

# KING'S BOOKLETS

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A thousand and one World-wide Subjects

## THE PENNSYLVANIA RAILROAD TUNNELS AND TERMINALS IN NEW YORK CITY

### Triumph of Railroad Engineering, Architecture and Construction

In bringing its tracks into the very heart of the retail-business district of New York City, close to the great hotels and theatres of the metropolis, the Pennsylvania Railroad Company has wrought a great triumph of railroad engineering at a special outlay of \$90,000,000, entirely apart from the cost of the Hudson River (McAdoo) Tunnels. The problem was not to spring a bridge over the mile-wide Hudson River—shipping forbade that comparatively simple linking of the city to the continent. It was underneath the river that the engineers sought ingress to the city, and in place of stable rock they encountered shifting silt. But great steel shields were forced forward by hydraulic power from shafts at either end, cast-iron and concrete lined the twin-bores, steel pillars were sunk to bed-rock to support the tubes, and now the Pennsylvania has two tracks right into the centre of New York City—the great metropolis that dominates America.

SEE BACK COVER

# The Pennsylvania Railroad Tunnels

By WILLIAM WIRT MILLS

**E**NTRANCE of the Pennsylvania Railroad into New York City was first proposed by Alexander J. Cassatt, president of the company, in his annual report to the stockholders in March, 1901, when he said:

"Your interests, as well as the convenience of the public, require the extension of your line into New York, and the establishment of a centrally located passenger-station in that city, through which the inconvenience and delays of the transfer by ferry will be avoided."

Mr. Cassatt and Samuel Rea, third vice-president, took up the problem and on Dec. 12 of the same year the company announced its plans to establish all-rail connection between its lines in New Jersey and Long Island, through the heart of New York by means of the most daring scheme of tunnels.

A year was occupied by negotiations for the franchise, which was signed by Mayor Low on Dec. 22, 1902, and on June 10, 1903, construction was begun and pushed with such energy and with so few set-backs that the twin Hudson River tubes were completed in 1907, two of the four East River tunnels were finished in February, 1908, and the entire system will be in operation in 1908.

This 15-mile link overcomes the insularity of Manhattan and unites the 10,978 miles of Pennsylvania Railroad tracks with the lines on Long Island and by the New York Connecting R. R. with the tracks of the New York, New Haven and Hartford system.

Leaving the present Pennsylvania main line at Harrison, N. J., the tracks cross the Hackensack river and meadows and enter the tunnels at Bergen Hill (p. 5), not coming out again upon the level until they reach the great Sunnyside terminal yards at Thompson Ave., Long Island City, a mile east of East River.

There are two tunnels under Bergen Hill and the Hudson River (pp. 4 and 7), the distance between the centres of the tubes under the river being 37 feet. These tunnels continue under Manhattan to the entrance to the depressed station-yard at 10th Avenue. This work from the West Portal at Bergen Hill to 9th Avenue is under the direction of Charles M. Jacobs, chief engineer, and James Forgie, chief assistant engineer. Between Bergen Hill and Harrison, A. C. Shand, chief engineer of the Pennsylvania Railroad, has charge.

In the great yard between 9th and 8th Aves., 60 feet below the surface, the two tracks multiply to 21 and pass through the

station (p. 15) at a depth of 40 ft.; at 7th Ave. the tracks, converging into six, enter three-track tunnels, one under 32d St. and one under 33d; near 6th Ave., at a depth of 75 ft., these tunnels change from two wide arches to two twin arches, carrying four tracks to 1st Ave., where they enter four separate tubes which extend under the East River, a distance of 3,916 ft.; near the Long Island shore the tunnels begin to converge and they meet in an open cut (p. 16) that leads into the Sunnyside yards at Thompson Ave., 2.85 miles from the station entrance in Seventh Ave. Alfred Noble is chief engineer for all work east of 9th Ave., with Charles L. Harrison as chief assistant engineer.

Including 16 miles of tracks in the central station and yards, there will be 31.70 miles of track between the Jersey Portal at Bergen Hill and the terminal yard at Sunnyside, L. I. City.

All the trains will be operated by electricity furnished from power houses in Long Island City and at Harrison, N. J., planned and built by Westinghouse, Church, Kerr & Co., under the direction of George Gibbs, chief engineer of electric traction.

The entire work has been prosecuted under the general direction of Vice-President Rea, with the advice of a board of consulting engineers consisting of Brig. Gen. C. W. Raymond, U. S. A., chairman, and Messrs. Jacobs, Noble and Gibbs. During the period in which the project was reduced to a working basis, Wm. H. Brown, chief engineer of the Pennsylvania Railroad, and Gustav Lindenthal, Bridge Commissioner of New York City, were members of the board.

Closely related to the vast tunnel and station enterprise is the New York Connecting Railway, which will carry trains from the tunnels through to New England and give the N. Y., New Haven & Hartford access to Pennsylvania station at 7th Ave. This \$15,000,000 improvement, including the Hell Gate Bridge (p. 17), twelve miles of railroad and four great freight terminals, will furnish a route for the Pennsylvania's New England and Long Island freight by means of car-floats across New York Bay to Greenville, N. J.

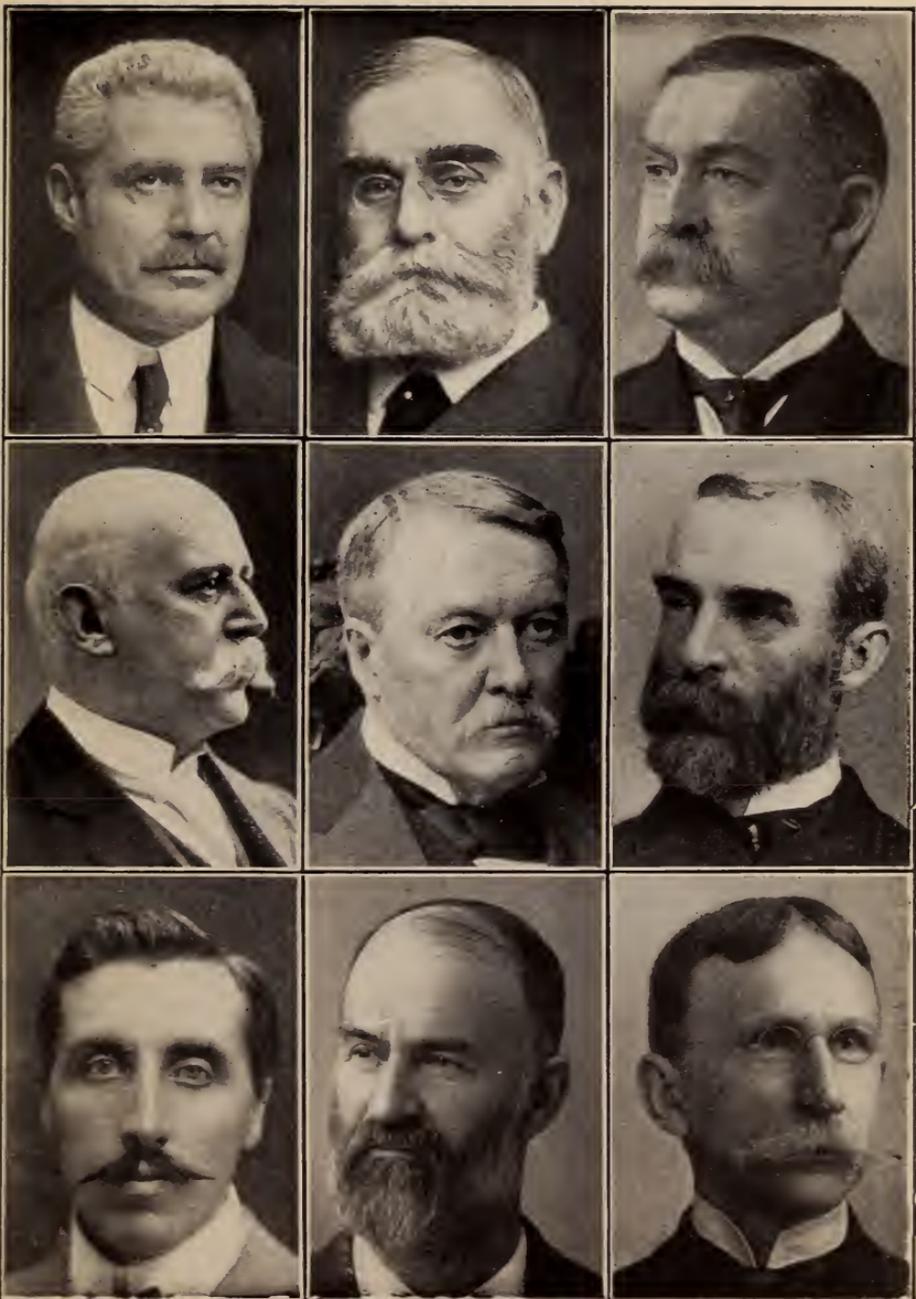
The portion of the Pennsylvania tracks from Harrison to Jersey City, relieved by the diversion of the large part of the main line heavy traffic through the tunnels, will be used for a suburban service through the McAdoo tubes to Cortlandt St., Manhattan (pp. 18-23).

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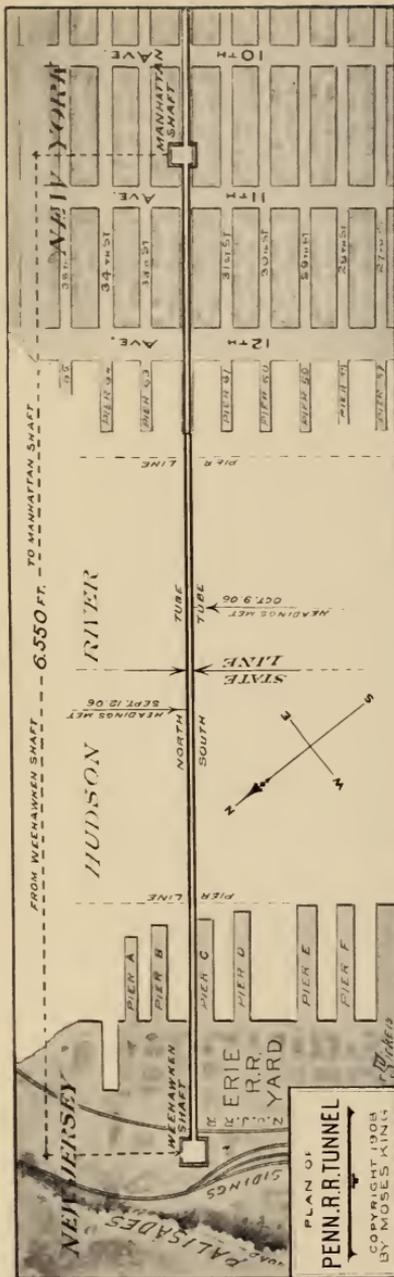
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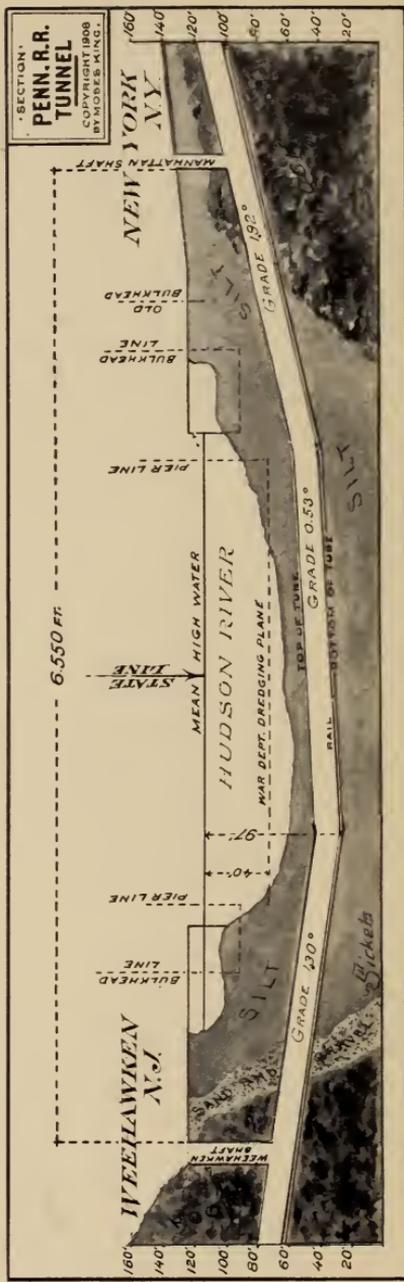
SEYMOUR DURST



SAMUEL REA, 3d v. p. P.R.R.; JAMES M'CREA, Pres. P.R.R.; CHAS. E. PUGH, 2d v.p. P.R.R.; CHARLES M. JACOBS, designer tunnels and ch. eng.; ALEX. J. CASSATT, late Pres. P. R. R.; JOHN P. GREEN, 1st v.p.; JAMES FORGIE, ch. asst. eng. N. Riv. Div.; WM. H. BROWN, bd. of eng.; J. T. RICHARDS, ch. eng. maintenance of way.

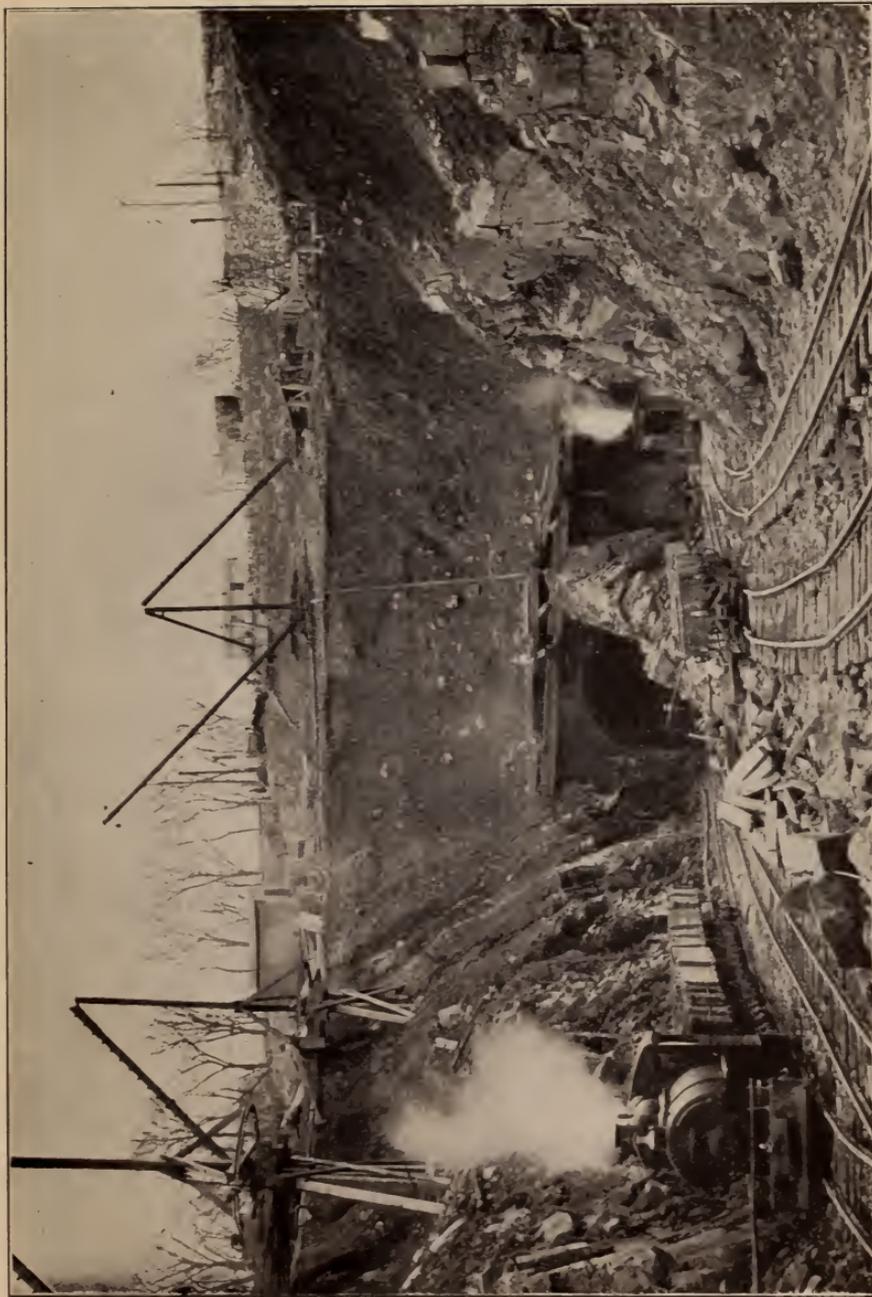


PENNSYLVANIA TUNNEL PLAN; contract let May 2, '04, to O'Rourke Eng. Con. Co.; work begun in Manhattan shaft April 1, '04, in Weehawken shaft Sept. 1; shields of north tube met 168 ft. west of state line Sept. 12, '06, south tube, 370 ft. east of state line, Oct. 9, '06.

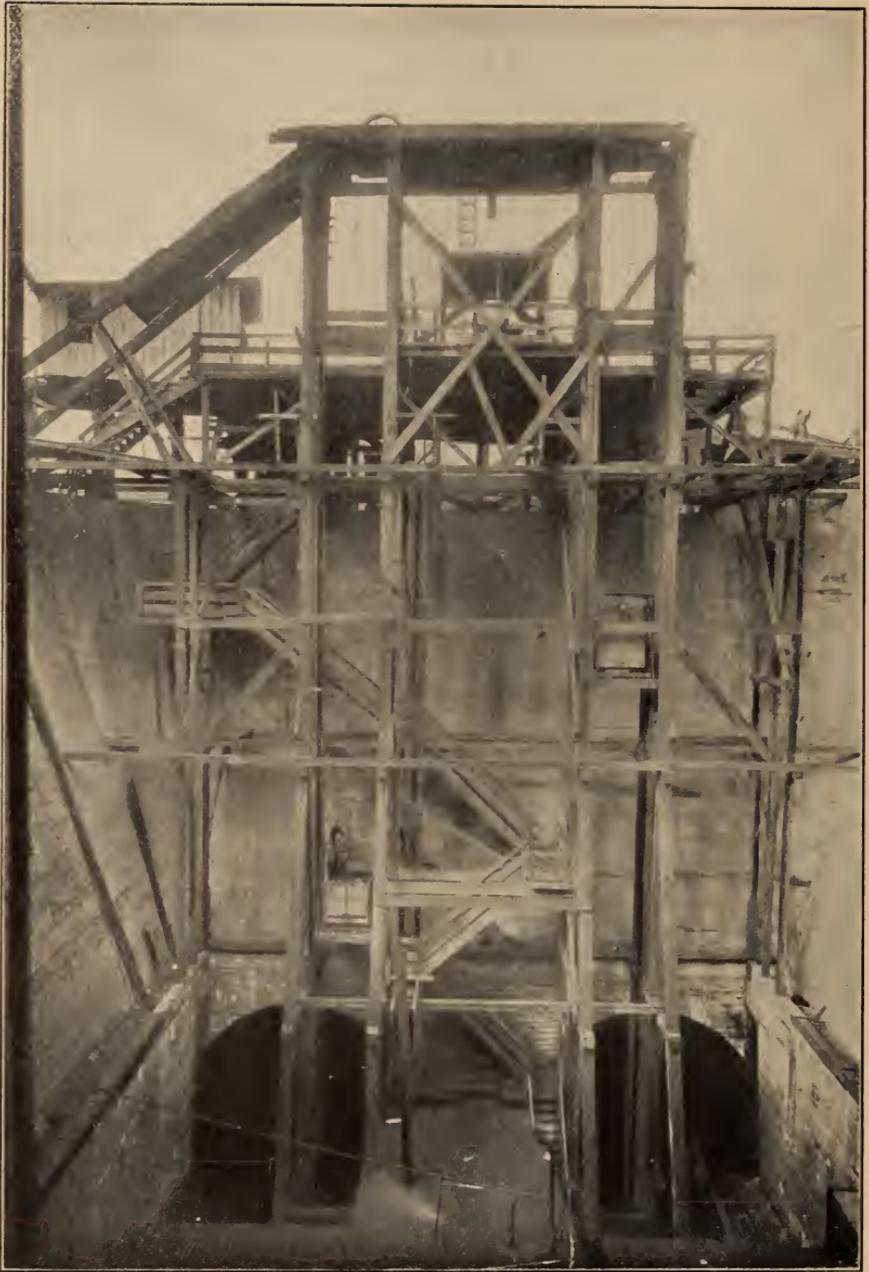


PENNSYLVANIA TUNNEL PROFILE, two concrete-lined, cast-iron tubes, each 23 ft. external diameter, made of rings 30 in. wide, each of 12 segments; weight of one ring from 2,373 to 30,318 lbs.; length of tube-lined portion, 6,118 ft.; column foundations sunk to bed rock.

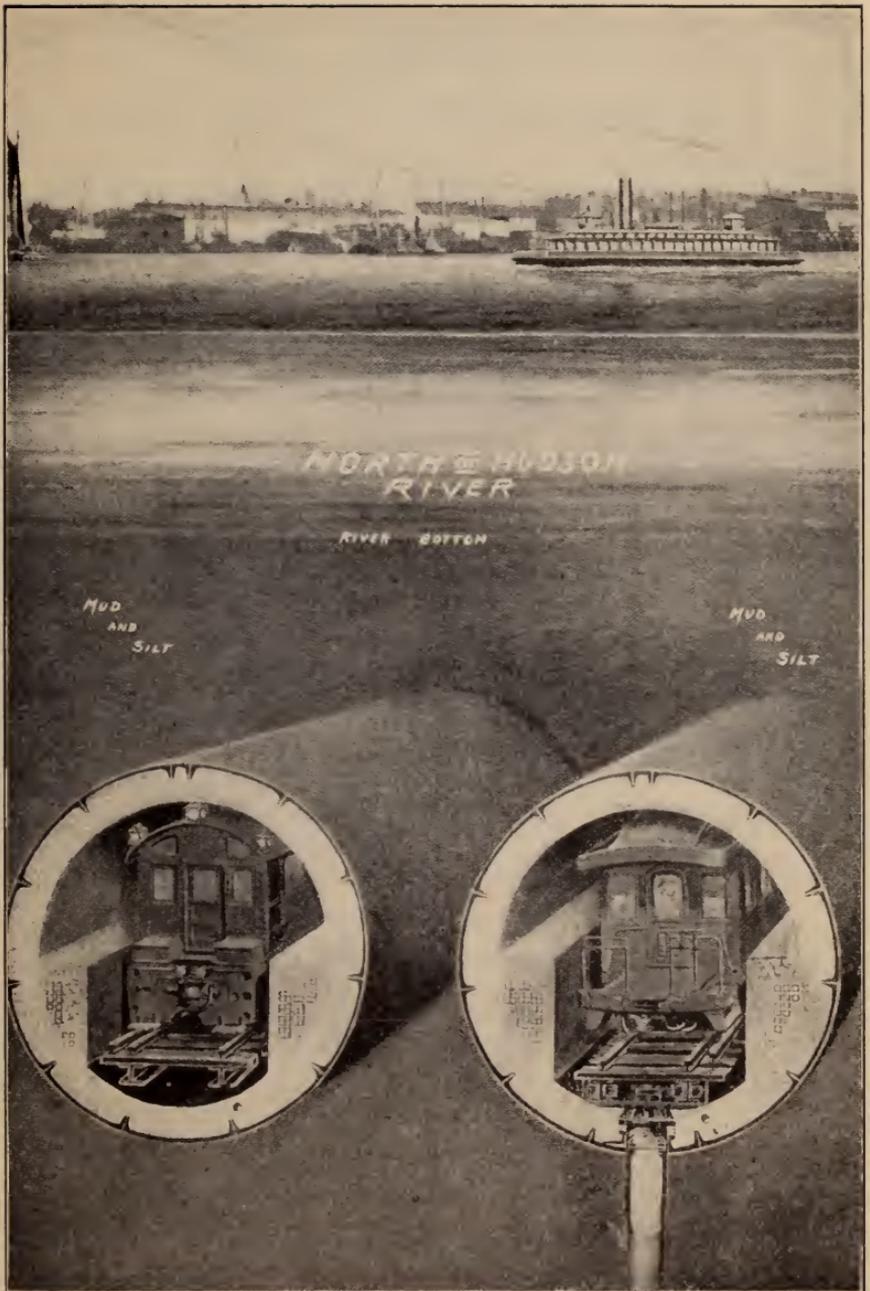
AVENUE  
DURS



**JERSEY PORTAL**, where Pennsylvania twin-tunnels enter west face of Bergen Hill, south end of Palisades, passing through rock 5,910 ft., thence under Hudson River through tubes 6,118 ft., thence 1,711 feet through soft ground and rock, emerging at 10th Ave., Manhattan, in depressed yards of station; total distance, 2.68 miles; all-rail route through centre of New York from West and South to New England States.



WEEHAWKEN SHAFT, 100x154 ft. at top; 56x116 ft. at bottom; 76 ft. deep; lined with 9,810 cu. ft. concrete; begun June 11, '03, finished Sept. 1, '04. Manhattan Shaft, 22x32 ft.; 55 ft. deep; begun June 10, '03; finished Dec. 11. Built by United Eng. & Con. Co.



CROSS SECTION PENNA. TUNNELS, trains running in tubes through silt bottom in Hudson, 4,432 ft. wide, 53 ft. deep; maximum depth bottom of tubes, 97 ft.; built by shields, air pressure, 15 to 37 lbs. sq. in.; north tube lining completed Oct. 9, '06, south, Nov. 18, '06.



TUBE, before lining with concrete; each tube weighs 35,000 tons and is made of 2,416 cast-iron and 31 cast-steel rings, each 30 in. wide; 29,364 segments held together by 310,769 bolts. AIR-LOCK, normal side bulkhead wall, 10 ft. thick; three locks into pneumatic section.



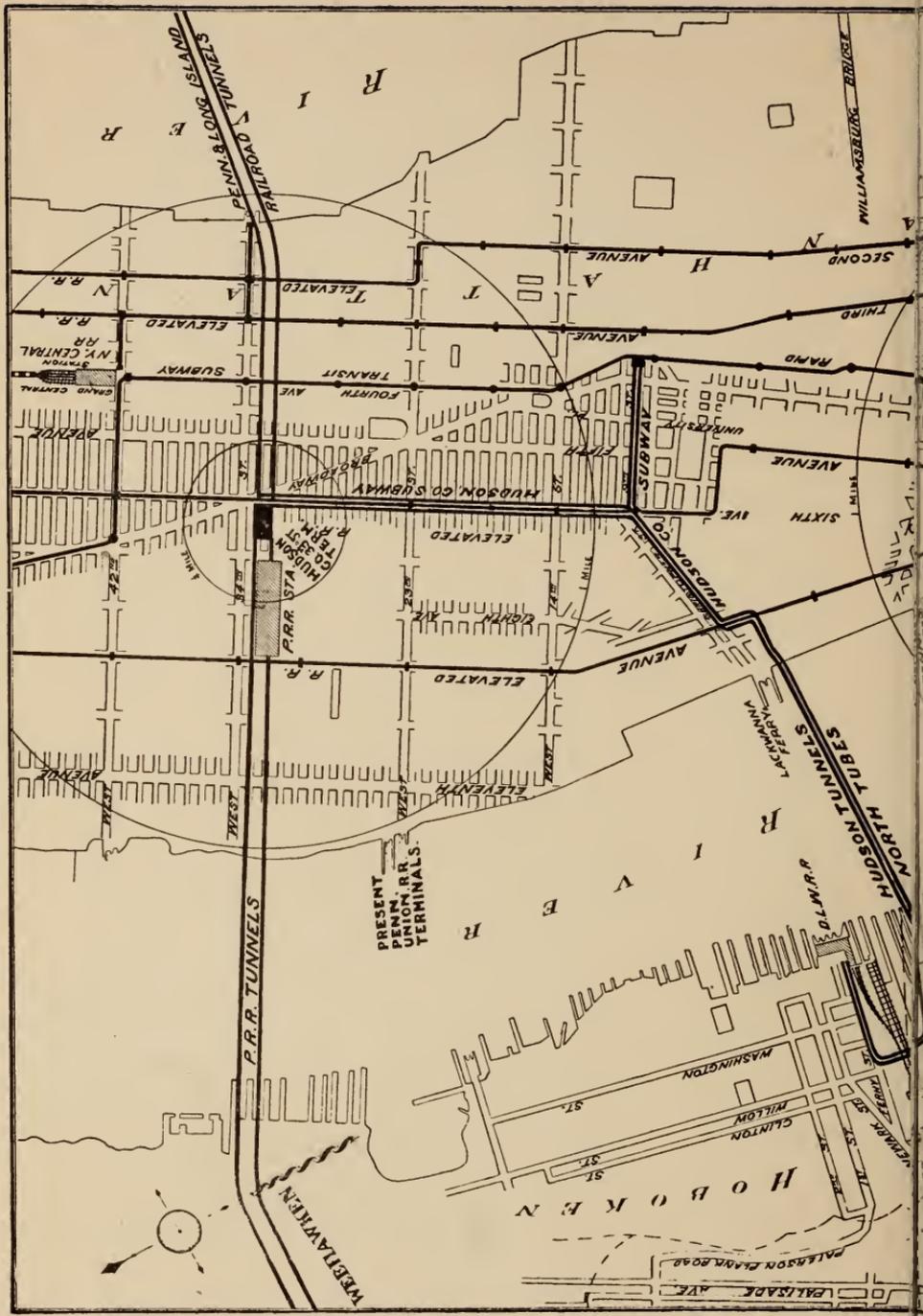
JUNCTION OF SOUTH TUBES, building last rings, Nov. 14, '06; bores made by driving 113-ton steel shield with 24 hydraulic rams exerting forward pressure of 6,000,000 lbs. Weight of shield and machinery, 193 tons. EMERGENCY AIR-LOCK for refuge in case of flooding.

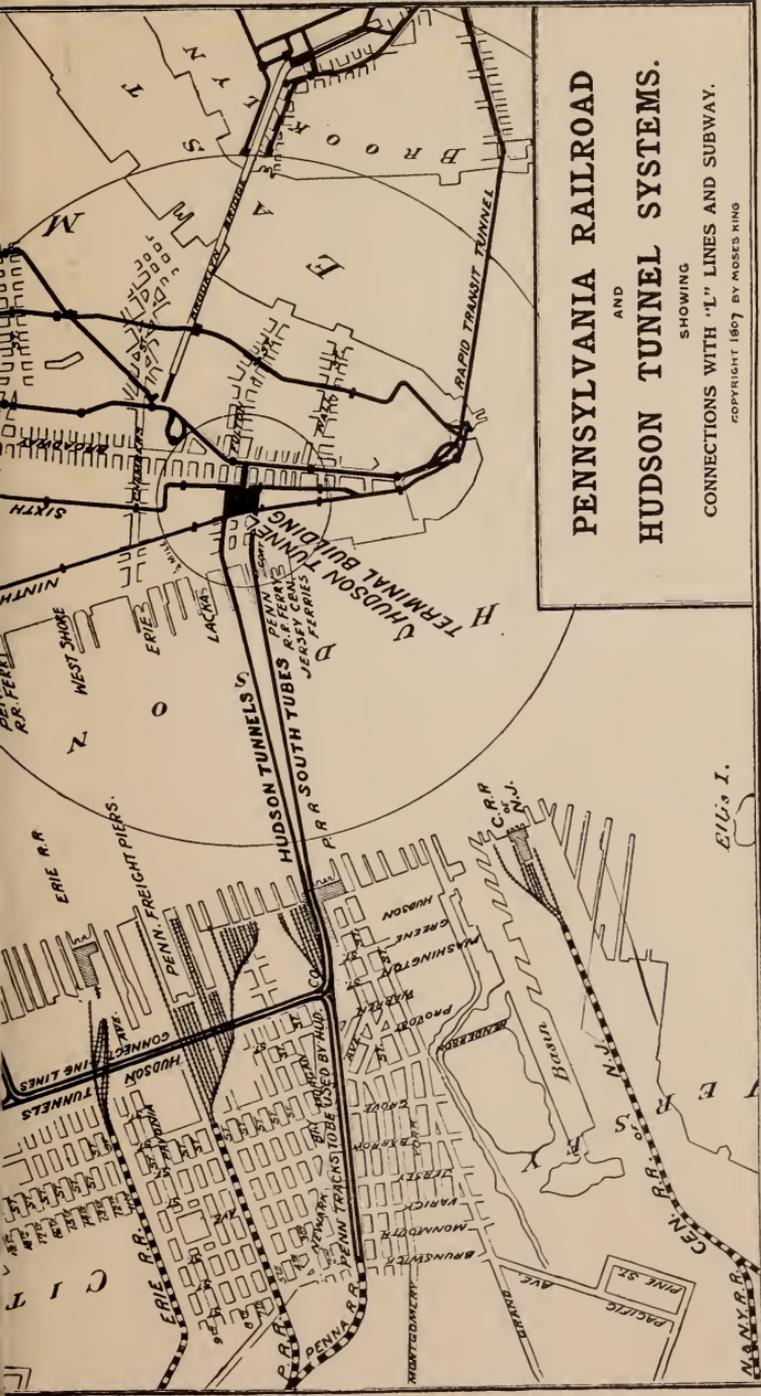


LINING AND WATERPROOFING rock section under Manhattan after excavation. LAYING DUCTS for electric power and light wires to carry the 105,000 electrical horse-power which will be required to move the trains and light stations and tunnels.



EXCAVATING under 9th Ave. "L" for cut through which materials from station excavation are carried to scows which are towed to Greenville, N. J., to fill in great freight yard. EIGHTH AVENUE, with trolley line supported on trestle during work on station excavation.

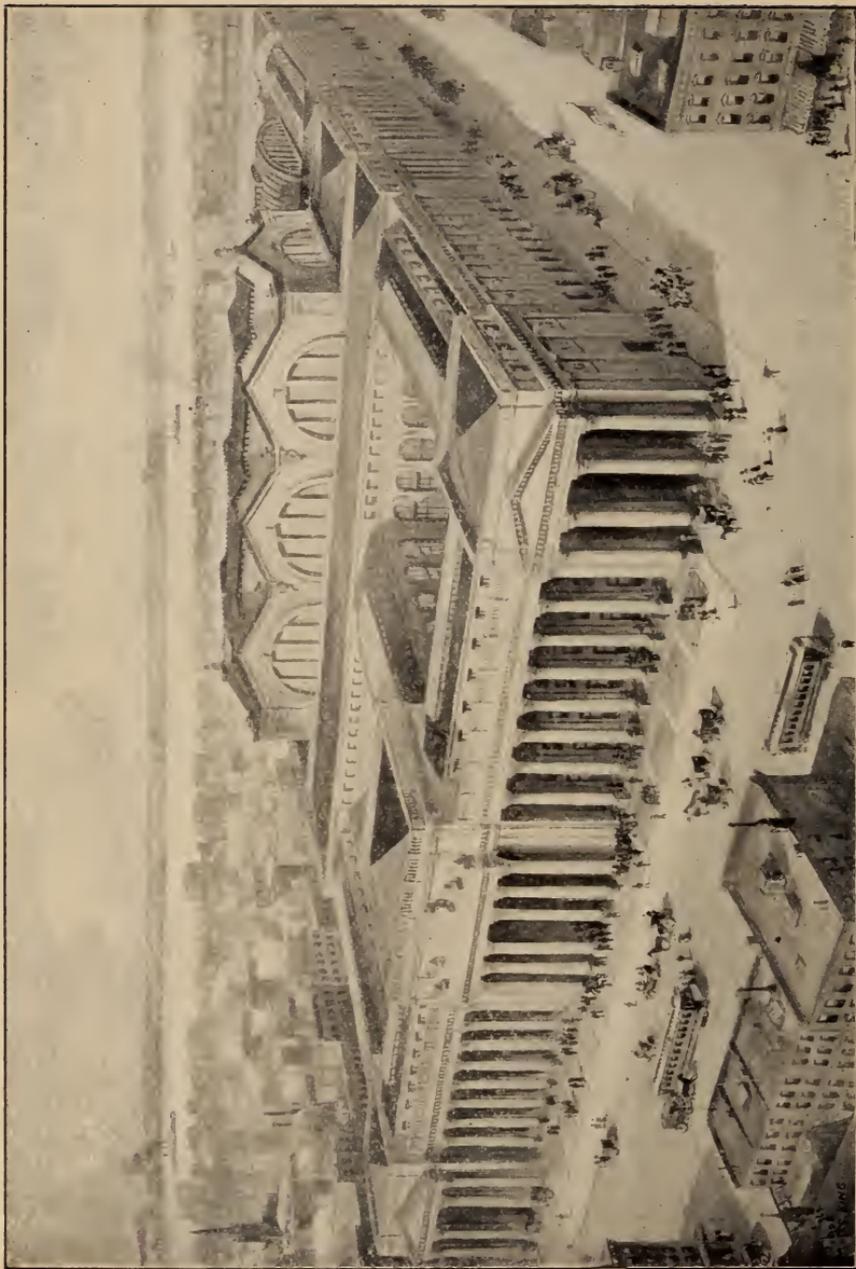




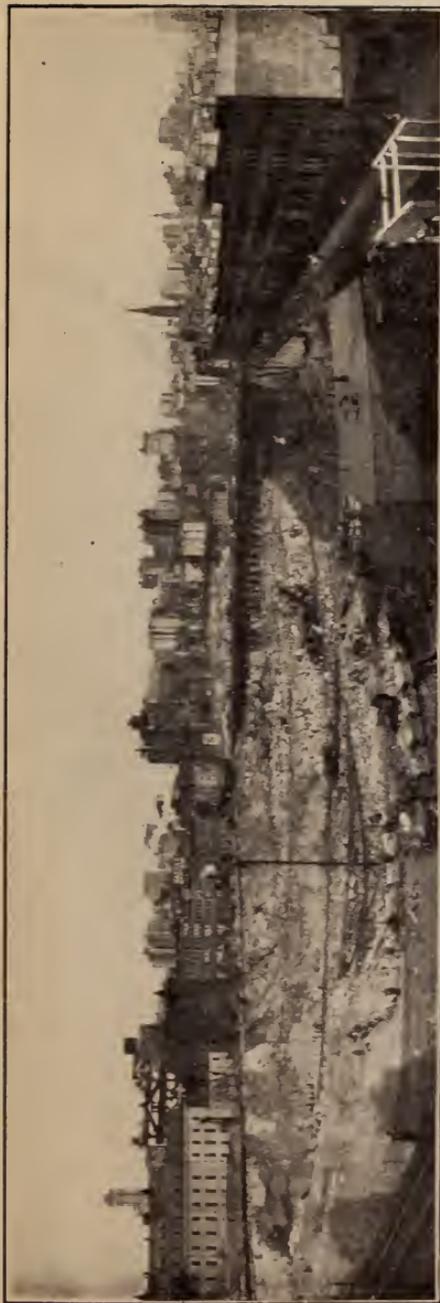
# PENNSYLVANIA RAILROAD AND HUDSON TUNNEL SYSTEMS.

SHOWING  
CONNECTIONS WITH "L" LINES AND SUBWAY.  
COPYRIGHT 1867 BY MOSES KING

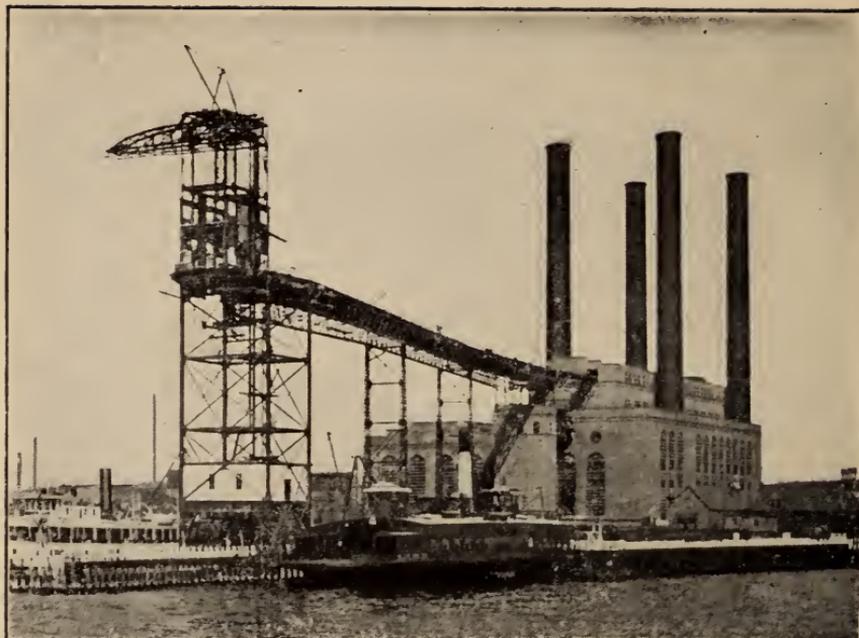
**PLAN OF TUNNEL SYSTEM.** The Pennsylvania Railroad's \$90,000,000 improvement at New York, besides giving the system all-rail communication with the city, connects the company's tracks with its Long Island R. R. lines and gives the latter entrance to New York and a through route to Boston is secured via the Connecting Railway. The tracks diverge to the north from the present Penn. line to Jersey City at Harrison, N. J., passing into two single track tunnels at Bergen Hill and emerging in the submerged yard at 10th Avenue, Manhattan (see page 4), there spreading out into 21 tracks. At 7th Ave., east of the station, the tracks converge into six, three under 32d St., three under 33d St. Near 6th Ave., each set of three tracks converges into two. Near the East River, 5,197 ft. from station, each of the four tracks enters a cast-iron tube, passing under river, 3,916 ft. through rock, gravel and sand, maximum depth of 88 ft., the four tracks converging in rock tunnels under Long Island, until they meet in an open cut near Thompson Ave., Long Island City. Charles M. Jacobs, Chief Eng'r; James Forgie, Chief Asst. North River Division; Alfred Noble, Chief Eng'n, East River Division. **THE HUDSON COMPANIES** have built four tubes under the North River and subways in Manhattan. (See page 18).



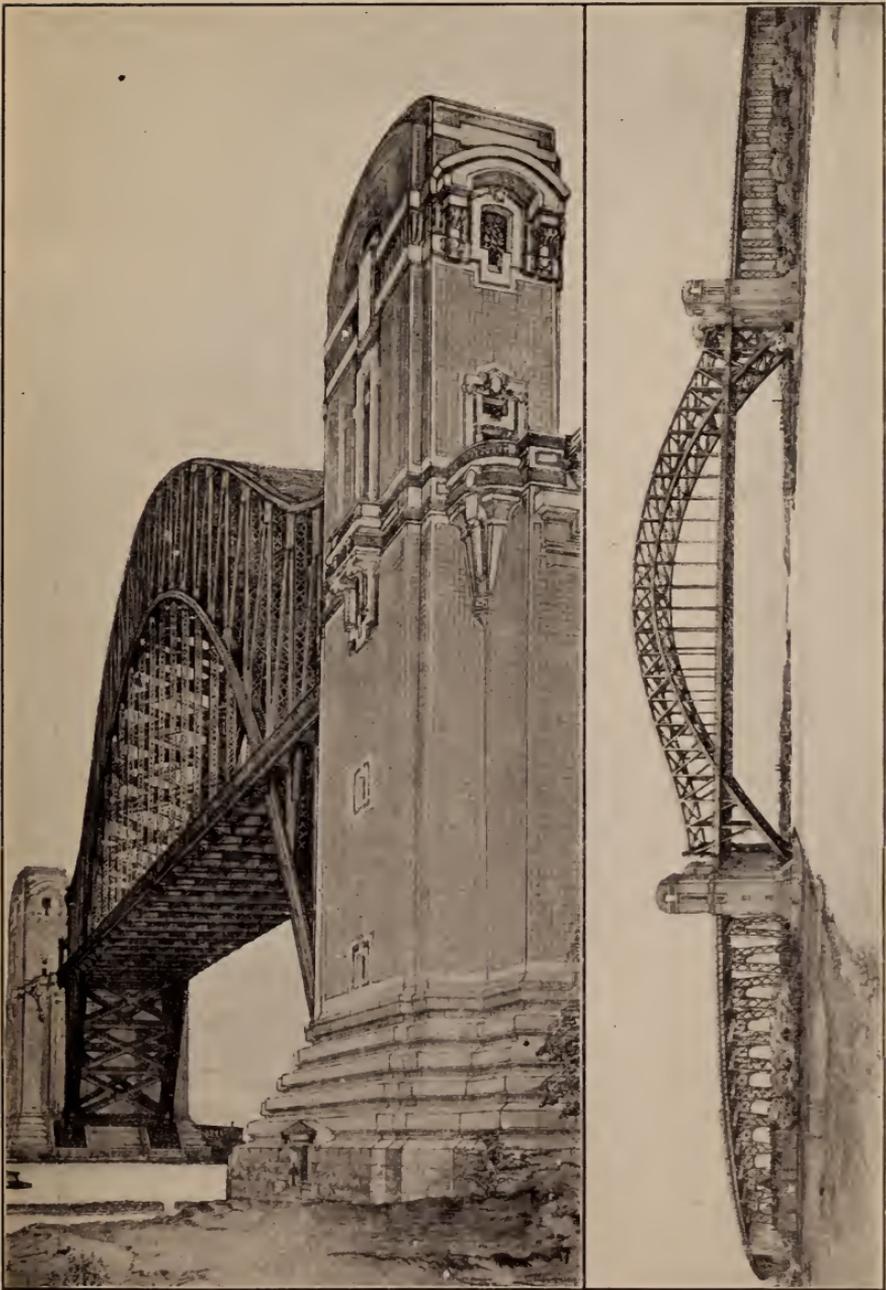
PENNA. STATION, 7th to 8th Ave., 31st to 33d St.; 780 by 430 ft.; 60 ft. high; 150 ft. in centre; Doric colonnade, 35 ft. high; tracks 40 ft. below street; main entrance 7th Ave., through arcade 45 ft. wide, 225 ft. long, to main waiting room, 320 by 110 ft. 150 ft. high, largest in world; two smaller waiting rooms, each 58 by 100 ft. concourse, 100 by 590 ft., with two flights of stairs to each train platform; sub-concourse, 60 by 340 ft., for passengers leaving trains; train shed, 340 by 210 ft., 21 tracks; McKim, Mead & White, architects.



STATION EXCAVATION, begun July 1, '04, after removing 400 buildings; completed, '07; 2,050 by 500 ft. depth, 45 ft. east end, 60 ft. west end; 2,500,000 cubic yds. excavated by N. Y. Contracting Company; concrete retaining walls 30 ft. at bottom, 5 ft. at top. UNDER FIFTH AVE., tunnels built by United Eng. & Con. Co. LOADING SCOWS with material taken from big station excavation.



POWER HOUSE, Long Island City, 200x500 ft. with coal tower 170 ft. high; 145,500 kilowatt generating units, 32 tubular boilers; George Gibbs, chief engineer electric traction.  
LONG ISLAND CITY, emergence of tunnels and connection with Long Island RR. system.



HELL GATE BRIDGE, four tracks; massive granite abutments surrounded by concrete towers; 220 ft. high; steel arch span, 1,000 ft. long; 135 ft. above water; with viaduct approaches, longest and heaviest bridge in the world; 80,000 tons. Gustav Lindenthal, Cons. Eng. & Arch.

HELL GATE BRIDGE, Connecting Railway from Queens over Hell Gate, Ward's Island, Randall's Island and Bronx Kills to connection with N. Y., New Haven & Hartford RR.; cut off in Queens connects with Penna. tunnels; freight tracks loop around Brooklyn to Bay Ridge, whence cars will be ferried across New York Bay to Penna. freight terminal at Greenville, N. J., the largest in the world.

# Hudson Tunnel System

IT WAS as long ago as 1871 that the tunnelling of the Hudson River was proposed by D. C. Haskin, who conceived the idea that iron cylinders, fitted with airlocks, placed horizontally below water-level, could be used with compressed air in tunnel construction. In November, 1874, he began, from a shaft sunk in Jersey City, to construct the first tunnel through the silt that forms the bottom of the Hudson River, and had reached a point about 1,200 feet from the shore, when, on July 21, 1880, a blow-out caused the loss of 201 ves and stopped the work.

In 1888 the project was revived, but the work stopped in 1892, with 3,000 feet of brick-lined tunnel completed. In 1902 Wm. G. McAdoo organized the New York and New Jersey Railroad Co., adopted the plan of building steel tubes, cut through the first tunnels under the Hudson, the headings of the north tube meeting on March 8, 1904, and south tube on Sept. 29, 1905.

These tunnels, which are 5,600 feet long, extend from 15th St., Jersey City, to Morton St., New York, and are being continued under Greenwich and Christopher Sts. and 6th Ave. to 33d St., with a spur across 9th St. to connection with Subway at Astor Place.

Another pair of tubes is being built by the Hudson & Manhattan Railroad Co. from Cortlandt and Fulton Sts., New York, to Montgomery St., Jersey City, with an extension of three-quarters of a mile to a connection with the Pennsylvania R. R. elevated tracks at Brunswick St. A transverse tunnel a mile and a quarter long through Jersey City and Hoboken, under the tracks of the Pennsylvania, Erie and Lackawanna Railroads, with entrances to the station of each road, will connect the two sets of tunnels.

Not only has Mr. McAdoo carried practically to completion in six years an enterprise that had dragged along unsuccessfully for thirty years, but he has greatly enlarged its scope, completing a system of 15 miles of underground railway, including four tubes under the Hudson whose total length is 23,256 feet, or 4.4 miles.

Where the northerly bores cross the river is 5,500 feet wide and the distance between the shafts is 5,650 feet, the maximum depth of the water, 60 feet; maximum depth of bottom of tube, 97 feet.

The southerly tubes, begun in January, 1906, will be 5,978 feet long, and will have a maximum depth of 92 feet. This work is being rapidly finished in 1908.

Charles M. Jacobs, the Pennsylvania tunnel builder, is chief engineer, with J. Vipond Davies, as chief assistant, in direct charge.

Both companies are controlled by the Hudson Companies, Walter G. Oakman president, and are financed by the banking house of Harvey Fisk & Sons.

Through these tunnels, which are 15 ft. 3 in. in diameter, high speed electric trains will be run from Newark to the Church St Terminal in 15 minutes; the passage under the river, from the present Penna. station in Jersey City, will take three minutes.

From Newark, through the transverse tunnel and the northerly tubes, to 33d St. and 6th Ave., Manhattan, will occupy 29 minutes; from Hoboken, 19 minutes. The portion of the system between Hoboken and 19th St., Manhattan, was opened to travel by President Roosevelt, February 25, 1908.

Eight-car trains are operated on a headway of 1½ minutes during the rush hours, providing seats for 16,000 passengers an hour. The cars have side doors as well as entrances at both ends, all operated by compressed air, and at the terminals the trains stop between broad, parallel platforms, so that passengers can be discharged from one side and admitted from the other, avoiding the chief cause of congestion and delays in the municipal subway operated by the Interborough Rapid Transit Co.

At Harrison, where the Hudson Companies' trains will start, when the entire system is in operation in 1909, there will be a great transfer station, where all the trains of the Pennsylvania Railroad will stop, and which will be the focus of the various lines of the Public Service Corporation, which has 640 miles of street railways in Newark, Elizabeth, and the other north Jersey cities and towns.

The Church St. Terminal will be the heart of underground transit in New York, for from this station, without at any time going from under cover, a passenger will be able to go by the municipal subway either to the Grand Central Station or to the Flatbush Station of the Long Island Railroad, by the McAdoo tubes to the Pennsylvania, Erie, or Lackawanna Stations in Jersey City, or to the Pennsylvania Station at Harrison, or by the elevators to either the 6th Ave. or the 9th Ave. elevated lines.

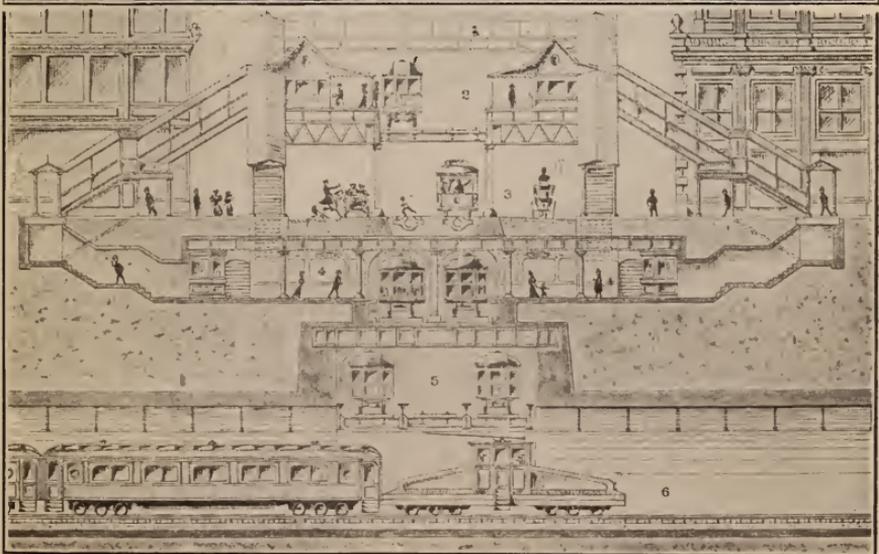
At 33d St. and 6th Ave. the Hudson Companies will have another large terminal, on the site of the Manhattan Theatre, with connection with the Pennsylvania Station at 7th Ave.



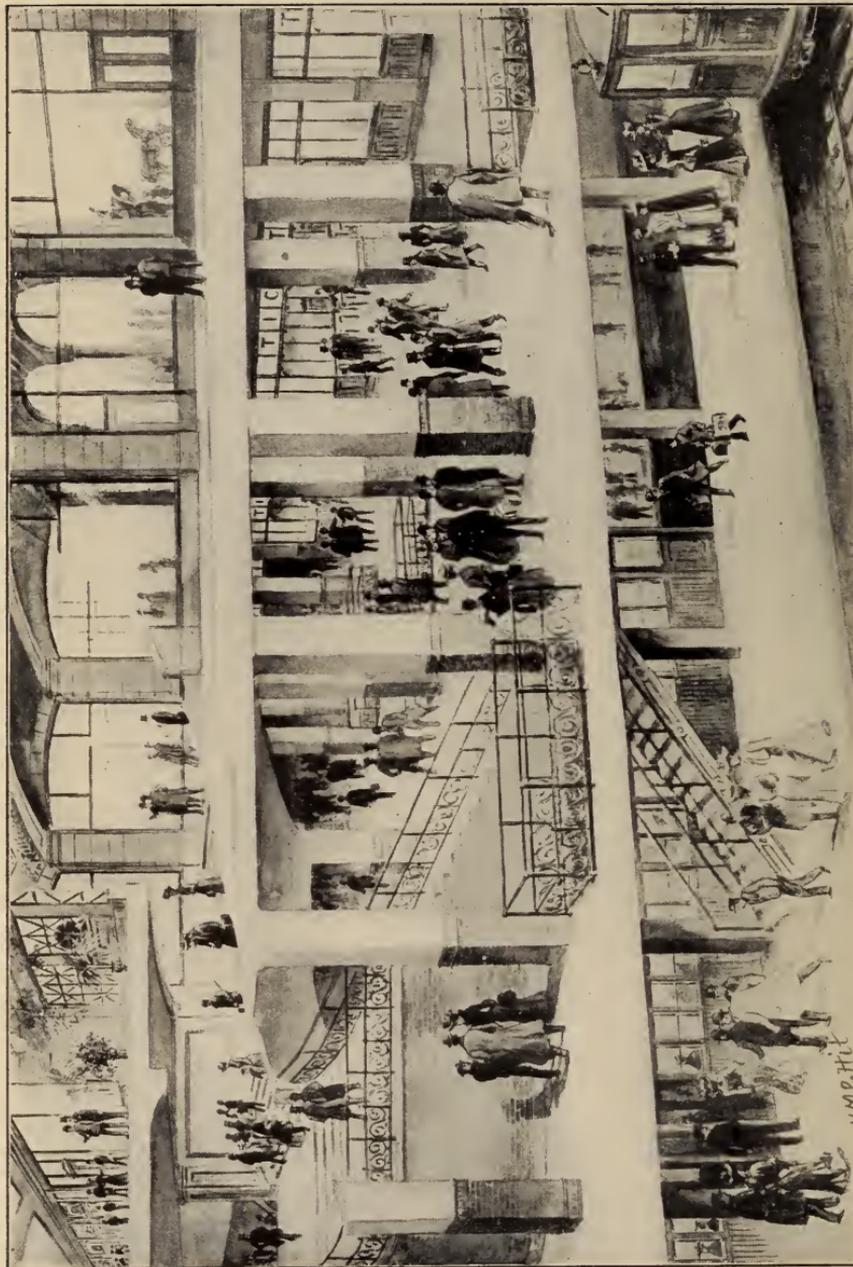
E. F. C. YOUNG, ANTHONY N. BRADY, E. H. GARY, directors Hudson & Manhattan RR.  
 J. VIPOND DAVIES, assistant to Eng'r Jacobs, W. G. M'ADOO, president. SIR WEETMAN  
 D. PEARSON, S. Pearson & Son, contractors for M'Adoo tubes and Penna.-East River tunnels.  
 C. F. McKIM and WM. R. MEAD, architects P.R.R. C. W. CLINTON, architect H.R. Term.



HUDSON COMPANIES TRAIN, under Hudson from 6th Av. & 19th St. to Hoboken.  
MORTON ST. TUBES, subway from Sixth Ave. entering twin tunnels under the Hudson  
at Morton and West Sts., trains descending to a depth of 95 ft. below mean high water.



M'ADOO TUNNEL; Morton St. tube, opened Feb. 25, '08; Cortlandt St. tubes under way. M'ADOO TERMINAL, 6th Ave. and 33d St.; Penna. tunnels on lowest level, proposed municipal subway; M'Adoo subway terminus; surface lines; 6th Ave. "L" and bridge over "L."



CHURCH ST. TERMINAL, Hudson & Manhattan RR., Cortlandt to Fulton Sts., built on largest coffer dam in the world, 400x178 ft., 75 ft. deep, at one point 98 ft.; trains from Jersey enter coffer dam at Cortlandt St. 30 ft. below surface, emerging at Fulton St.; passengers ascend from 20-ft. platforms by stairways to concourse, passage under Dey St. connecting with subway in Broadway and stairs leading to street and "L" stations; estimated that 600,000 people will pass through this station in a day. Clinton & Russell, architects.



CHURCH ST. TERMINAL, largest and heaviest building in city; 200,000 tons, including 24,000 tons structural steel, 37,500 tons concrete, 16,300,000 bricks, 4,500 tons terra cotta, 120,000 sq. ft. glass, 140 miles of pipe, 113 miles wiring, 39 electric elevators, 22 stories, 275 ft. above curb; entire structure, 18,150,000 cubic ft. Clinton & Russell, Architects.

# The Ingenious Construction of Hudson River Tunnels

NEW problems were met and solved in the building of the tunnels under the Hudson and East Rivers—problems considerably more difficult than those encountered in any of the eight small tunnels under the Thames at London, or in the 6,000 ft. bore under the St. Clair River connecting Port Huron with Sarnia in Canada, all of which were constructed by the shield method.

In each of these cases the tunnel was driven through clay, or sand, or gravel, and only moderately high air-pressures were necessary to prevent the water oozing into the tube, but in boring under the rivers that gird Manhattan, the builders encountered a very soft mud, unstable and treacherous, and besides using air pressures as high as 39 lbs. per sq. in. above the normal, they had to resort to numerous devices to prevent this Hudson silt from engulfing the workers and machinery.

A special type of shield was devised by Chief Engineer Jacobs and Assistant Engineer Forgie, builder of tunnels under the Thames, London. Before the bore entered the silt a concrete bulkhead, 10 ft. thick, was erected in the rock section of the tunnel. This was pierced with three air-locks, those for passing materials into the shield-chamber and for the admission of the workers being on a lower level, and the emergency air-lock near the top of the tube.

Within the chamber formed by this bulkhead the shield was erected—a steel structure, 23 feet 6¼ inches in diameter and 15 feet 11½ inches long, with nine pockets, three on lower level, four in midsection, two at top.

From the pockets sliding platforms were pushed forward into the silt, under a movable hood that could be projected 25 inches forward of the cutting edge of the shield. On the platforms the “sand hogs” worked at the silt, passing the excavated material back through the pockets into the shield-chamber, and as they cleared the way the shield was pushed forward by hydraulic rams.

On the chamber side of the shield was another hood or “skin” of steel-plates, extending back 6 ft. 4 in., to hold up silt while cast-iron lining was being put in.

In each of the tunnels different difficulties were encountered. While the Pennsylvania tubes went from shore to shore, under the Hudson, through silt, the McAdoo north tubes encountered rock, and blasting had to be resorted to; in the East River tunnels the top of the bores came so close to the river bottom that blankets of clay had to be placed in the water over the place of the boring.

But the most remarkable feature of the construction of these tunnels is the scheme by which they have been converted into sub-aqueous bridges.

In lining the tunnels, on the bottom centre line, a cast-steel shoe or plug 2 feet 7 inches in diameter was inserted every fifteen feet. On this was screwed a 7-foot tube of the same diameter, made of steel, 1¼ inches thick, and this was forced down into the silt by a hydraulic ratchet until it was flush with the inner bottom of the tube; then another 7-foot section was screwed to it and forced down, and this was continued until a hollow steel column had been constructed and forced down 10 feet or 100 feet, as might be, until the steel shoe was firmly planted on bed-rock. Then the hollow column was cut off flush with the inner lining and filled with concrete.

Thus a series of steel and concrete foundations in the river form a bridge carrying the tracks of the Pennsylvania Railroad under the river within the tube, which in turn was strengthened by a lining of two feet of concrete, held in solid mass and running from shore to shore, affording a solid structure in which heavy express-trains can be moved with safety at high speed, at the rate of a train every two minutes.

*William Wirt Mills,*