

KING'S BOOKLETS

One 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 theaters of the metropolis, the Pennsylvania Railroad Company has wrought a great triumph of railroad engineering at a special outlay of over \$50,000,000, entirely apart from the cost of the Hudson River (McAdoo) Tunnel. The problem was not to span a bridge over the mile-wide Hudson River—shipping facilities 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-bore, 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

ENTRANCE 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 inconveniences and delays of the transfer by ferry will be avoided."

Mr. Cassatt and Samuel Roe, third vice-president, took up the problem with Charles M. Jacobs, who was then successfully building the McAdoo tubes under the Hudson and the 10-ft. Gas Tunnel from Riverwood, L. I., under East River to East 71st St., Manhattan.

So expeditious were the engineers in developing the project that on Dec. 22 of the same year the company announced its plans to establish all-rail connection between New Jersey and Long Island, through the heart of New York by means of the most daring scheme of tunnels ever devised.

A year was occupied by negotiations for the franchise, which was signed by Mayor Law on Dec. 22, 1902, and on June 16, 1903, construction was begun and pushed with such energy and with so few set-backs that the great \$100,000,000 work is expected to be completed by the Fall of 1908.

This 15-mile link overcomes the inequality of Manhattan and unites the 12,375 miles of Pennsylvania Railroad tracks with the lines on Long Island and 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 crossways and enter the tunnels at Bergen Hill (p. 1) 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 centers of the tubes under the river being 37 ft. These tunnels coincide under Manhattan to the entrance to the depressed station-yard at 9th Avenue. This work has been done under immediate direction of Mr. Jacobs' deputy, James Foyles, who built Blackwell tunnel under the Thames.

In the great yard between 9th and 8th Aves., 50 ft. below the surface, the two tracks multiply to 22 and pass through the

station (p. 15) at a depth of 42 ft., at 9th Ave. the tracks, converging into six, enter three-track tunnels, one under 12d St. and one under 12th at 9th Ave., at a depth of 75 ft., these tunnels change from two wide arches to two twin arches, carrying four tracks to 12 Ave., where they enter four separate tubes which extend under the East River, a distance of 1,915 ft., near the Long Island shore the tunnels begin to converge and they meet in an open cut (p. 25) that leads into the Thompson Ave. yards, 1.85 miles from the station entrance in Seventh Ave. Alfred Noble is chief assistant engineer, under Mr. Jacobs, for all work east of 9th Ave.

Including 15 miles of tracks in the central station and yards, there will be 31.75 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 9th Ave. and 71st St., Manhattan, 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 Roe and Chief Engineer Jacobs, with the advice of a board of consulting engineers consisting of Eng. Gen. C. W. Raymond, U. S. A., chairman, and Messrs. 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 George Lindbergh, Bridge Commissioner of New York City, were members of the board.

Closely related to this vast tunnel and station enterprise is the Connecting Railway, which will carry trains from the tunnels through to New England and give the N. Y., New Haven & Hartford access to the Pennsylvania station at 9th 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 cut-thru across New York Bay to Greenville, N. J.

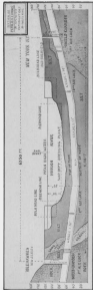
The portion of the Pennsylvania tracks from Harrison to Jersey City, abandoned by the diversion of the main line through the tunnels, will be given over to the Hudson & Manhattan Railroad for a suburban service through the McAdoo tubes to Cortlandt St., Manhattan (pp. 18-21).



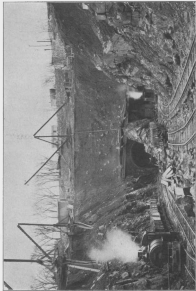
SAMUEL BEAL, 54 v.p. P.R.R.; JAMES MCKEE, Pres. P.R.R.; CHARLES E. FUGH, and v.p. P.R.R.; CHARLES M. JACOBS, designer tunnels and ch. eng.; ALEX J. CASSATT, late Pres. P.R.R.; JOHN P. GREEN, 1st v.p.; JAMES FORGIVE, ch. and. eng. N. Riv. Div.; WM. H. BROWN, 64 of eng.; J. T. RICHARDS, ch. eng. maintenance of way.



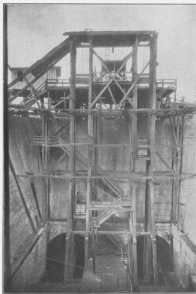
PENNSYLVANIA TUNNEL PLAN, continued by May 1, 1904, on D'Route Eng. Co., Co., work begun in March about April 1, 1904, in an extension about Sept. 1; blocks of north side not till E. east of main line Sept. 19, '04, north side, 270 ft. east of main line, Oct. 26, '04.



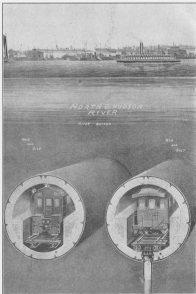
PENNSYLVANIA TUNNEL PROFILE, cross section-head, east-west, each 21 ft. 3 in. in diameter, made of pipe 20 in. wide, each of 12 segments, weight of one ring from 2 1/2 ft. to 3 1/2 ft. (3 in.) length of tube-head portion, 6 1/2 ft. by columns foundation sunk to bed rock.



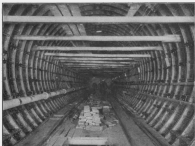
JERSEY PORTAL, where Pennsylvania rock-cuttings enter west flank of Bergen Hill, north end of Palisades, passing through rock 1,500 ft. above outer Hudson River through soft ground and rock, strapping at 10th Ave., Manhattan, in approved path of nation's total itinerary, a 18 mile, 18-in. tunnel through center of New York from West end through to New England States.



WICKHAMKIN SHAFT, 100x114 ft. at top, 96x116 ft. at bottom, 96 ft. deep, lined with 9,815 cu. ft. concrete; begun June 10, '03, finished Sept. 1, '04. Mainman Shaft, 100x78 ft., 55 ft. deep; begun June 10, '03, finished Dec. 11. Built by United Eng. & Con. Co.



CROSS-SECTION PENNSA. TUNNELS, tubes resting in tubes through old bottom in Hudson, 44 ft. E. wide, 22 ft. deep; maximum depth bottom of tubes, 97 ft.; built by shield method; air pressure, 1 1/2 to 27 lbs. sq. in.; south tube completed Oct. 9, '08, north, Nov. 18, '08.



TUBE, before lining with concrete, each rib weighs 25,000 tons and is made of 2,400 cast-iron and 32 cast-steel rings, each 30 in. wide, 20, 204 segments held together by 210,769 bolts. AIR-LOCK, normal rib bulkhead wall, 10 ft. thick, three locks into pneumatic section.



JUNCTION OF SOUTH TUBES, building last rings, Nov. 14, '06; bars made by driving 12 1/2-in. steel shield with 14 hydraulic rams exerting forward pressure of 4,000,000 lbs. Weight of shield and machinery, 197 tons. **EMERGENCY AIR-LOCK** for refuge in case of flooding.

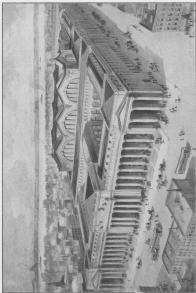


LINING AND WATERPROOFING rock section under Manhattan after excavation. **LAYING DUCTS** for electric power and light wires to carry the 100,000 electrical horsepower which will be required to move the trains and light stations and tunnels.

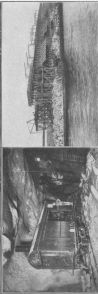


EXCAVATING under 4th Ave. "L" for cut through which materials from station excavation are carried to mows which are towed to Greenville, N. J., to fill in great freight yard. EIGHTH AVENUE, with trolley line supported on trestle during work on station excavation.

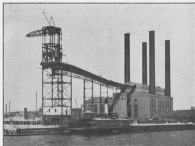




PENNA. STATION, 7th to 8th Aves., 128 to 134 St., 7th to 8th Aves., 128 to 134 St. High, 150 ft. In center, Doric colonnade, 21 ft. high; reaches 48 ft. below street; main entrance 7th Ave., through arcade 41 ft. wide, 22 ft. high, to main waiting rooms, 320 by 120 ft., 150 ft. high, largest in world; two smaller waiting rooms, each 68 by 120 ft. concourse, 120 by 390 ft., with two flights of stairs to each train platform; sub-concourse, 80 by 240 ft., for passengers leaving waiting main shed, 240 by 220 ft., at tracks; McKim, Mead & White, architects.

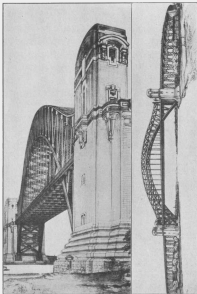


STATIONS EXCAVATION, began July 1, '64, after removing 400 buildings, completed, '67, 1,510 by 100 ft. deep, 45 ft. east end, 40 ft. west end, 1,000,000 cubic yds. excavated by N. T. Contracting Company, concrete retaining walls 30 ft. at bottom, 1 ft. at top. UNDER PIPING AGE, tunnels built by United Reg. & Con. Co. LOADING SCUMS with material taken from big station excavation.



PENNSYLVANIA RAILROAD TUNNELS
BY LONG ISLAND CITY
Copyright, 1914, by STEPHEN H. HARRIS

POWER HOUSE, Long Island City, 4,000,000 ft. with coal tower 170 ft. high; 24 5,000-horsepower generating units; 28 tubular boilers; George Gibbs, chief engineer electric traction.
LONG ISLAND CITY, emergence of tunnels and connection with Long Island RR. system.



HELL GATE BRIDGE, connecting railway from Queens near Hell Gate, Wood's Island, Little Hell Gate, Randall's Island and Bronx Kills to connection with N. Y. New Haven & Hartford R.R., cut off by Queens connection with Penna. (outside) bridge tracks loop around Brooklyn to Bay Ridge, where ocean will be ferried across New York Bay to France. Height terminal at Greenwiche, N. J., the largest in the world.

HELL GATE BRIDGE, four tracks; massive granite abutments incased in concrete towers containing offices of operating forces; 200 ft. high; steel arch span, 2,000 ft. long; 240 ft. above water, with viaduct approaches, longest and heaviest bridge in the world; 80,000 tons.

Hudson Tunnel System

IT WAS as long ago as 1871 that the tunneling of the Hudson River was proposed by D. C. Mackin, 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 25 lives and stopped the work.

In 1888 the project was revived, but the work stopped in 1890, with 3,000 feet of brick-lined tunnel completed. In 1904 Wm. G. McAloon organized the New York & New Jersey Railroad Co., adopted the plan of building steel tubes, cut through the first tunnel under the Hudson, the headings of the north tube meeting on March 8, 1904, and those of the south tube on Sept. 19, 1905.

These tunnels, which are 2,800 feet long, extend from 14th St., Jersey City, to Marton St., New York, and are being continued under Greenwich and Christopher Sts. and 4th Ave. to 134th St., with a spur across 9th St. in a connection with the 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, will connect to the station of each road, and will connect the two sets of tunnels.

Not only has Mr. McAloon carried practically to completion in five years an enterprise that had dragged along unsuccessfully for thirty years, but he has greatly enlarged its scope, comprising a system of 14 miles of underground railway, including four tubes under the Hudson whose total length is 11,148 feet, or 4.4 miles.

Where the northerly tubes cross the river is 2,500 feet wide and the distance between the shafts is 2,500 feet, the maximum depth of the water, 60 feet; maximum depth of bottom of tube, 97 feet.

The southerly tubes, begun in January, 1904, will be 3,878 feet long, and will have

a maximum depth of 92 feet. This work is being done entirely from the Jersey side.

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

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

Through these tunnels, which are 17 ft. 7 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 134th St. and 4th Ave., Manhattan, will occupy 29 minutes; from Hoboken, 19 minutes. This service will be in operation by January, 1908.

Eight-car trains are to be run on a headway of 15½ minutes during the rush hours, providing seats for 18,000 passengers an hour. The cars will have side doors as well as doors at both ends, all operated by compressed air, and as the terminals the trains will stop between 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.

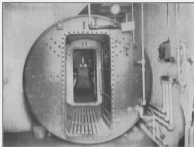
At Harrison, where the Hudson Companies' trains will start, there will be a great transfer-station, where all the trains of the Pennsylvania Railroad will stop, and which will be the focus of the various lines of the Public Service Corporation, which has 600 miles of street railways in Newark, Elizabeth, 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 down 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 McAloon 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 4th Ave. or the 9th Ave. elevated lines.

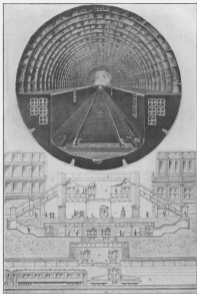
At 134th St. and 4th Ave. the Hudson Companies will have another large terminal, on the site of the Manhattan Theatre, with connection with the Pennsylvania Station at 7th Ave.



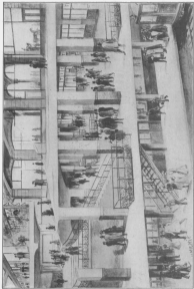
E. F. C. YOUNG, ANTHONY M. BRADY, E. H. GARY, *Directors Hudson & Manhattan R.R.*
 J. VINSON DAVIES, *assistant to Eng'rs Jacobs*, W. G. M'ADOO, *president*, SIR WERTMAN
 D. PEARSON, S. PEARSON & SONS, *contractors for M'Adoo tubes and Penna.-East River tunnel*.
 C. F. McKIM and WM. R. MEAD, *architects P.R.R.* C. W. CLINTON, *architect*. H.R.T.



HOSPITAL AIR LOCK, where walkmen are tested for the "bends" in reduced pressure.
FIRST PASSAGE UNDER HUDSON RIVER, north side of Hudson & Manhattan tunnels
from Morris St., Manhattan, to 124th St., J. C., Sept. 29, 1875; begun 1872; twice abandoned.



M'ADOO TUNNEL, Motion Street takes completely, Corlandt Street takes under way. M'ADOO TERMINAL, 6th Ave. and 151 St., From tunnel on lowest level; proposed municipal subway; M'Adoo subway terminal; surface lines; 6th Ave. "L" and bridge over "L."



CHURCH ST. TERMINAL, Hudson & Manhattan R.R., Combustible Fuel Oil, built on largest roller dam in the world, generating 25,000 h. p., cheaply at one point, 400 h. p. below from Jersey water roller dam at Coarctate St., 700 h. p. below further, emerging at Fulton St.; passengers ascend from 100-ft. platform by railway to concourse, pumps under Day St. connecting with subway in basement and stairs leading to street and "A" subway entrance; estimated that 400,000 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, 17,000 tons concrete, 16,500,000 bricks, 4,000 tons terra cotta, 188,000 sq. ft. glass, 120 miles of pipe, 17 1/2 miles wiring, 50 electric elevators, 28 stairs, 27 1/2 ft. above city water structure, 18,150,000 cubic ft. Clinton & Russell, Architects.

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 4,000-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 rising into the tube, but in boring under the rivers that join Manhattan, the builders encountered a very soft mud, unstable and free borax, and besides using air pressure as high as 40 lbs. per sq. in. above the normal, they had to resort to numerous devices to prevent this Hudson air from engulfing the workers and the masonry.

A special type of shield was devised by Chief Engineer Jacobs and Assistant Engineer Foyte, the builder of Blackwall tunnel, England. Before the bore entered the air a concrete bulkhead, 10 feet thick, was erected in the rock section of the tunnel. This was placed 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, 21 feet 4½ 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 air, under a movable head that could be projected 2½ inches forward of the cutting edge of the shield. On these platforms the "sand hogs" worked at the air, passing the excavated material back through the pockets into the shield-chamber, and as they closed the way the shield was pushed forward by hydraulic rams.

On the chamber side of the shield was another head or "skin" of steel-plates, extending back 5 ft. 4 in., to hold up air while cut-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 air, the McAdoo north tube encountered rock, and blasting had to be resorted to in the East River tunnels the top of the bore 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 subaqueous bridges, the concrete tube becoming merely a protective shell to keep out the water and air.

In lining the tunnels, on the lower concrete line, a cast-iron 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, 1½ inches thick, and this was forced down into the air by a hydraulic rammer until it was flush with the inner bottom of the tube; then another 7-foot section was screwed on and forced down, and this was continued until a hollow steel column had been constructed and forced down 20 feet or 100 feet, as might be, until the steel shoe was firmly placed 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 columns were securely placed 15 feet apart in the river bottom resting on the bed-rock, and on these pillars were laid, forming a bridge for carrying the tracks of the Pennsylvania Railroad under the river within the tube, at once guarding against the drifting of the tube by any possible movement of the air and affording a solid structure on which heavy express-trains could be moved with safety at high speed.