the left is extended as a dwarf retaining wall to confine the toe of the upper slope and give room for the tracks on the lower level.

The most important structure is the five-span skew bridge over the Illinois Central R.R. at 79th St. It is notable in having plate girders 125 ft. 6 in. long and one girder 132 ft. long. It has three lines of girders. An unusual feature of the abutments is that the girders do not rest upon bridge seats in the usual way, but each rests upon a steel column in the face of the abutment. This is done to reduce the length of span as far as possible. The abutment was built with rectangular recesses, the steel columns being set later, each on an I-beam grillage on the footing. The recesses will be filled with concrete flush with the face of the abutment. This construction is shown in Figs. 3 and 5. Steel bents with wide columns on concrete footings form the intermediate supports. The superstructure will be described in a separate article.

The construction is under the direction of E. E. Hart, Chief Engineer of the New York, Chicago & St. Louis R.R.; and A. C. Harvey, Assistant Engineer, is in di-

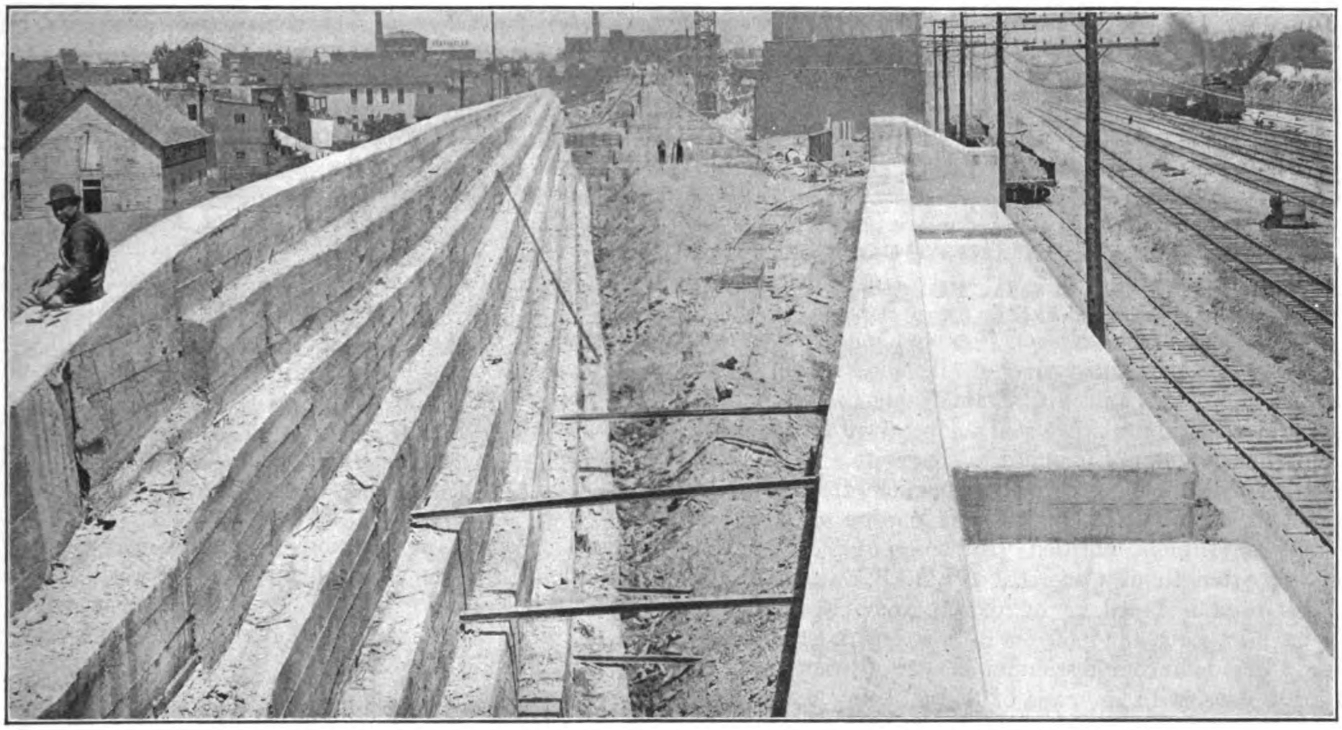

FIG. 5. MASONRY FOR NORTH APPROACH TO THE 79TH ST. BRIDGE AT CHICAGO

The railway comes down from the direction indicated by the concreting tower in the center and swings across the Illinois Central R.R. at the right. At the left is the retaining wall along the alley, which unites with the end of the bridge abutment. The recesses in the face of this abutment are to receive steel columns which support the ends of the bridge girders

rect charge. The Brownell Improvement Co., of Chicago, had the contract for the concrete and P. T. Clifford & Son, of Valparaiso, Ind., had the contract for the filling. The steel street bridges and the bridge over the Illinois Central R.R. were built by the Pennsylvania Steel Co., of Steelton, Pa.

The New York State Barge Canal can be put into complete service in two years, according to a statement in the "Barge Canal Bulletin," the organ of the State Engineer's office. It is stated in the October issue of this journal that "if the referendum of Nov. 2 is approved and if the money can be appropriated soon after the first of next January, it is safe to assert that the Champlain Canal can be completed in one year, as can also the canal between Waterford and Oswego and the branch into Cayuga and Seneca lakes. The balance of the canal through to Buffalo will require one additional year to finish." The statement goes on as follows: "It is not necessary at the present time to enumerate the advantages expected to follow the completion of the canal and its terminals. These benefits have been ably set forth by numerous advocates. However, it may be well to state that there is ample evidence to indicate that transportation men and navigation companies stand ready to make quick use of the canal as soon as the new channel is opened throughout its entire length. Some companies are already organized and are prepared to put fleets in service, chiefly for local traffic, the kind of traffic from which the people of the state will derive most direct and greatest benefit. With wisdom the state decided to add the building of terminals to the canal project. The lack of terminal facilities was one of the greatest faults of the old canal system. In fact, unmonopolized terminals is the crying need of our American waterways today."

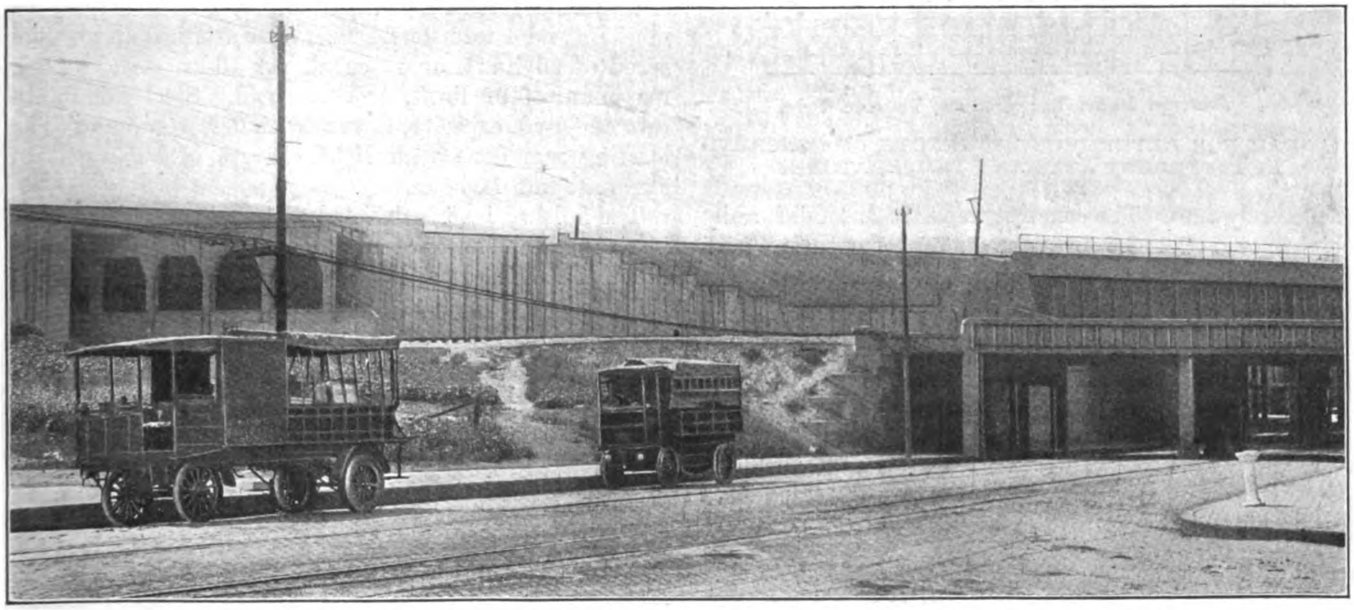

FIG. 6. DOUBLE-DECK TRACK ELEVATION AT 78TH ST., CHICAGO (GRAND CROSSING)

The upper line is the Lake Shore & Michigan Southern Ry. The New York, Chicago & St. Louis R.R. crosses under it by a long skew subway and then runs parallel with it on an ascending grade until at 73rd St. it reaches the same level and makes a junction with the Lake Shore R.R.