PDHonline Course C709 (9 PDH)

Conquest of the Hudson

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2020

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Conquest of the Hudson

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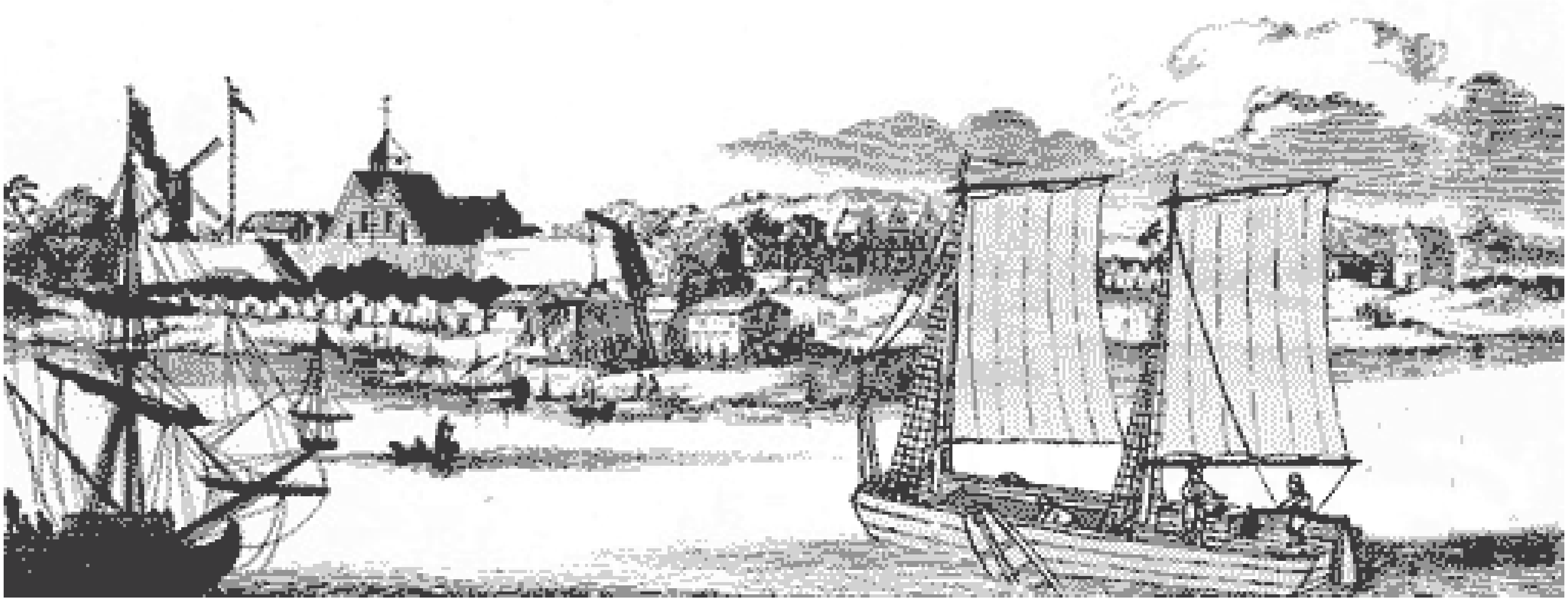
Part 1

To Get to the Other Side

Periaugers



"…The history of the transportation facilities between Jersey City and New York shows a steady but slow improvement. The canoes of the Indians and the rowboats of the first settlers were followed by the queer sailing boats of the early Dutch inhabitants, called 'periaugers.' These were used until the early part of the nineteenth century, when they were superseded by the steam ferry boats introduced by Fulton. For years, however, these were little better than the old sail boats, but they gradually improved, changing to the side wheel steamers and these again to the magnificent screw propelled vessels which now ply the waters of the Hudson and are probably the finest river ferry boats in the world…"

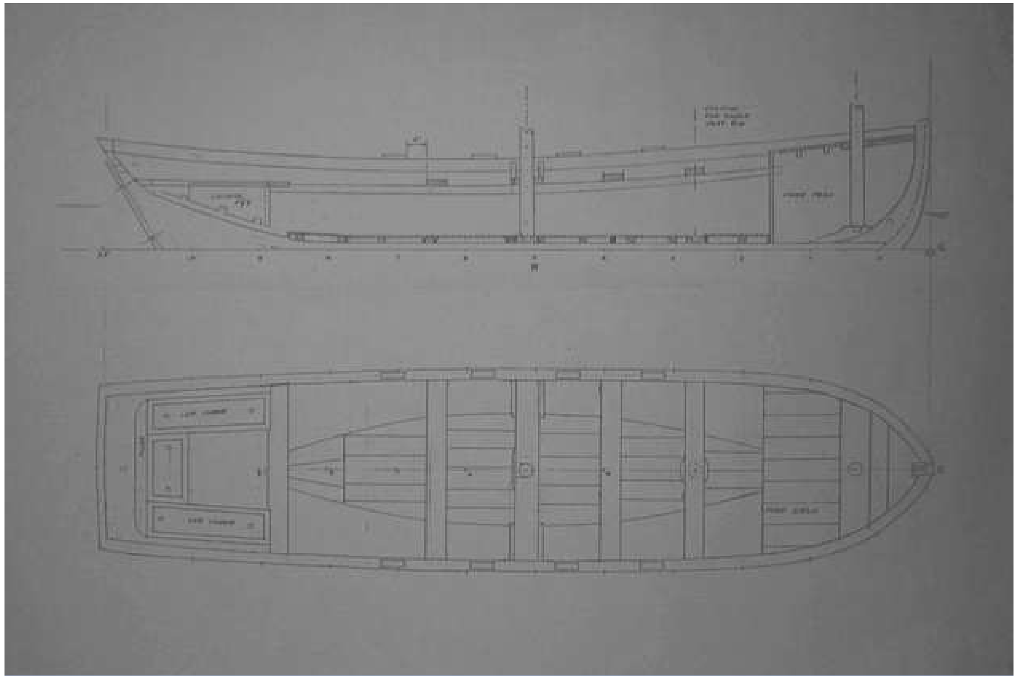
RE: excerpt from *A Sketch History of Transportation Between Jersey City and New York, 1661-1909*

Above: caption: "Hudson River Periauger"


t' Fort nieuw Amsterdam op de Manhatans
FORT NEW AMSTERDAM (NEW YORK), 1651.

"…The first ferry between the present cities of Jersey City and New York, of which there is any record, was established near what is now the foot of Communipaw avenue, in 1661, and William Jansen was licensed to take charge of it. The boats used in these early ferries were rowboats, and small decked sailboats, known as 'periaugers.' These were pointed at both ends and carried two masts and boom sails. When horses and carriages were to be taken across they were detached and lifted into the boat. Jansen was the ferryman for eight years, but there seems to have been considerable trouble between him and the inhabitants. He claimed the exclusive right to ferry people over the river and insisted that they had no legal right even to use their own boats to cross over in. The settlers resisted this claim and also complained that the ferryman did not do his duty. Jansen on the other hand claimed that the people refused to pay. The matter was laid before the authorities at New Amsterdam, and judgment was rendered 'that the Sheriff must assist the ferryman in getting his pay and that he must do his duty or be dismissed.'…"

RE: excerpt from *A Sketch History of Transportation Between Jersey City and New York, 1661-1909*

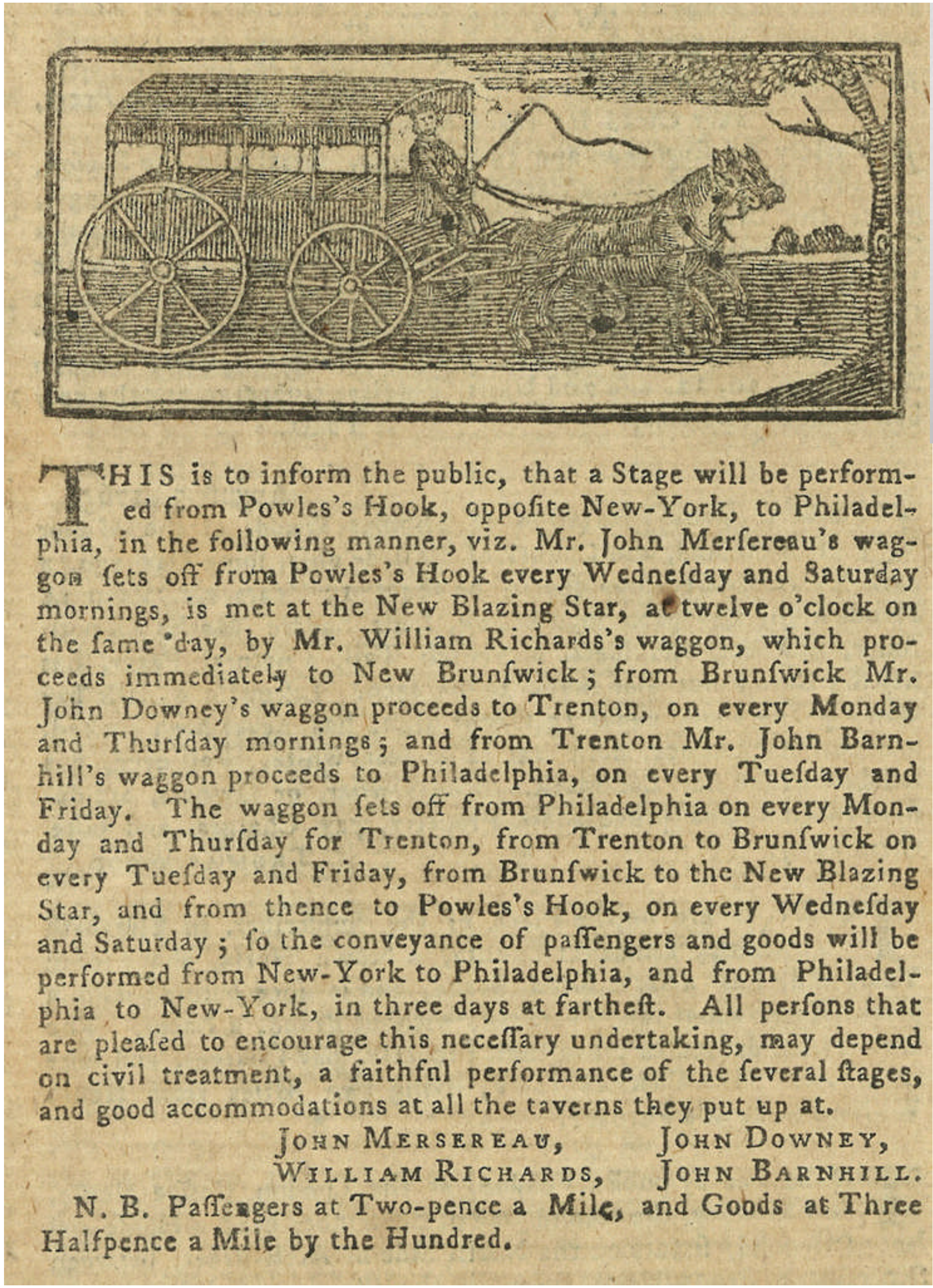


"…What became of Jansen is not known, but in June, 1669, Governor Carteret appointed Pieter Hetfelsen to succeed him. This license gave Hetfelsen the exclusive privilege to transport passengers and goods, but permitted the inhabitants to use their own boats for ferrying their families or their own possessions. The ferryman was required to attend the ferry on Mondays, Wednesdays and Fridays; so that it was only on three days in the week that the settlers were sure of means of transportation across the river. This document also fixed the rates to be charged. The fare for passengers was six stuivers; for a horse four guilders; for a cow three guilders, and so on. The Governor and his family and 'any person, letter or packet, or message of public business' were to be carried free. The fares were to be paid in 'Wampum.' This was the Indian name for the beads made by the Indians from shells. These were highly prized by the Indians and were used by them, and consequently by the Colonists, as a medium of exchange. Hetfelsen acted as ferryman until 1672, when John Tymensen was commissioned to take his place. It is probable that this ferry continued in operation until the opening of the Paulus Hook ferry drove it out of business, but there is no mention of it until 1783, in which year an advertisement appeared stating that 'Aaron Longstreet would take passengers to Communipaw to connect with the stage running to Newark and Philadelphia.'…"

RE: excerpt from *A Sketch History of Transportation Between Jersey City and New York, 1661-1909*

"…Soon after the British evacuated Paulus Hook in 1783 the Communipaw ferry seems to have fallen into disuse until the Central Railroad of New Jersey was extended to Jersey City, about 1864, when the ferry was revived and has been running ever since. The Jersey City ferry was established June 18, 1764, and was part of a new route to Philadelphia by way of Bergen Point and Staten Island. It was founded by Abraham Mesier and Michael Cornelissen. The landing place at New York was at Mesier's Dock at the foot of Cortlandt street. By arrangement with Cornelius Van Vorst the landing on the Jersey side was at Paulus Hook at the foot of Grand street. Passengers en route to Philadelphia stopped at Major Hunt's tavern at the landing place and took the stage the next morning. The trip between New York and Philadelphia took three days. It will be noted that these early ferries were principally for the convenience of persons traveling between New York and Philadelphia and other points. It is evident that Jersey City was considered in those days, as unfortunately it was for long afterward, not as a place to go to, but only as a place to pass through when going somewhere else. From the very first the owners of the ferry found it difficult to make it pay. The ferry changed hands several times and was leased to different persons, and the amount of rent to be paid was readjusted again and again. In March, 1799, the Common Council of New York established the rates of ferriage, which in view of the present fares seem decidedly high. For example an ordinary foot passenger was charged 9 pence; a coach or covered wagon 8 shillings; a horse 1 shilling 9 pence. Almost everything that can be thought of is specified; thus a feather bed is rated at 6 pence; a common chair 1 penny; a mahogany chair 2 pence; a chest of tea two shillings…"

RE: excerpt from *A Sketch History of Transportation Between Jersey City and New York, 1661-1909*



THIS is to inform the public, that a Stage will be perform-ed from Powles's Hook, oppoſite New-York, to Philadel-phia, in the following manner, viz. Mr. John Merſereau's wag-gon ſets off from Powles's Hook every Wedneſday and Saturday mornings, is met at the New Blazing Star, at twelve o'clock on the ſame day, by Mr. William Richards's waggon, which pro-ceeds immediately to New Brunſwick; from Brunſwick Mr. John Downey's waggon proceeds to Trenton, on every Monday and Thurſday mornings; and from Trenton Mr. John Barn-hill's waggon proceeds to Philadelphia, on every Tueſday and Friday. The waggon ſets off from Philadelphia on every Mon-day and Thurſday for Trenton, from Trenton to Brunſwick on every Tueſday and Friday, from Brunſwick to the New Blazing Star, and from thence to Powles's Hook, on every Wedneſday and Saturday; ſo the conveyance of paſſengers and goods will be performed from New-York to Philadelphia, and from Philadel-phia to New-York, in three days at fartheſt. All perſons that are pleaſed to encourage this neceſſary undertaking, may depend on civil treatment, a faithful performance of the ſeveral ſtages, and good accommodations at all the taverns they put up at.

JOHN MERSEREAU, JOHN DOWNEY,
WILLIAM RICHARDS, JOHN BARNHILL.

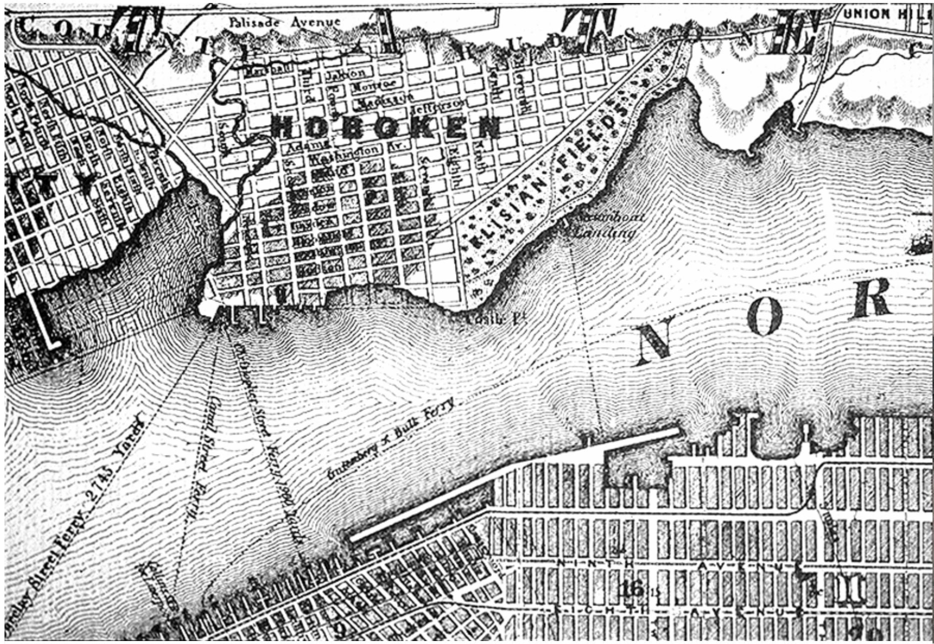
N. B. Paſſengers at Two-pence a Mile, and Goods at Three Halfpence a Mile by the Hundred.

<u>Above</u>: caption: "Litho-graph of the Communipaw settlement during the mid-dle of the 19th Century. View looking west from Communipaw (or South) Cove (now Liberty State Park)"

<u>Left</u>: caption: "1765 newspaper advertisement for New York to Philadel-phia Stagecoach"

"…Until 1804 the ferry and the adjoining land was owned by Cornelius Van Vorst. In 1804 the 'Associates of the Jersey Company' were incorporated and the ferry conveyed to them. In the same year Joseph Lyon of Elizabethport leased the ferry, and the landing place was moved to a point lying between York and Grand streets. Up to this time the ferry accommodations consisted of a few rowboats with two oarsmen to each and a few extra oars which the passengers were expected to use if they were in a hurry to cross. There were also two periaugers which were used when the wind was good, or when it was necessary to take a horse and carriage. With a favorable wind the passage could be made in half an hour, but sometimes it took three hours to cross. The success of Fulton's 'Clermont' in 1807, however, suggested the use of steam for ferry boats; and in 1809 Elisha Boudinot, General Cummings and a number of other Newark men subscribed $50,000 to start a steam ferry, and Fulton was asked to construct a boat suitable for such a purpose. In March, 1811, they obtained a lease of the ferry and the privilege of landing on the New York side…"

RE: excerpt from *A Sketch History of Transportation Between Jersey City and New York, 1661-1909*

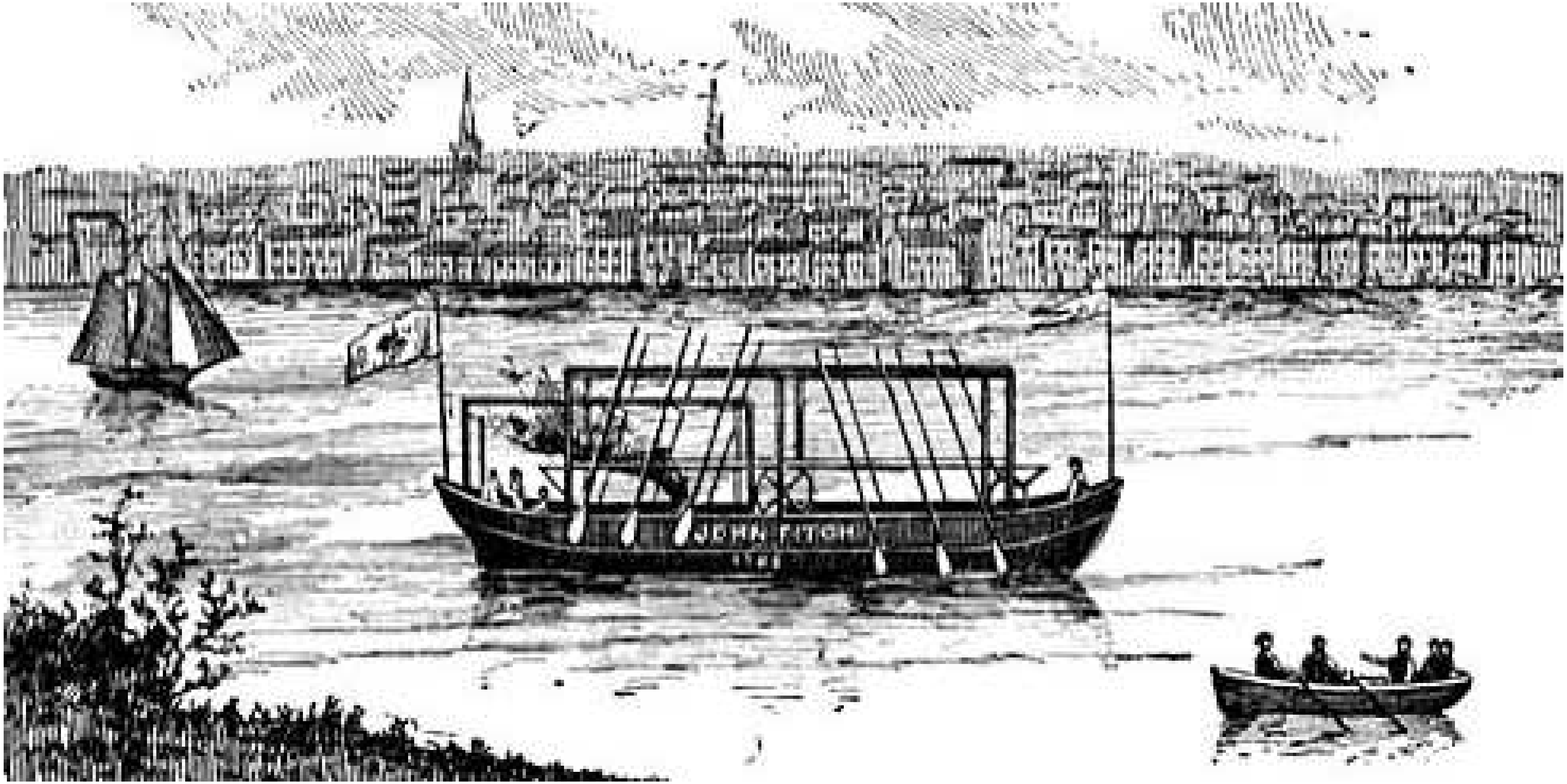


"…In the meantime John Stevens of Hoboken commenced the construction of a steam ferry boat for the Hoboken ferry and succeeded in completing it by October, 1811, nearly a year before Fulton's boat was used on the Paulus Hook Ferry. The honor of putting in operation the first steam ferry boat therefore belongs to John Stevens; but having won the credit he seems to have abandoned the use of steam after a short period and gone back to the old fashioned horse boat…"

RE: excerpt from *A Sketch History of Transportation Between Jersey City and New York, 1661-1909*

Left: caption: "Hoboken Ferry Service Map ca. 1954"

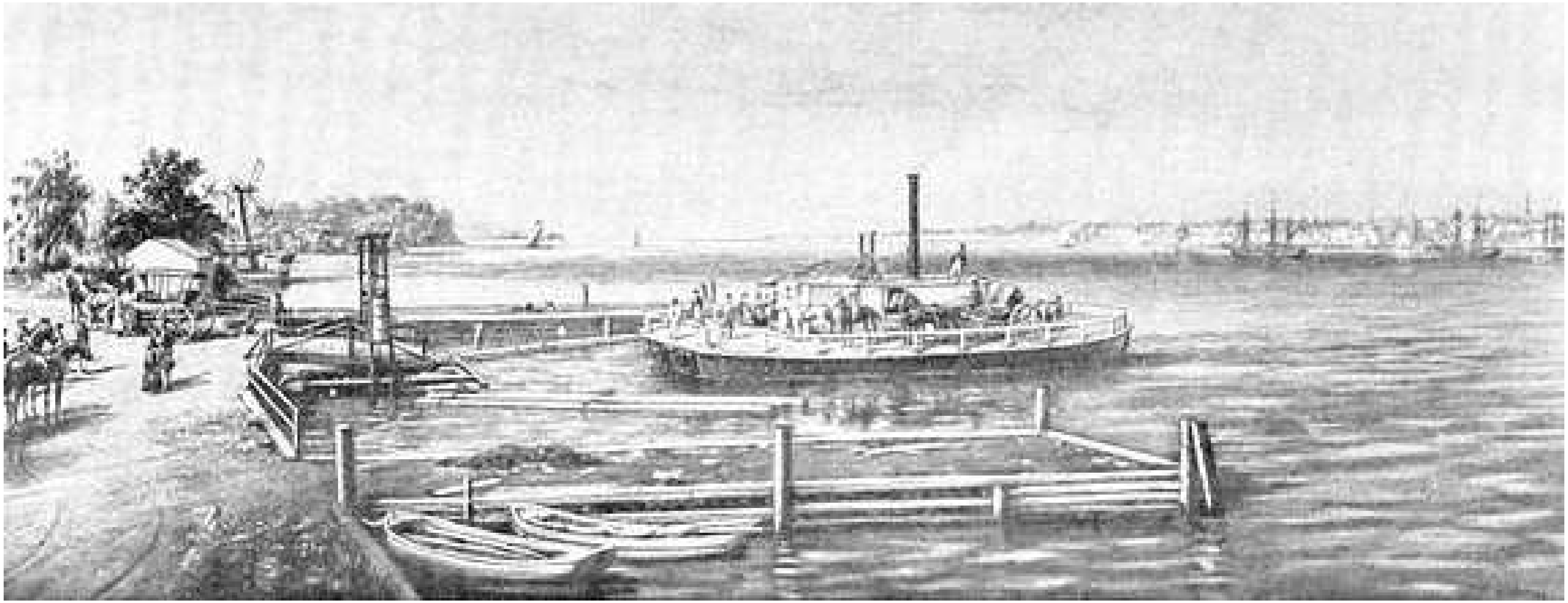
Right: caption: "Lackawana Ferries, Hoboken, NJ"



"She is built of two boats, each ten feet beam, eighty feet long, and five feet deep vived by the Erie Railroad Company, who have run the ferry ever since"

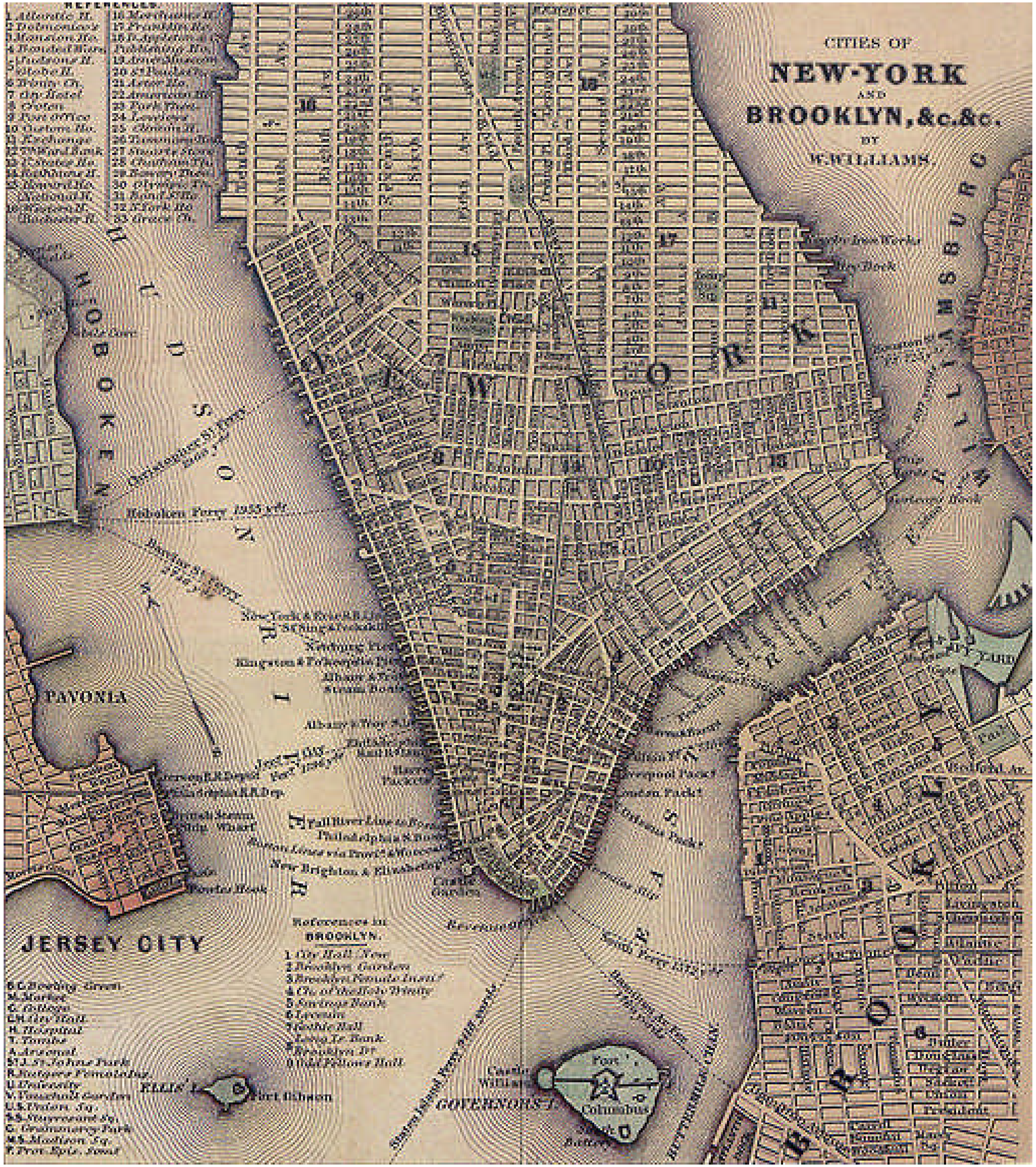
Robert Fulton

RE: description of the first steam-powered ferry (above) between *Jersey City, NJ* and *Manhattan*



"I crossed the North River yesterday in the Steam Boat with my family in my carriage, without alighting therefrom, in fourteen minutes with an immense crowd of passengers. I cannot express to you how much the public mind appeared to be gratified at finding so large and so safe a machine going so well. On both shores were thousands of people viewing the pleasing object."

RE: passenger comments. On July 17th 1812, the first of two Fulton steam ferries began operations between *Jersey City, NJ* and *Manhattan Island.* Soon after the steam ferry service was started, the boiler of one of the ferries (the "New Jersey," above) exploded while she was lying in her slip. Two persons onboard at the time were killed.



<u>Left</u>: caption: "1847 map showing the street layout and ferry routes for lower Manhattan"

<u>Above</u>: caption: “View of Jersey City Ferry, about 1857.” The Twenty-third street branch of this ferry service was established in May 1868 and in 1822, a *Brooklyn* ferry was run between *Jersey City* and *Long Island City* (only used for the accommodation of people attending the races which were being held at the *Union Race Course* on *Long Island*). The first permanent ferry between Jersey City and Brooklyn was started when the *Brooklyn Annex* was put in operation on August 12th 1877. On December 7th 1897, this ferry was purchased by the *Pennsylvania Railroad.* On December 1st 1891, the Pennsylvania Railroad opened a ferry from the foot of *Morgan Street, Jersey City* to *Thirteenth Street, Manhattan*. This was used principally for wagon traffic and was discontinued May 1st 1900.

"…At the present time there are eight ferry lines connecting Jersey City with New York. These are the Erie Railroad ferries, running from the foot of Pavonia avenue and landing at Chambers street and West 23rd street, New York City; the Pennsylvania system, leaving from Exchange Place and landing at Cortlandt street, Desbrosses street, and West 23rd street, New York, and the Annex to the foot of Fulton street, Brooklyn; the New Jersey Central ferries, running from the railroad terminal at Communipaw, with landings at Liberty street and West 23rd street. All these lines are equipped with first class boats and maintain excellent service day and night…"

RE: excerpt from *A Sketch History of Transportation Between Jersey City and New York, 1661-1909*

<u>Left</u>: caption: "Ferry routes connecting NJ to Manhattan: The map pre-dates the Tubes and gives an approximation of the route of the Tubes' uptown tunnel as 'Hudson River Tunnel.'"

<u>Above</u>: the ferry *Eliizabeth* of the *Central Railroad of New Jersey* was one of a fleet of ferries carrying passengers and vehicles across the *Hudson River* between *New York City* and the railroad's *Communipaw Terminal* in *Jersey City, NJ*. Direct railroad connections offered passenger train service locally in *New Jersey* to destinations such as *Baltimore, Maryland*, *Washington D.C.* and throughout *Pennsylvania.*

Into the first decade of the *20th Century*, there was not a continental railroad from the south or west having a direct connection to *New York City*, the largest city in the *Western Hemisphere*. The terminals of the railroads - whether they be for the major roads like the *Pennsylvania RR* and/or the *Erie RR* nor the minor ones, like the *West Shore RR* and/or the *Susquehanna RR -* stood on the *New Jersey* shore of the *North River* (the British name for the stretch of the *Hudson River* adjoining *Manhattan Island*). In *Jersey City, Hoboken* and *Weehawken,* the major railroad companies built large passenger terminals at the edge of the river which is close to a mile wide in this vicinity. Numerous ferry routes connected these New Jersey terminals to Manhattan, particularly to lower *Manhattan*.

<u>Above</u>: caption: "Pennsylvania Railroad Depot, Jersey City, NJ"

The Hudson Challenge

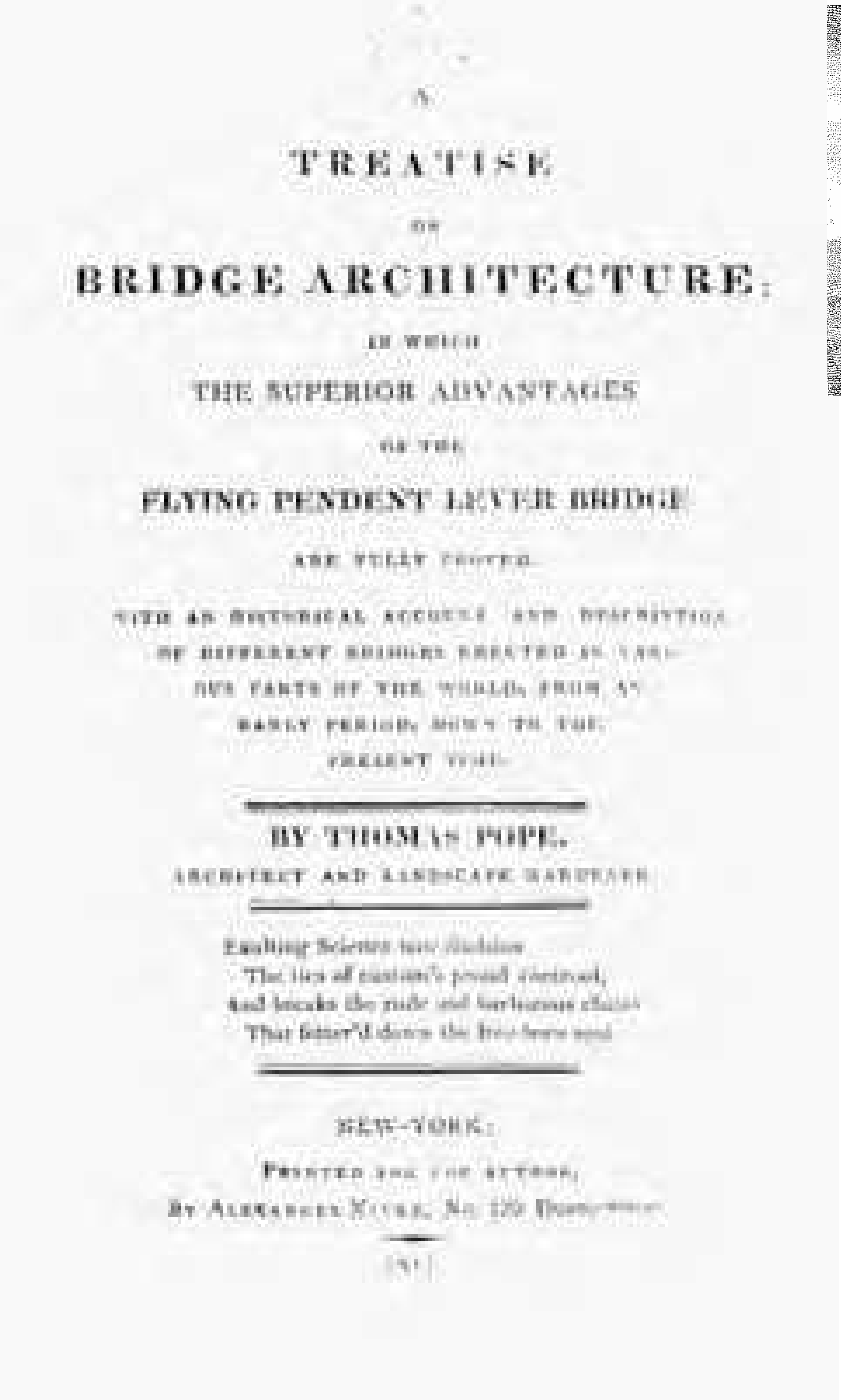
"…To those who planned America's highways in the past the broad waters of the Hudson formed a serious obstacle. It is not surprising, therefore, that serious schemes for bridging it have been proposed…"

Wonders of World Engineering, **November 1937**

"…The traffic situation in New York and vicinity labors under many dis-advantages, and by far the greatest of them is the existence of the broad stretch of the Hudson River, cutting off Manhattan Island, the heart of New York, from the mainland and its vast network of railroads. Once this obstacle has been removed, the traffic problem will be solved. That has always been well understood. The question has been how best to accomplish this…"

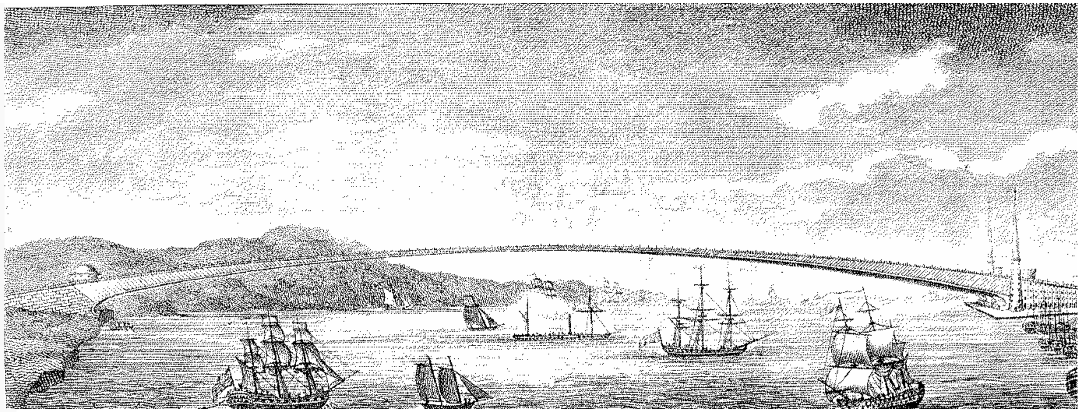
Popular Science, **April 1921**

One Grand Flying Leap


A
TREATISE
ON
BRIDGE ARCHITECTURE;
IN WHICH
THE SUPERIOR ADVANTAGES
OF THE
FLYING PENDENT LEVER BRIDGE
ARE FULLY PROVED.
WITH AN HISTORICAL ACCOUNT AND DESCRIPTION
OF DIFFERENT BRIDGES ERECTED IN VARIOUS PARTS OF THE WORLD, FROM AN
EARLY PERIOD, DOWN TO THE
PRESENT TIME.

BY THOMAS POPE,
ARCHITECT AND LANDSCAPE GARDENER.

NEW-YORK:
PRINTED FOR THE AUTHOR,



Like half a rainbow rising on yon shore,
While the twin partner spans the semi o'er
And makes a perfect whole that need not part
Till time has furnished us a nobler art
Thomas Pope

RE: shipwright, poet and visionary, in 1811 Pope published: *A Treatise on Bridge Architecture* (left). In it, Pope proposed *Rainbow Bridge* – a wooden "Flying Pendant Lever Bridge," to span the *East* and/or *North* (*Hudson*) *River/s* in "one grand flying leap" (the latter scheme illustrated above).

"…No matter when it was built, the first bridge to span the Hudson River from New Jersey to New York City was destined for fame. After the Civil War, a single span was determined most suitable for the wide, heavily trafficked river just west of the fast-growing metropolis. But materials and engineering skill lagged far behind the dream…"

Smithsonian **magazine, October 1999**

“We shall have a bridge across the Hudson into this city ere the century closes”
***The New York Times,* July 3rd 1888**

"…As long ago as 1868, when the Roebling's celebrated Brooklyn suspension bridge was first being planned, similar proposals were being made for spanning the Hudson, for in that year the State of New Jersey passed an Act for the building of such a bridge. The Act allowed for a structure with a clear span of not less than 1,000 feet, with not more than two piers founded in the bed of the river itself, and a clear height of at least 130 feet over the fairway in the center. Though nothing was done at the time, in spite of the formation of a company for building the bridge, this and other early proposals are of considerable interest…"

***Wonders of World Engineering*, November 1937**

From Shore to Shore

"…Over twenty years later, the scheme was revived and a new Act was passed, this time by the State of New York. This second Act did not allow the founding of any piers in the river, which was, whatever the type of bridge to be adopted, to be cleared in a single gigantic span from shore to shore…"

***Wonders of World Engineering*, November 1937**

"…The bridge company now encountered the law entrenched, for it did not at the time want to build a suspension bridge, which seemed to be the only type possible under the ruling of the New York State Act. The primary purpose of the bridge – it was long before motor transport had any significance – was to link two railway systems. In the opinion of the company a suspension structure was unsuited to the great shifting weights of heavy steam locomotives which were expected to pass to and fro over the structure…"

***Wonders of World Engineering,* November 1937**

The North River Bridge Company

Beneath a tree on a college campus in *New Jersey* (top), there's a cornerstone of a bridge that was never built (bottom). The stone is the only vestige left of a planned 6K-foot bridge that would have spanned the *Hudson River* from Manhattan's *57th Street* to *New Jersey*. Originally laid on June 18th 1895 (at the corner of *Garden* and *12th Street/s* in *Hoboken*), the stone was later moved to its current location at the *Stevens Institute of Technology*.

"…Just five years after the completion of John Roebling's Brooklyn Bridge, then the world's longest suspension bridge, 38-year-old Austrian-born engineer Gustav Lindenthal put forth a plan for a suspension bridge across the Hudson. It was a grand concoction: six railroad tracks, more than a mile in total length. Its center span was to be nearly twice as long as that of Roebling's widely admired masterpiece. Great feats of engineering require greater feats of imagination. For both, Lindenthal was well qualified. With little formal education and a physique to match the size of his dreams, he had taught himself English and the rudiments of engineering. Immigrating to America in 1874, he quickly prospered in his adopted land, whose engineers had more use for quick thinking and practical energy than college degrees…"

***Smithsonian* magazine, Oct. 1999**

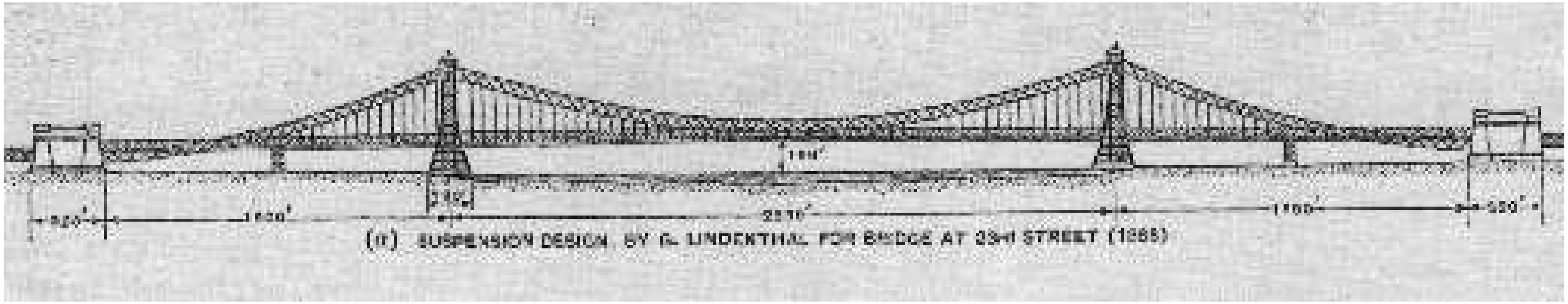
Left: ***Gustav Lindenthal*** **(ca. 1880s)**

In 1885, *Gustav Lindenthal*, a self-educated bridge engineer who had established his reputation on two notable *Pittsburgh* spans, was approached by officials at the *Pennsylvania Railroad* regarding the feasibility of a railroad bridge across the *Hudson River*. At the time, the Pennsylvania Railroad was at a serious disadvantage since it did not have direct service into *Manhattan* as did its chief competitor; the *New York Central Railroad*. Because of the smoke that emanated from the steam locomotives of the day, the railroad favored a bridge across the Hudson rather than a tunnel. After giving serious thought to a cantilever design, Lindenthal decided on a suspension bridge (because it would allow wider distances between piers). However, the suspension bridge would have to have a main span of about 3K-feet; nearly twice the length of the main span of the *Brooklyn Bridge* which was completed just two years earlier (1883). Constructing such a bridge, along with its approaches and Manhattan terminal, was considered too expensive for one railroad to handle alone. In response, in 1887 Lindenthal organized the *North River Bridge Company* to seek financial support from several railroads. These railroads would share not only the bridge, but also the terminal facilities. The completion of the bridge would be a boon for these railroads, whose transcontinental tracks dead-ended on the *New Jersey* shore of the Hudson. Freight trains bound for *New York City* by rail-ferry would no longer be at the mercy of Hudson River traffic and/or foul weather nor would they have to make a 300-mile detour via *Albany* to get across the wide river.

"…The great arteries of circulation, the railroads, extend to the shores across the river, but, with only one exception, they do not bring their trains of freight and passengers directly into Manhattan. All the material carried by these outside lines must be transferred and re-handled before it is conveyed across the river to be distributed. This involves expense which is reflected in the cost of living. Long Island and Manhattan are connected by bridges as well as tunnels. Why have we waited so long before attempting to bridge the Hudson?..."

Popular Science, **December 1920**

<u>Left T&B</u>: B&ORR's Hudson ferry terminal, Manhattan (ca. 1920s)

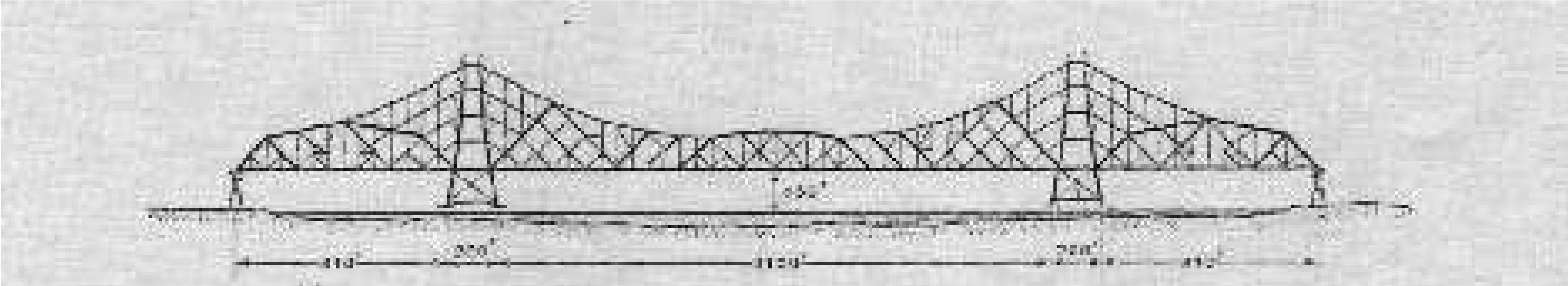


"…as close as convenient to the principal hotels"

Gustav Lindenthal

<u>Above</u>: caption: "Suspension design by Gustav Lindenthal for a bridge at West 23rd Street (1888)." In late 1887, Lindenthal published: "The Proposed New York City Terminal Railroad, Including North River Bridge and Terminal Station, in New York City," in which he described the parameters of the project. The proposed bridge featured a main span of 2,850-feet between towers, with side spans of 1,500-feet. Eyebar chains were to be suspended from 530-foot-tall steel-and-masonry towers, together supporting the deck 150-feet above the *Hudson River*. The six railroad tracks that were to be carried by the bridge required deep stiffening trusses. These tracks were to continue into *Manhattan* on high viaducts to a proposed terminal station near *Sixth Avenue* and *West 18th Street*. Lindenthal and the *Pennsylvania RR* wanted the bridge to exceed its rival - the *Firth of Forth Railway Bridge* (1890), in *Scotland*.

The complete *Hudson River* bridge and terminal project, which was to include a tunnel through *Bergen Hill* in *New Jersey*, was projected by Lindenthal to cost $23 million. An additional $14 million was to be set aside for right-of-way acquisitions. Because the expenses of operating the system were to be covered by the railroads (about $2 million per year in revenue would come from passenger fares alone) the proposal appeared financially sound. In 1888, a competing proposal for a cantilever bridge across the Hudson had been submitted to the legislatures of *New York* and New Jersey. This plan called for two piers in the middle of the Hudson River, a 1K-foot main span, and a 135-foot clearance above the river. However, *Engineering News*, defending the Lindenthal suspension bridge proposal, said that the cantilever bridge would compromise navigation along the Hudson and be less visually appealing than a suspension bridge.

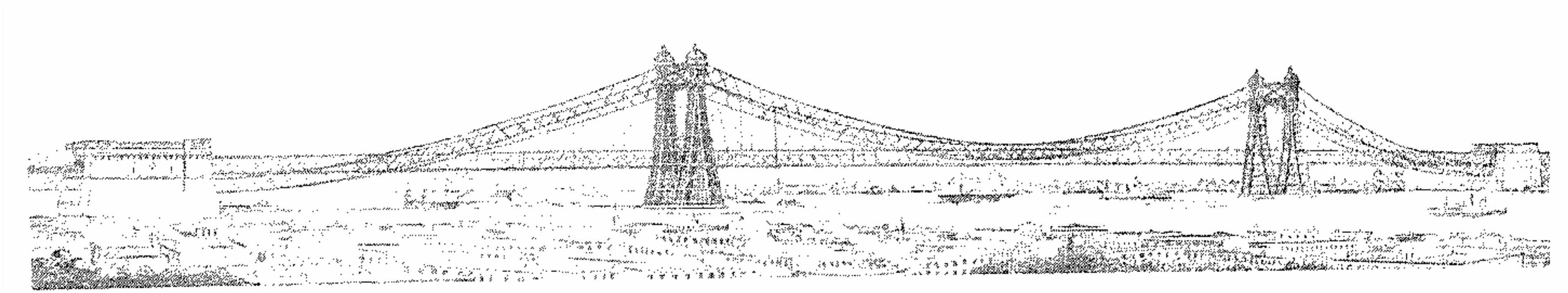


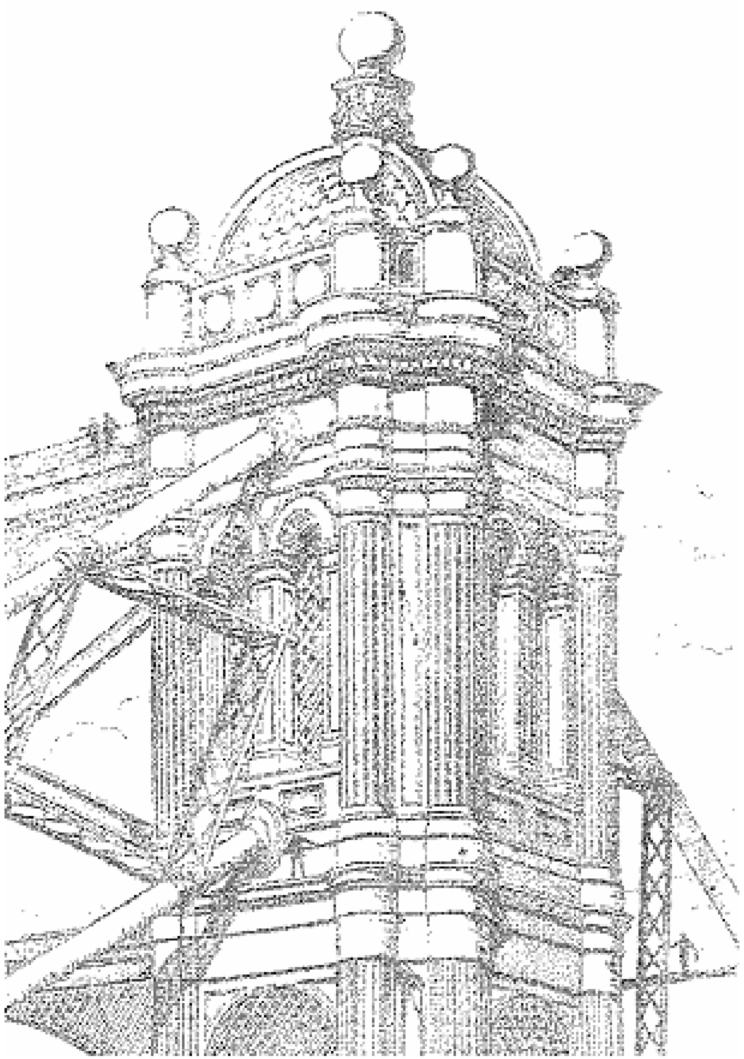
(c) CANTILEVER DESIGN, BY UNION BRIDGE CO. FOR BRIDGE AT 70TH STREET (1893)

"…The proposal contemplates the erection of a cantilever, and stipulates for the placement of one pier in the river channel, neither of which should be permitted unless absolutely found necessary, even if the cost were considerably increased. If there be one place where a mere 'utility structure' should not be permitted, but where dignity and beauty of form should be a controlling feature, it is over the North (Hudson) River in New York, and in that and other respects the suspension type seems to us to have great advantages for the location…"

***Engineering News,* 1888**

<u>Above</u>: caption: "Cantilever design by Union Bridge Company for a bridge at West 70th Street (1893). The design featured a 2,100-foot-long main span, two 810-foot-long side spans, and a clearance of 150-feet"





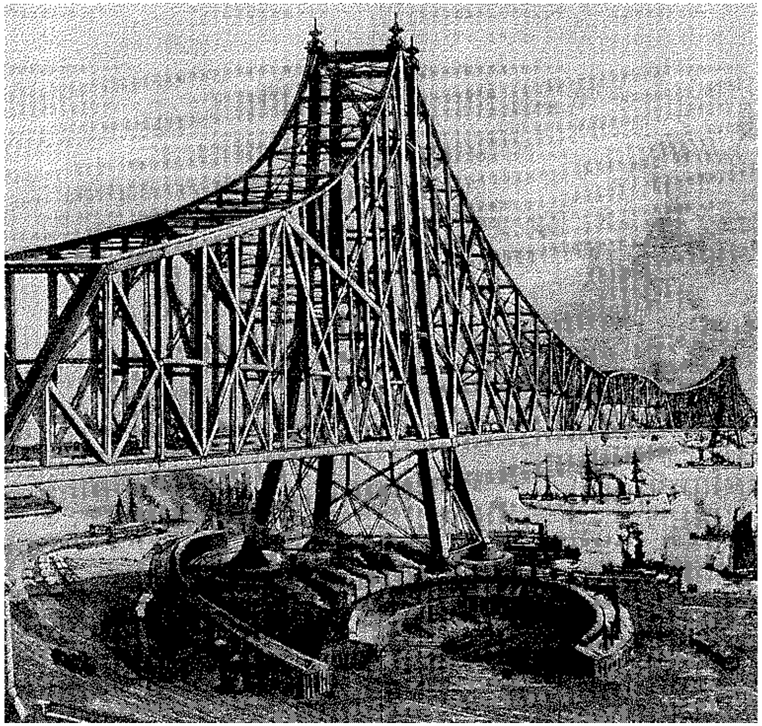
"It is certainly true that New York Harbor, acknowledged to be the most beautiful in the country, should be defaced by a utility bridge of shabby appearance, it would be an unpardonable offense against the civilization of mankind"

Gustav Lindenthal

RE: excerpt from *Engineering News,* February 1888

<u>Above</u>: caption: "Gustav Lindenthal's first proposal for a Hudson River Bridge. Note his characteristic eyebar bracing between cables."

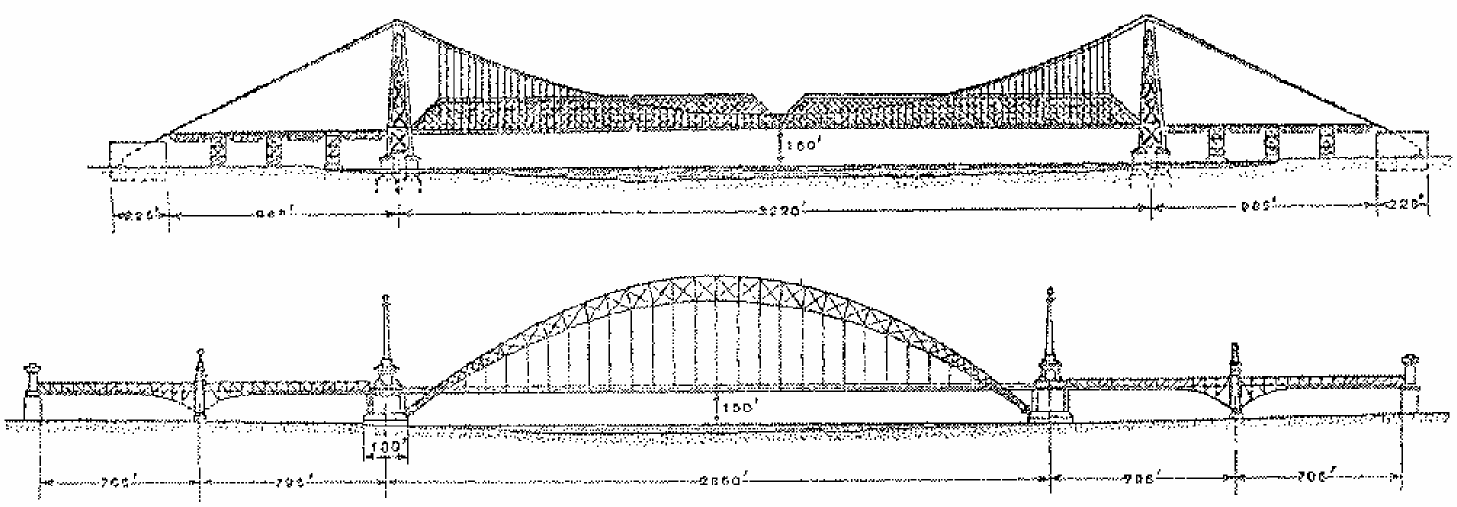
<u>Left</u>: caption: "Detail of 525-foot tower displays ornamental steelwork"



"…Again, the engineers called into consultation did not think that they could build a suspension bridge on such a scale as that demanded by the Hudson. The original plans had been for a cantilever bridge from 70th Street, Manhattan, carrying six railway tracks and having a clear span of 2,000 feet, the distance between the piers being 2,300 feet. The New York pier was to be on shore, and the New Jersey pier was to be situated 900 feet out…"

***Wonders of World Engineering,* November 1937**

Left: caption: "Proposed cantilever bridge over the Hudson River"

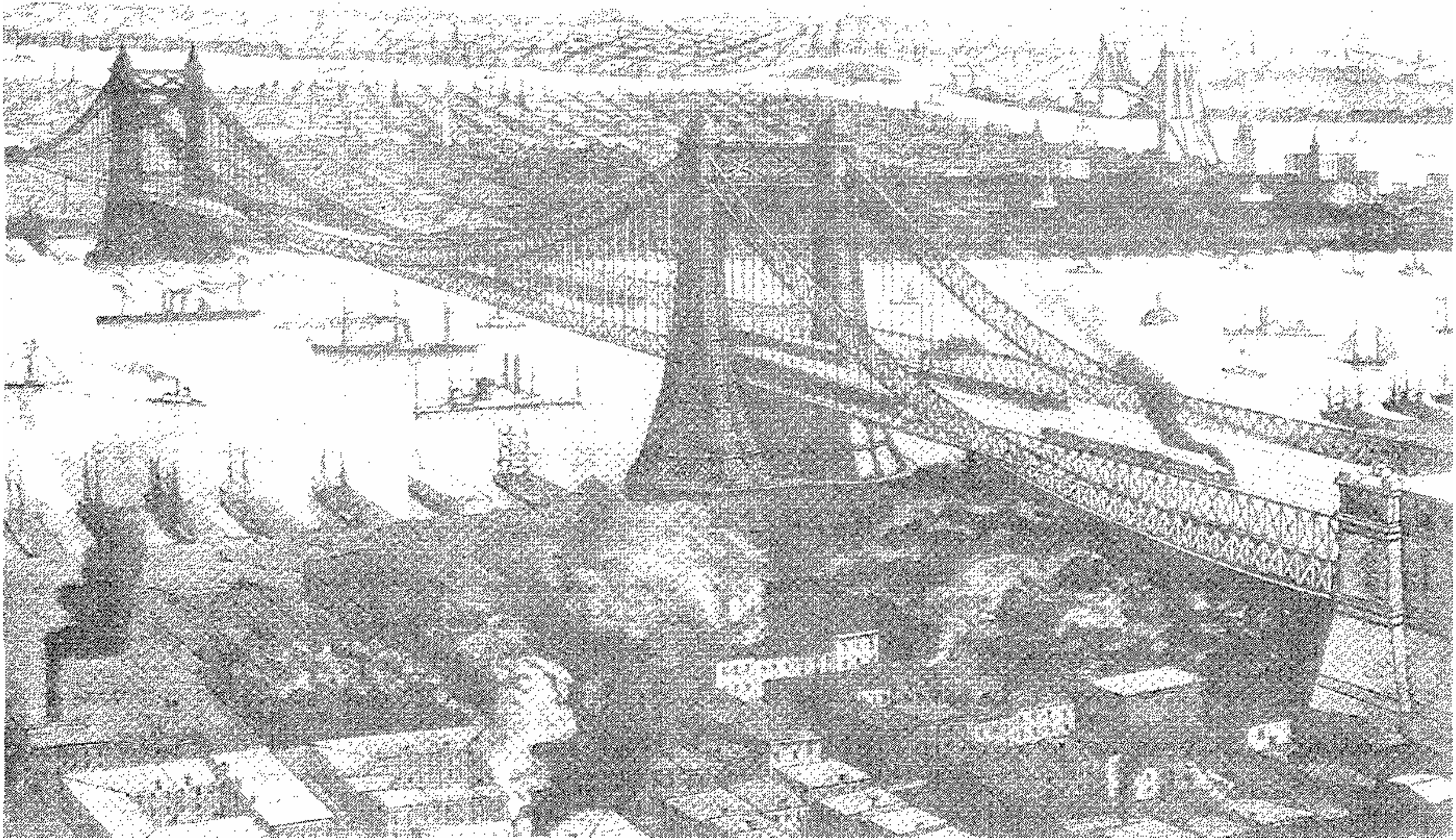


"…a suspension bridge spanning the North River without a pier would involve such elements of uncertainty as regards first cost, novelty in its magnitude as a hitherto untried engineering feat, and time of construction, to say nothing of the well-founded prejudice against the suspension principle for railroad purposes, as would render the enterprise impracticable from a financial standpoint"

***NY & NJ Bridge Company,* 1890**

RE: first plan submitted to the federal government for a six-track, 2,300-foot cantilever railroad bridge at *70th Street* in *Manhattan* – considered most practical and economical as compared to a suspension bridge.

<u>Above T&B</u>: caption: "Top: Suspension design by the Board of Engineers appointed by the U.S. Secretary of War (1894). The design featured a 3,220-foot-long main span, two 965-foot-long side spans and a clearance of 160-feet. Bottom: Arch design by Max Am Ende (1889). The design featured a 2,850-foot-long main span, two 795-foot-long side spans, two 705-foot-long flanking spans, and a clearance of 150-feet"



<u>Above</u>: caption: "Lindenthal altered his design and it appeared in Scientific American, May 1891. It carries 10 railroad tracks."

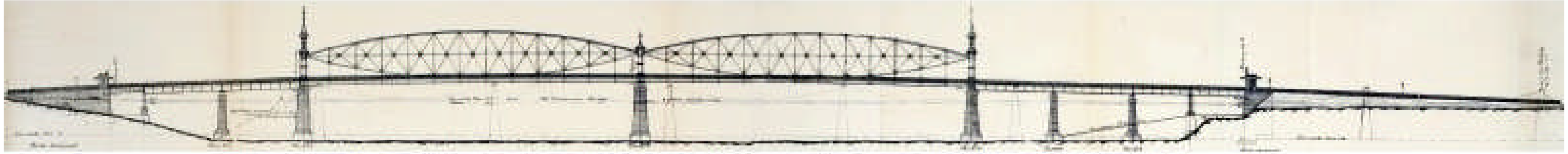
Financiering

"…the financiering of the bridge far exceeds in difficulty the engineering problems presented."

Gustav Lindenthal

RE: construction of a suspension bridge was proposed by Federal legislation, pending approval of plans by the *Secretary of War*. For a *Hudson River* bridge to be constructed, no piers would be allowed in the river. By 1890, the bridge proposal passed both houses of *Congress*. Ground was broken for the bridge on June 18th 1895, and the first foundation masonry was laid at the site of the *Hoboken* anchorage, across the Hudson River from *West 23rd Street* in *Manhattan*. Work did not progress much further because of the difficulties in financing the $37 million cost of the project. The bridge's construction would have cost $23 million, $40 million with related costs; about the same amount it cost to run all of *New York City* in 1888.


NORTH
BROKEN
FOUNDATION
JUNE



"…By the turn of the century, Lindenthal was renowned among his peers. His Seventh Street and Smithfield Street bridges in Pittsburgh were some of the most significant of their time. In 1902, Lindenthal became commissioner of bridges for New York City, a political appointment that gave him considerable power and prestige as an engineer and designer. But his dream bridge still had not been built. Despite endorsement of Lindenthal's Hudson River bridge plan by the War Department, a rival bridge concern had sued to stop the project. By the time the case was settled, the depression of the early 1890s had dried up most of the funds. Replaced as commissioner after the 1903 city elections, Lindenthal found himself in the odd position of peddling new Hudson River bridge designs to myriad interested groups - with no agreement on location, cost or funding. In the meantime, the city grew. By 1912, Lindenthal was busy completing plans for a railroad bridge - the world's longest steel arch bridge, in fact - across the dangerous channel between Manhattan and Queens called Hell Gate. To help with the task, the august designer took on a 33-year-old assistant not long arrived from Switzerland…"

Smithsonian **magazine, October 1999**

<u>Above</u>: caption: "Original (1881) elevation of the Smithfield Street Bridge"

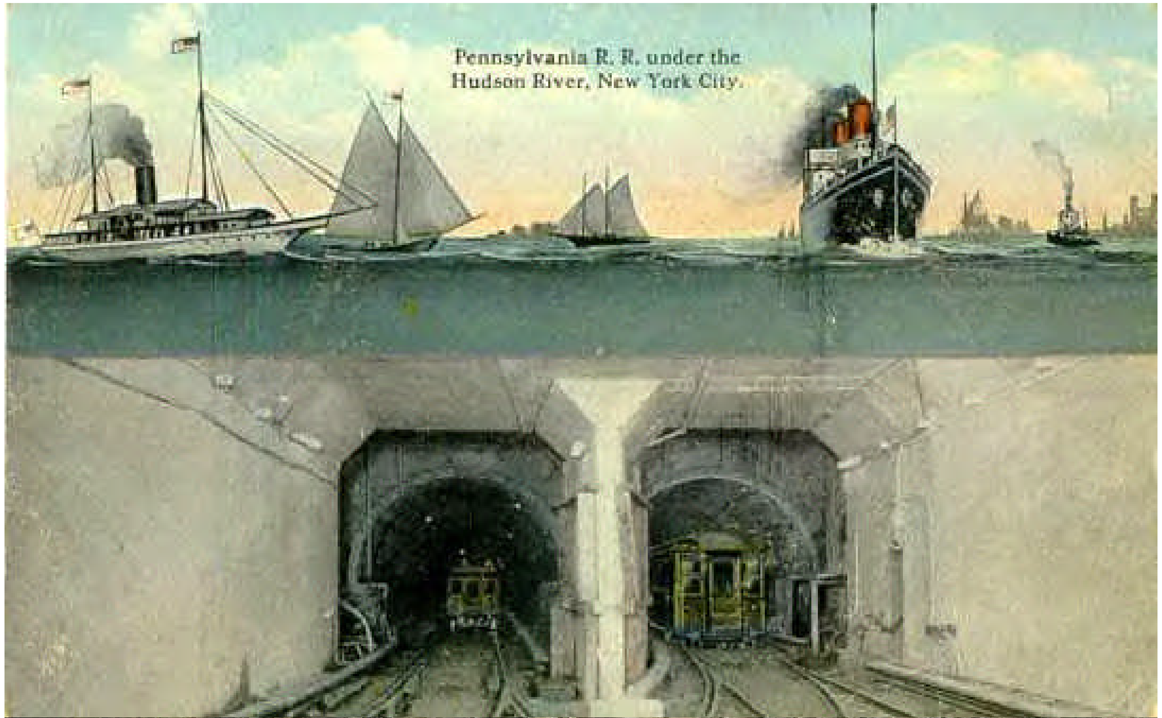
"Steinman, bridge engineering is easy. It's the financial engineering that's hard"

Gustav Lindenthal

<u>Above</u>: *Hell Gate Arch* (present-day)

<u>Left</u>: the engineering staff pose for a photograph near *Hell Gate Arch* during construction (October 1916). *Gustav Lindenthal* (highlighted) is the large man at center with *D.B. Steinman* fourth from left. *O.H. Ammann* is to Lindenthal's right.

<u>Above</u>: engineering staff for the *Queensboro Bridge* (*Gustav Lindenthal* at far left). Construction of the *Hudson River* bridge was delayed by the financial panic of 1893 and, eventually, plans fell by the wayside. In the meantime, construction had begun on the *Manhattan & Hudson RR* tunnels (now *PATH*) into lower *Manhattan.* As the *19th Century* drew to a close, developments in tunneling and in electric-traction locomotives led the *Pennsylvania Railroad* to pull out of the Hudson River bridge project, opting instead to construct tunnels under the Hudson using electric trains. In 1910, the Pennsylvania RR completed construction on tunnels to link *Weehawken, NJ* and their new *Pennsylvania Station* in Manhattan. In 1902, after being appointed *New York City Bridge Commissioner* by Mayor *Seth Low*, Gustav Lindenthal shifted his attention from the Hudson River to the *East River*, concentrating on the *Williamsburg* (1903), *Manhattan* (1909) and Queensboro (1909) *Bridge/s* (the former then under construction). With *O.H. Ammann* serving as his first assistant, he would complete his crowning achievement – *Hell Gate Arch* (1917). But his dream of a Hudson River bridge would live on.



"The plan to bridge the Hudson from New York to the Jersey side of the river has at last been abandoned. Railroad constructors who have been at work on the project have had but poor results from their experiments with foundation borings and have been forced to give up their work. In no instance have they discovered bedrock within working depths below the water level. The indications are, however, that a tunnel between Manhattan and Jersey can be constructed at much lower cost than a bridge, and from the results obtained in the operation of existing subways, such a form of connection can be operated even cheaper than ferries."

***Popular Mechanics,* July 1910**


Pennsylvania Station, New York City.

"To insure success, any plan for connecting Manhattan with New Jersey should include the cooperation of the railroads, at least so far as the handling of freight is concerned. Every one of the four existing East River bridges cost from 89% to 120% more than the original estimate at the time the bridges were authorized, and this is only in keeping with the sad experience which New York City and State have had with regard to other important engineering works that have been built with public funds. If the present grossly unfair treatment of the railroads shall come to an end, that is to say if they are once more permitted to operate according to true economic laws, and therefore should feel justified in facing larger expenditures to improve their systems, they will find the proposed railway connections with Manhattan an attractive proposal."

Gustav Lindenthal, **1910**

RE: Lindenthal's (left) revised proposal for a suspension bridge at *59th Street* accommodating both automobiles and sixteen railroad tracks

“Put two million eight hundred thousand on an island, give them houses, subways, surface cars, factories, stores, and all the equipment of a city - but fail to provide a means of reaching these people with the materials with which their factories can work, fail to give them fuel and food - and the vast population of the isolated island will perish. The means of conveying material, food, and fuel to the citizens of the island-city is of utmost importance. Manhattan island must be hooked up to the United States, and many plans have been suggested to accomplish this ambitious purpose…”

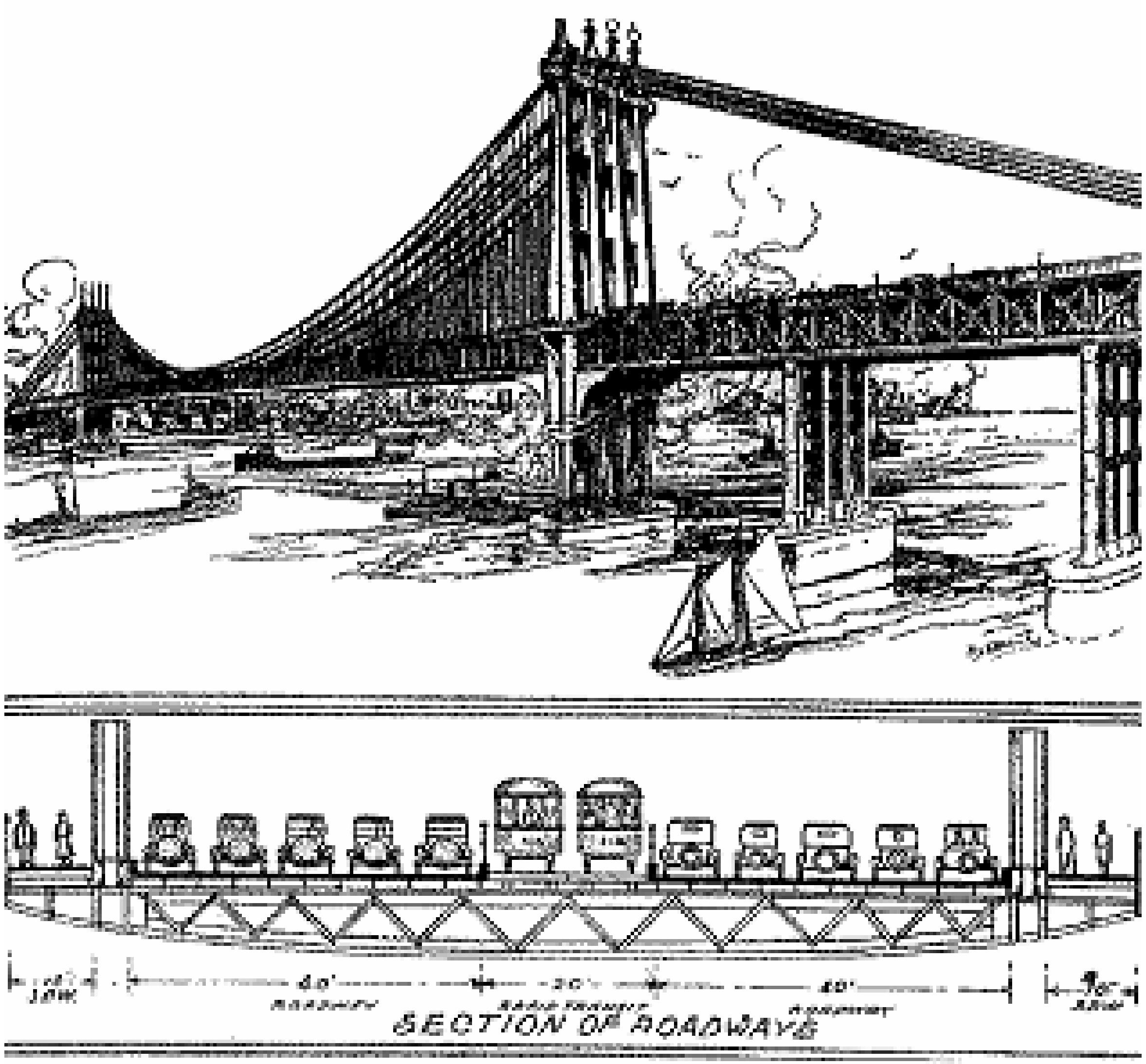
***Popular Science*, December 1920**

“That there is need for better connection between Manhattan and the western half of the Metropolitan District lying across the Hudson River is evidenced by the prodigious growth of Brooklyn and the Bronx, to which convenient interboro transportation facilities have been provided; and also by the fact that the States of New York and New Jersey have recently begun the joint construction of a vehicular tunnel between Jersey City and lower Manhattan. Because of these and many other economic reasons which are acute and press for closer connections between the two shores of the river, it now seems justifiable to consider a bridge across the Hudson…”

Baltimore & Ohio **magazine, January 1923**

“…But new forces were at work. With construction under way for what would be known as the Holland Tunnel, it was assumed that connecting the metropolis to its burgeoning New Jersey suburbs by underwater routes would be cheaper than a bridge (a notion proved wrong well before the tunnel’s 1927 completion). By that time, too, necessarily heavy (and expensive) railroad spans across the Hudson were steadily being eclipsed by less costly ones dedicated to a newly popular conveyance: the car. Already, in Philadelphia and Detroit, huge suspension bridges had been built for cars. The future was clear…”

***Smithsonian* magazine, October 1999**



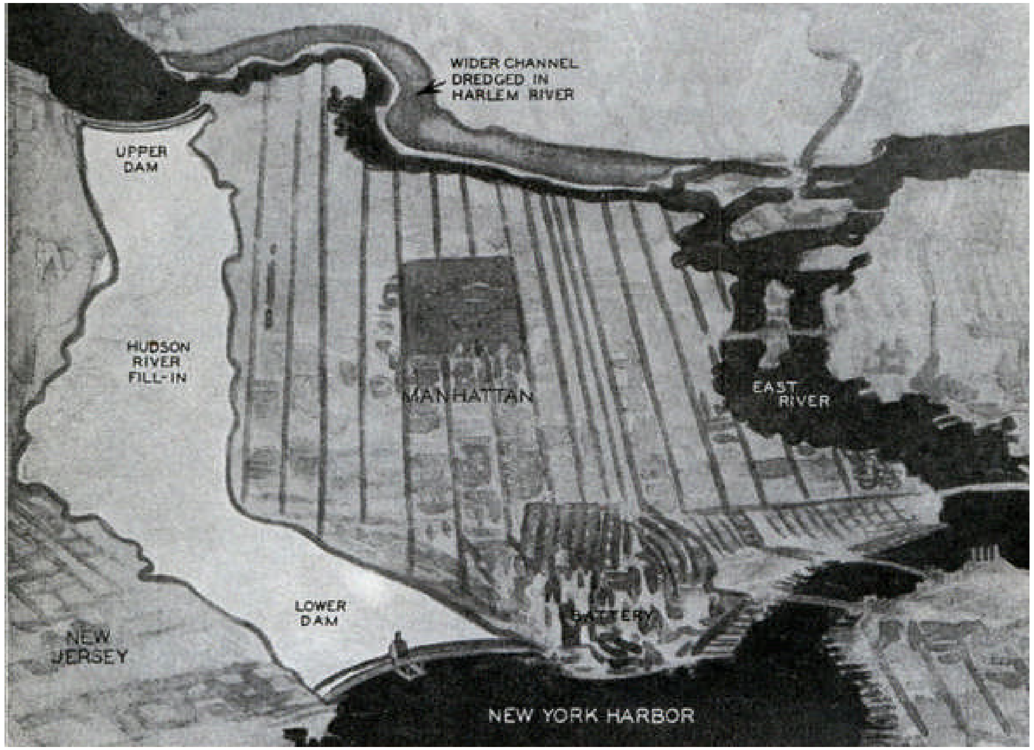
<u>Above</u>: caption: "Sketch of Charles Evan Fowler's proposal for suspension bridges of 3,500-to-4,000-foot main span to cross the Hudson River at three locations (59th Street, 83rd Street and 178th Street) for a total cost of about $100 million, essentially the same design he proposed for a bridge between Detroit and Windsor, Canada." (ca. 1925)


Detroit-Windsor Bridge
1803 ft. Span. Longest and Heaviest Bridge in the World

Plan B

"Plug up the Hudson river at both ends of Manhattan…divert that body of water into the Harlem river so that it might flow out into the East river and down to the Atlantic ocean…pump out the water from the area of the Hudson which has been dammed off…fill in that space…ultimately connecting the Island of Manhattan with the mainland of New Jersey…and you have the world's eighth wonder - the reconstruction of Manhattan! That is the essence of the plan proposed by Norman Sper, noted publicist and engineering scholar. It is calculated to solve New York City's traffic and housing problems, which are threatening to devour the city's civilization like a Frankenstein monster. In keeping with the Norman Sper plan, the ten square miles of land which would thereby be reclaimed from the Hudson would not only provide for thousands of additional buildings, but also for avenues and cross streets which would greatly relieve the congestion in present thoroughfares. Today there are ten avenues laid out along the length of Manhattan. These are crossed by 125 streets. It is the lack of up-and-down arteries which has given rise to the existing traffic crisis. Sper would double the number of avenues…"

***Modern Mechanix*, March 1934**



<u>Left</u>: caption: "This map vividly tells the story of the plan to dam the Hudson river and rebuild New York, ending the isolation of Manhattan Island. Water which now finds an outlet through the Hudson river would be diverted via widened Harlem river to the East river and then into outer harbor. What is now Manhattan Island would be grafted to New Jersey"

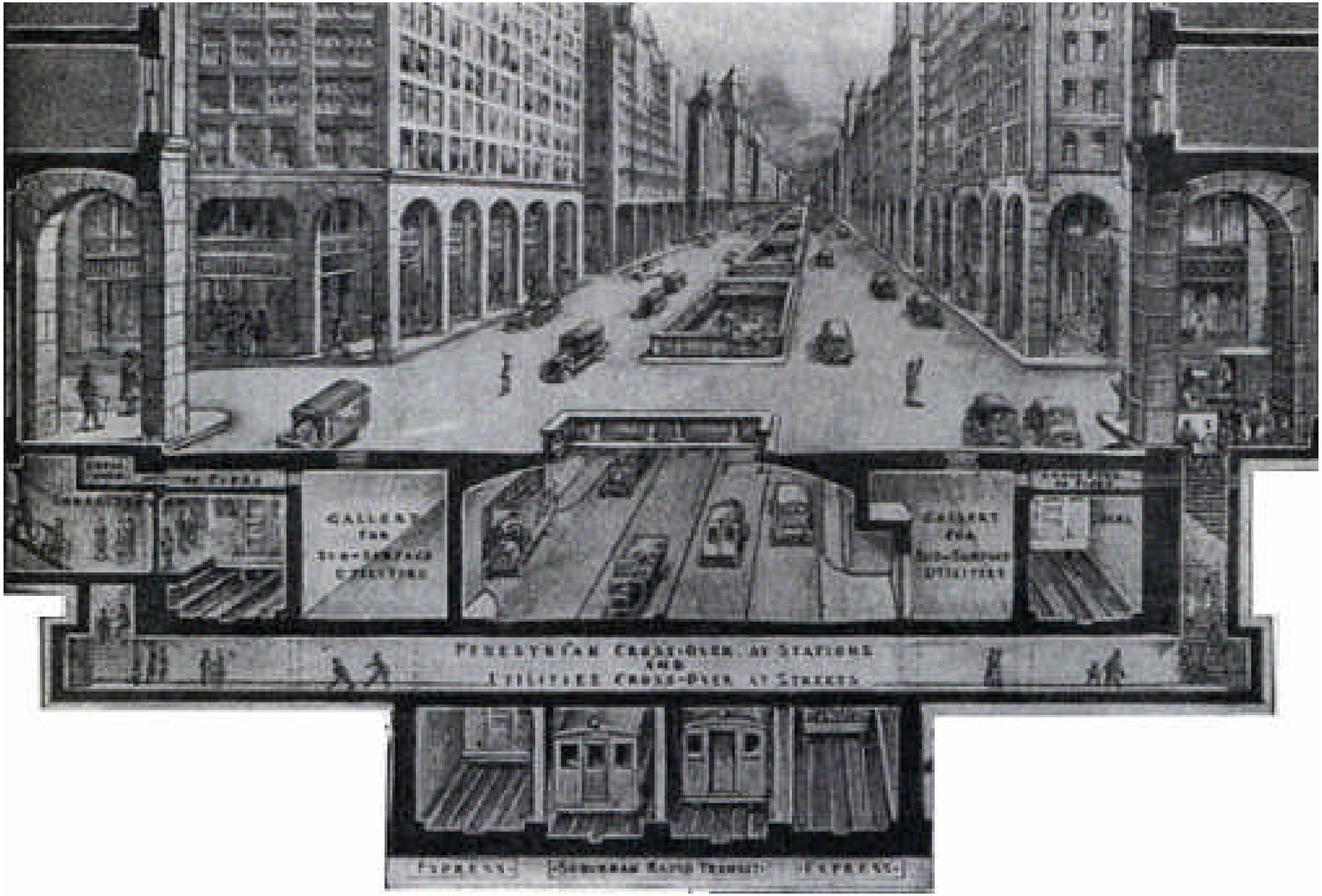
“…His suggestions go still further. No use waiting, he says, until the entire area is filled in before starting underground improvements. Build your tunnels, conduits, mail and automobile tubes, and other sub-terranean passages indispensable to comfort in the biggest city in the universe as you go along. Do it in the process of filling the basin left by the drawing off of the water. ‘When every possible subterranean necessity had been anticipated and built,’ Sper points out, ‘a secondary fill would bring the level up to within twenty-five feet of the Manhattan street level. Upon this level would rest the foundations and basements of the buildings that would make up the new city above, planned for fresh air, sunshine and beauty. Thus, below the street level would be a sub-terranean system of streets that would serve a double purpose. All heavy trucking would be confined to it, but primarily it would serve as a great military defense against gas attack in case of war, for in it would be room for practically the entire population of the city. If the Russians had the vision and the courage not only to build huge cities from the ground up, but to practically rebuild an empire, surely America should not be frightened at a project as big as this’…”

***Modern Mechanix*, March 1934**

Above: caption: “Manhattan Island as it looks today from the U.S.S. Macon. The lower dam, under Norman Sper’s proposal, would start at the Battery, shown here, extend across the Hudson to the New Jersey shore. Reclamation of river bed would provide New York with ten square miles in which to expand. Necessity for expansion is graphically shown in this aerial photograph.”

"…It would cost about one billion dollars to build, he figures. If you think such a project is beyond the abilities of modern engineers, asserts Mr. Sper, think of these achievements: The seemingly invincible Colorado river has been diverted to build the biggest dam in the world - Boulder dam. Fifty-foot tunnels were hewn out of the stubborn rock on either side of the river to make way for diversion of the water, which, in flood seasons, becomes a raging torrent. Look at the engineering wonders accomplished in construction of bridges. The two bridges now being built across San Francisco bay, one over the Golden Gate and the other from San Francisco to Oakland, defied problems which seemed unsurmountable even a few years ago. Consider the success of Colonel George Goethels in finishing the Panama Canal and opening it to traffic of the world's largest ocean going vessels after others had failed. That virtually closed Mr. Sper's case. Engineers uniformly agree that there are very few problems which can successfully defy the determination of civilization to conquer. As in many other instances, the project to dam the Hudson river and reclaim the river bed to provide New York with an additional ten square miles of land, would depend largely upon the ability of the government to finance such a project…"

***Modern Mechanix*, March 1934**



<u>Above</u>: caption: "Here is how the proposed new section of Manhattan would look when finished. Buildings in normal fashion on the surface, with beautiful, wide streets and only casual, block to block vehicular traffic. Below you find the numerous automotive, pedestrian and rail tunnels, all well ventilated and all having easy access to the street above."

"…In the past, individual projects were considered in terms of millions of dollars and only recently in terms of hundreds of millions. Now comes Mr. Sper with a plan which must be considered in the light of a billion dollar expenditure. This single project would cost within approximately one-thirtieth of the total of the public debt of the United States government as it now stands. While such a figure is enough to stagger an ordinary financial mind, engineers point to the fact that the project would provide an immediate income of almost unbelievable dimensions. For instance, the land reclaimed could be sold outright or leased for 99-year periods to private concerns or to individuals and because of the desirability of the location, would bring extremely high rentals or sales prices. Then, too, the franchises for electric and telegraph conduits, steam heat tubes, street car and railway tubes would bring in millions of dollars annually. An annual income of a hundred million dollars a year would represent a return of ten percent on the investment of a billion dollars and engineering experts all agree that this would be only a trifle of the amount that could be realized from this great project. Thus, it is easy to comprehend the advisability of the Hudson river reclamation project from both an engineering and financial standpoint…"

***Modern Mechanix*, March 1934**

"…C. Keith Pevear, well-known Manhattan consulting engineer, who has been identified with various projects for municipal improvement said: 'I have conferred with several marine engineers on the plan you have told me about. After several hours of spirited discussion - for we actually became very much interested in the various phases presented - it was our unanimous conclusion that the project is one which comes within the realm of possibility and could actually be accomplished. There were a multitude of problems, perhaps I should say obstacles, which cropped up in our discussion. We gave each one full consideration. Soundings and borings have disclosed that the bed of the Hudson river is rock with a silt, or mud covering. The foundation work in connection with the Holland Tunnel, the Pennsylvania Railroad Tunnel and the Washington Bridge showed that the Hudson had a rock bottom. The Manhattan rock structure goes under the Hudson river and proceeds west beyond the hills of Hoboken'…"

***Modern Mechanix*, March 1934**

"…Albert V. Sielke, formerly consulting engineer for the City of New York, and now executive of a New York engineering group which specializes in remodeling entire cities, stated: 'I recall some years ago a man named Thompson had a plan to fill in the Harlem river and eliminate the East river entirely. So, since I was in the midst of the discussion on the Thompson plan, I have a fairly good idea of what the Hudson job involves. Furthermore, it was under my supervision that we made 135 acres of land along the Hudson river, filling it in from west Seventy-Second Street up to the Harlem River Canal, which is near Two Hundred and Twelfth Street. We used fill derived from subway construction work. No, I wouldn't for a moment say that the Sper plan is an impossible one by any means. I would say, offhand, that the greatest difficulty would be in procuring enough fill, as you would have need for a tremendous volume of material to load up that valley.' Jesse W. Reno, a pioneer in numerous vast engineering jobs and who is well-known for his salvage operations, and generally recognized as an engineering wizard, had this to say: 'Getting down to the proposal to divert the Hudson river, there is an old saying that if you have money enough, everything else merely resolves itself into finding something to do with it. Provided with sufficient money and time, particularly money, the project could be carried through to completion with unquestionable success. It would take more than a billion dollars, I have estimated. On the other hand, it would be quite in keeping with President Roosevelt's rehabilitation and N.R.A. plan and put an enormous army of men to work. I heartily endorse the plan - though I am fully aware of the almost insurmountable impediments which appear at first study of the idea.'"

***Modern Mechanix*, March 1934**

<u>Part 2</u>

Haskin's Folly

The Art of Tunneling

The art of tunneling has been known to man from prehistory, originating in the caves and other natural underground passages which were used for shelter by primitive man. In *Egypt,* long tunnels have been found which were cut through solid rock serving as passages to the tombs of ancient Pharoahs. Similar rock cut tunnels were made by the early inhabitants of *India* in building their temples and by many other ancient civilizations. The tunnels constructed by the *Assyrians* are the earliest examples of built-up tunnels. The vaulted drain under the *Palace of Nimrod*, built about 860 B.C., may be considered a genuine soft-ground tunnel. A similar example (and what might be considered the first sub-aqueous tunnel on record) was under the *Euphrates River*. This tunnel was built of brick masonry and was 12-feet wide and 15-feet high. However, it was built under the dry bed of the river (the waters of the river were diverted until the tunnel was completed). The work was all done by hand; the tools being pick and shovel (for the soft ground) and hammer, chisel and wedges (for rock tunneling).

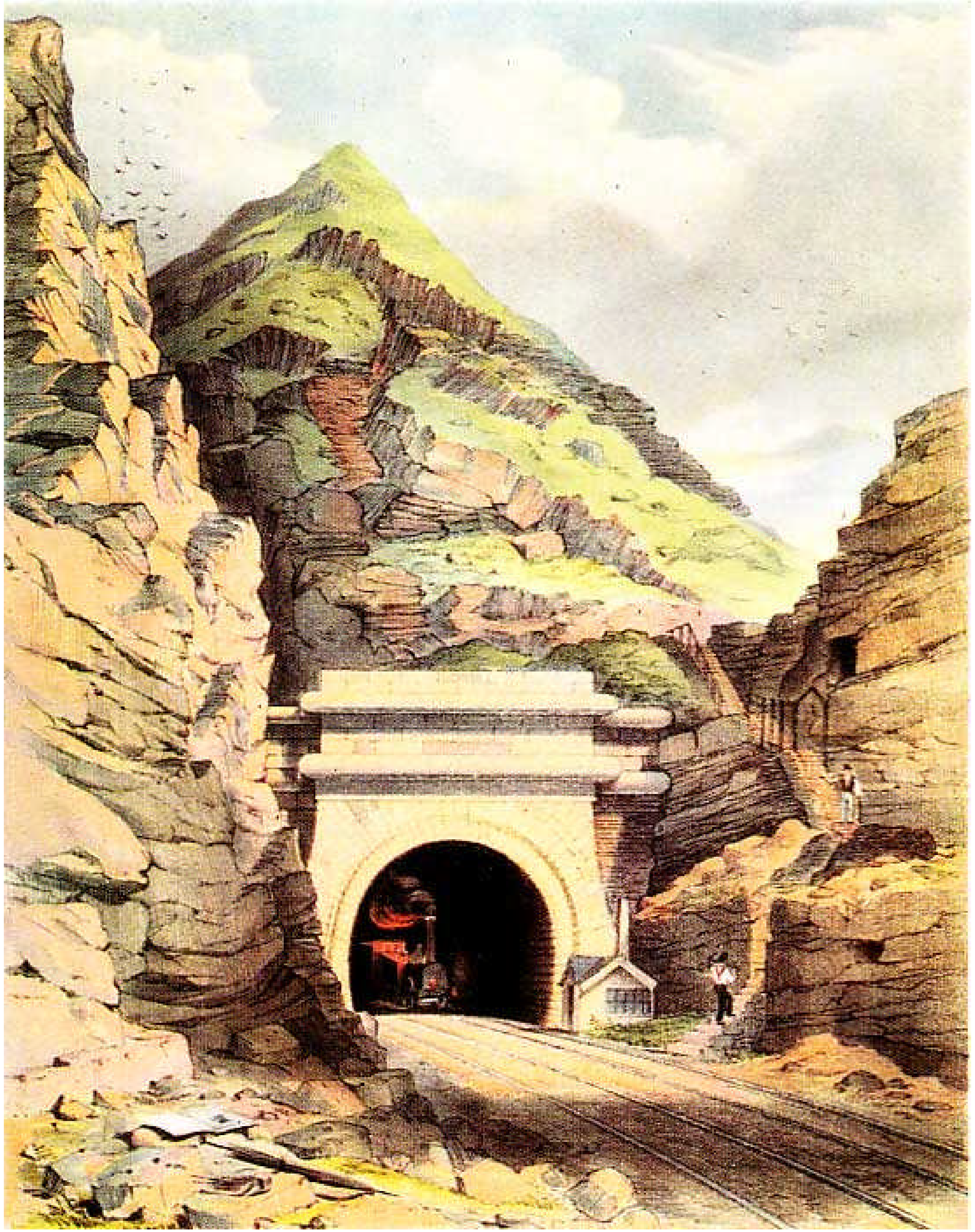
<u>Above</u>: caption: "Ancient Egyptian workers carve out and embellish the tomb of Seti I in a cutaway illustration"

The Romans were the greatest tunnel builders of the ancient world and devised many ingenious methods for the work (their tunnels were constructed principally for aqueducts and roads).

<u>Above</u>: beneath *Naples* runs an underground geothermal zone called the *Campi Flegrei* (fiery fields). The geothermal activity and later mining operations opened up wide caverns and passageways that have been used over the centuries by the Romans and their successors as sewers, cisterns and aqueducts.

During the *Middle Ages*, tunnels were only built for military purposes and little progress was made in the methods of work until the introduction of gunpowder. Up to the beginning of the *19th Century,* most tunnels were built through rock or hard ground (soft ground tunnels were too dangerous thus they were hardly ever attempted). In 1803, a tunnel 24-feet wide was cut through soft soil for the *St. Augustine Canal* in *France*. Timbering was used to support the roof and sides while the earth was being removed followed by a lining of masonry.

<u>Left</u>: caption: "North entrance of the canal tunnel at Poully-en-Auxois, France"



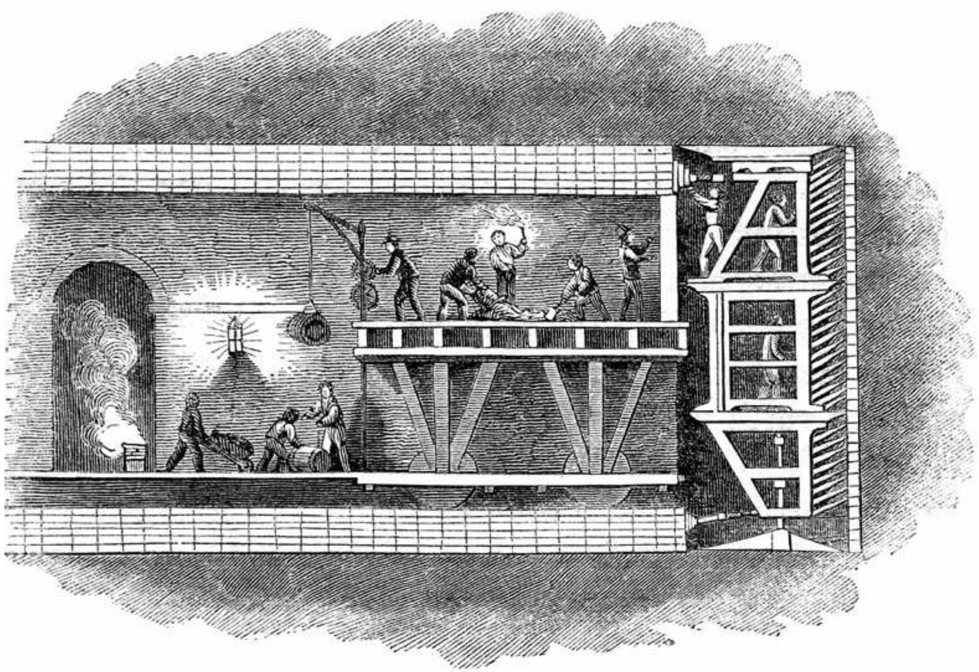
One of the greatest factors in advancing the art of tunneling was the development of the steam railway. Almost immediately upon its introduction in the early *19th Century*, tunnel building increased many fold. In about 1820, two tunnels were constructed on the *Liverpool and Manchester Railway* in *England*. From 1831-1833, the first railway tunnel in the U.S. was built on the *Allegheny Portage Railroad* in *Pennsylvania*. This increase in tunnel building was accompanied by corresponding progress in methods of construction and the introduction of improved machinery and special devices.

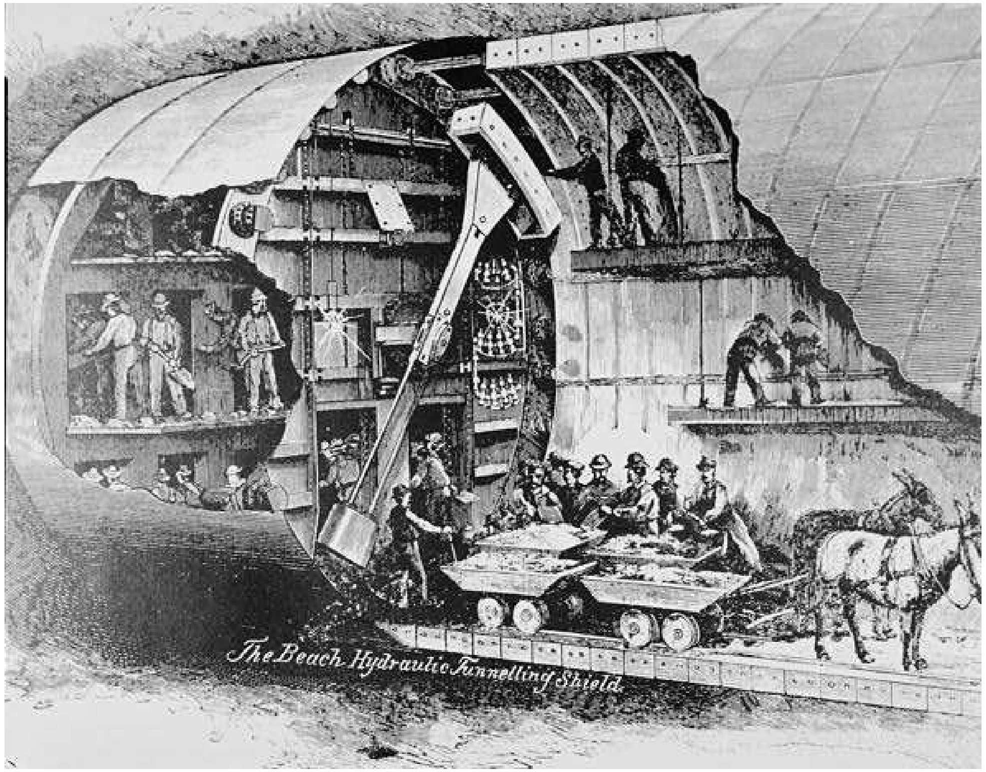
Left: caption: "Early railroad tunnel through mountain"

The Shield

"This shield, which is one of the greatest inventions in construction machinery of the past half century, resembles in appearance a great drum built of heavy steel plates. In the head of the drum, which is known as the diaphragm, there are doors for the passage of the workmen and the withdrawal of the clay and other excavated material. The upper edge of the drum is a cutting knife which goes through the hardest material when the shield is driven forward by the pressure from hydraulic jacks, holding up the river as it goes with compressed air while the waste material is removed. The upper portion of the drum which extends backward over that portion of the tunnel tube which has been completed, known as the 'tail of the shield,' forms the protection for the men who are setting up the iron castings, ring by ring, and making the tunnel proper. Immediately back of the head is the great crane, or 'erector,' which picks up the castings and holds them in place while they are bolted together. The entire work is carried on under air pressure which is made possible by placing in the mouth of the completed tunnel some distance in the rear of the shield a solid bulkhead in which are fitted and placed air-locks through which workmen and materials pass to the work at the shield. Thus the completed tunnel advances. The tunnels themselves are made up of iron castings bolted together and set in place consecutively as the boring shield opens the way for them."

Review of Reviews **(ca. 1909)**

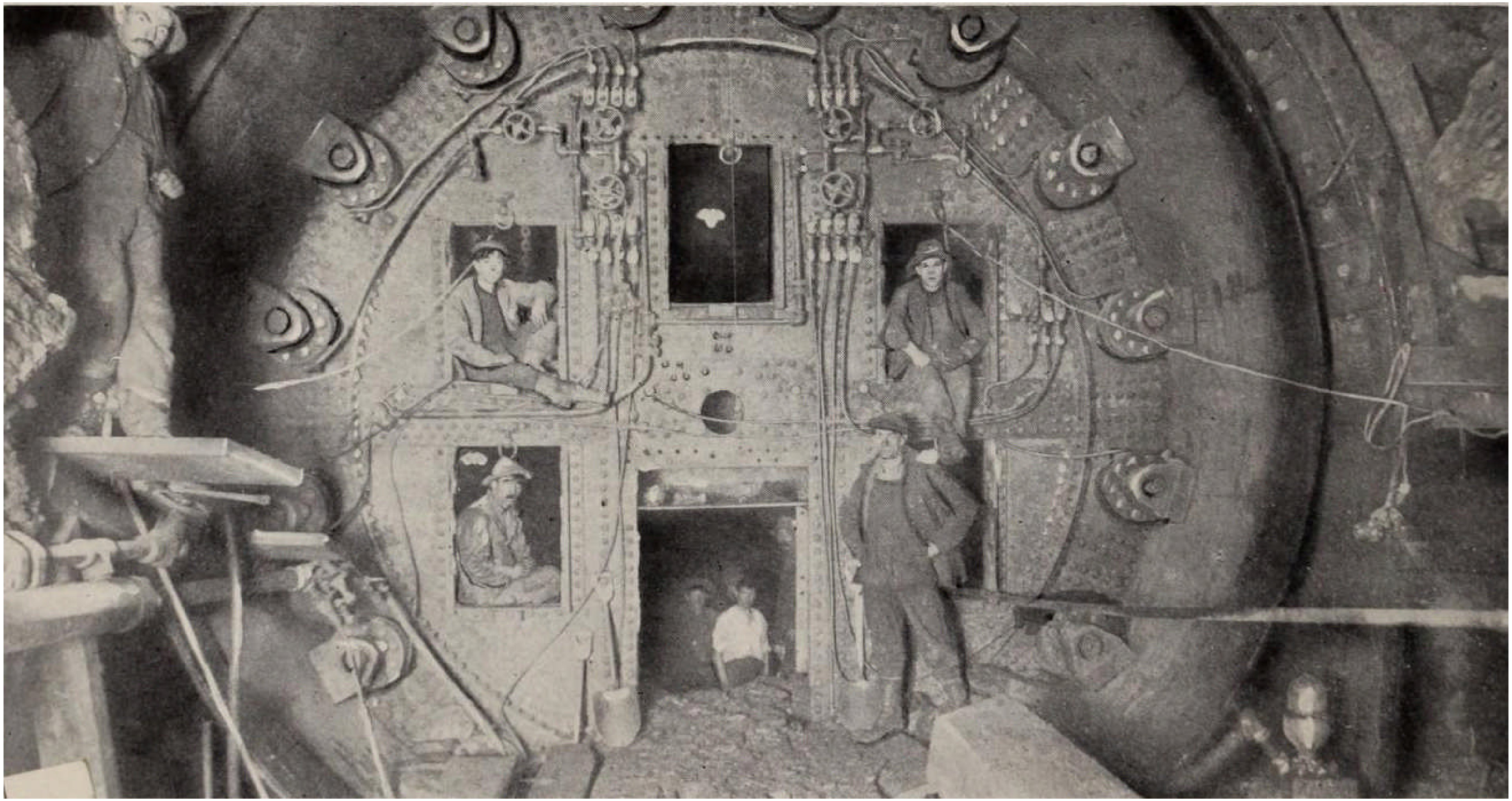




One of the greatest improvements in the art/science of tunneling was the development of the shield system. In the construction of rock tunnels, the principal difficulties encountered are the hardness of the rock, the length of tunnel and/or the lack of ventilation. However, sub-aqueous tunneling is very different. The mere excavation presents little trouble (it's typically through soft soils; mud, gravel or clay) but the threat of flooding must constantly to be guarded against. By the use of the shield and compressed-air, these difficulties were overcome. The shield was invented by *Sir Marc Brunel* (father of *I.K. Brunel*) in 1825 and was steadily improved, though the original idea remains the same.

<u>Top</u>: caption: "Diagram of the tunneling shield used to construct the Thames Tunnel"

<u>Bottom</u>: caption: "The Beach Hydraulic Tunneling Shield"



Above: caption: “View of shield used in tunnel construction.” One of the greatest improvements in connection with the shield method of tunneling was the use of cast-iron lining by *Peter Barlow* in 1869 (used in the *Thames Tunnel*). *Lord Cochrane* first suggested the use of compressed-air and in 1830, he took out a patent for air-locks and other appliances to be used in tunneling. The next great step in tunneling technology was made in 1887 when an improved shield was invented by *J.H. Greathead*.

A Universal Need

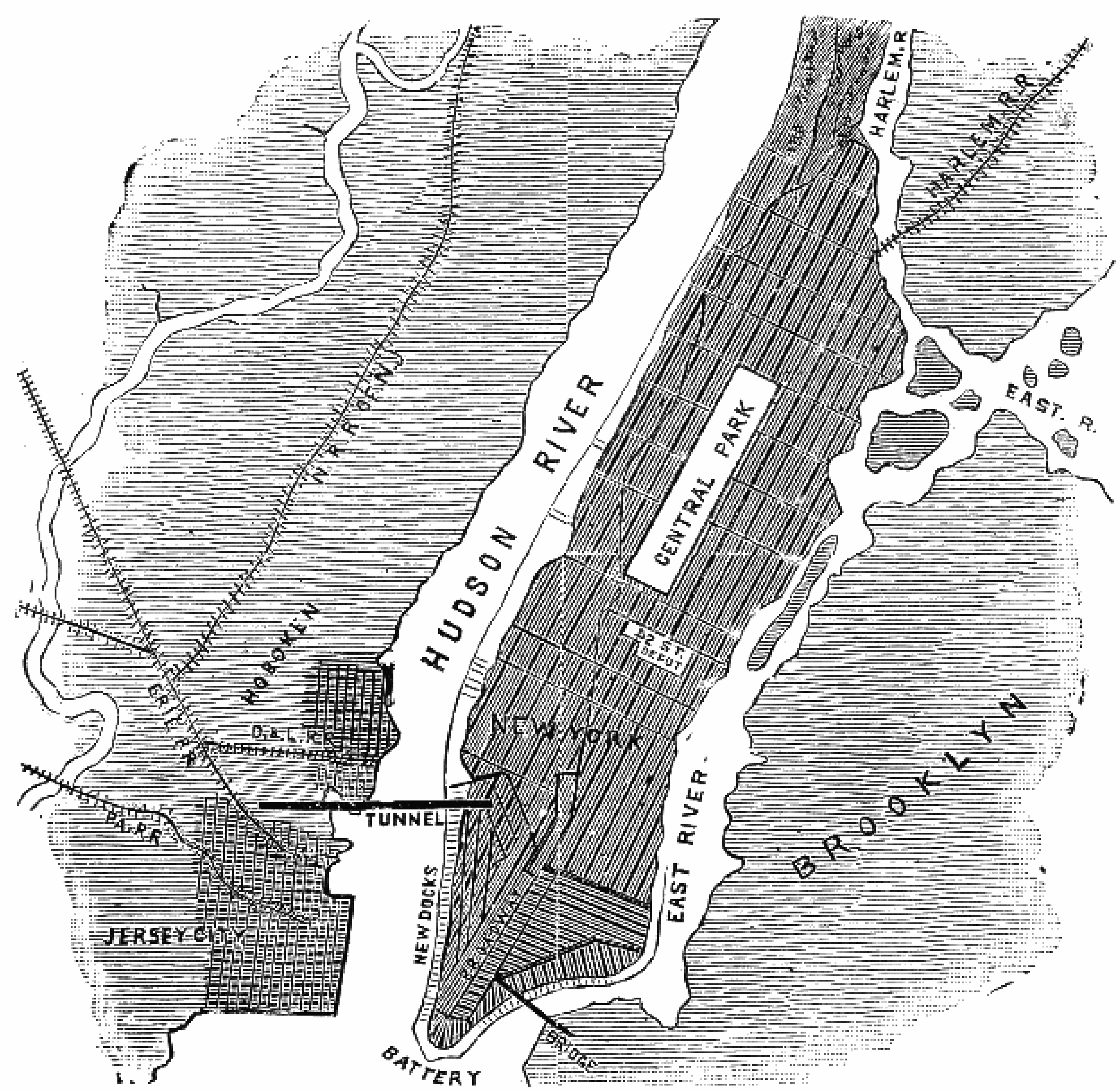
"Novel experiences are constantly sought, new emotions ever desired. The hindrances of surface transportation and traffic hold no fascination or magnetism for the romantic soul; the delays and uncertainties of surface congestion present no allurements to the busy traveler. And so it came to pass that tunnels became a necessity; almost a rage with busy workers in the hives of industry in the great American metropolis, and now have become necessary channels of communication beneath rivers, the surface of which is always congested with an ever-increasing shipping, and often bound hard and fast in ice or the dangerous and annoying embrace of heavy fogs…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

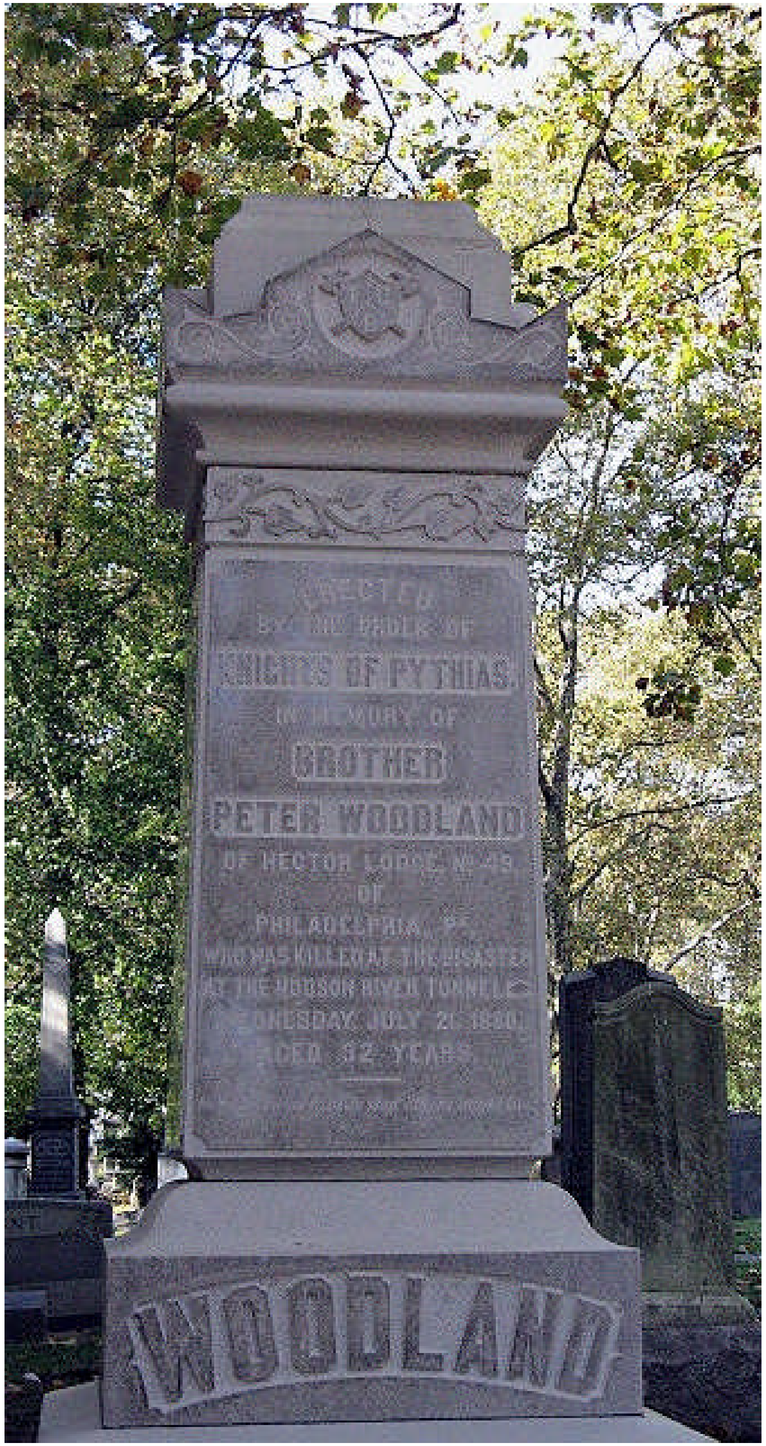
Colonel Haskin

"…The idea of tunneling under the Hudson River had its conception in the fertile brain of Colonel D.C. Haskin, an English civil engineer of considerable note and ability, in 1874, and he set about organizing a company to finance and bore the tunnel, and after arduous labor, and much persuasion succeeded in interesting about two millions of dollars of New York capital in his undertaking. He began work in 1878, and had constructed one thousand, two hundred fifty feet of tunnel, when a cave-in of the roof sheathing, in 1880, drowned twenty-one men in the air-locks. The money having been all expended, and further financial aid being lacking, the company was forced to abandon the enterprise in that year…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story.* In 1874, an English civil engineer by the name of *DeWitt Clinton Haskin* (1824-1900) conceived the idea and organized a company to construct two tunnels from a point near the *Palisades*, in *Jersey City*, *New Jersey,* to a terminus at or near *Washington Square, New York*. It was his intention to build a Union railroad station at Washington Square and induce trunk line railroads in New Jersey to make joint use of it. Haskin began the construction of one of these tunnels in 1879 and built about 1,800-feet of one tunnel. In 1882, his company failed.



<u>Above</u>: caption: "Location of Hudson River Tunnel. (*Leslie's Weekly*, 1879)"

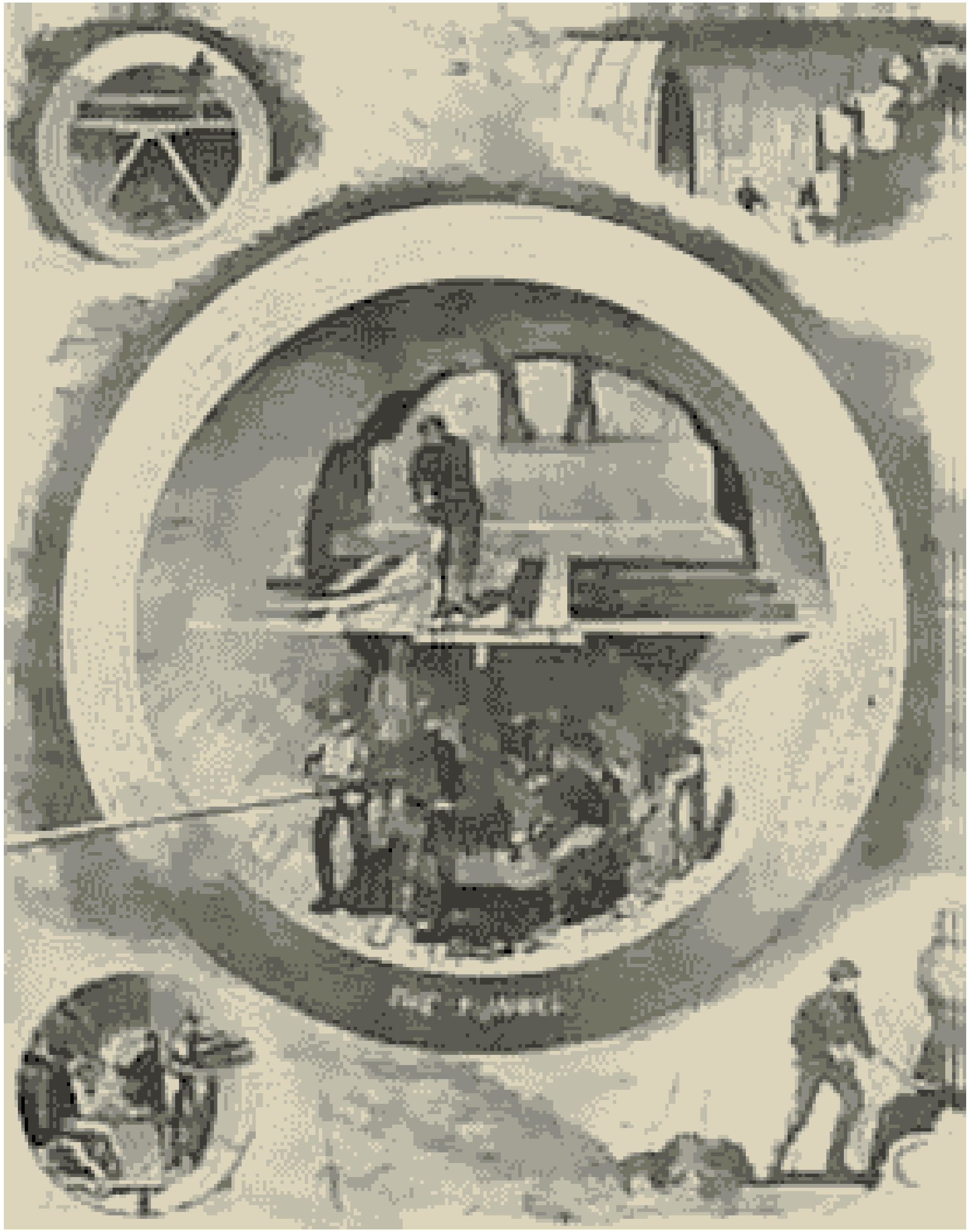


At first, a shield was not used, the excavation being made under pneumatic pressure. However, it was extremely difficult to keep up this pressure as the earth was too loose to retain the air and as soon as it escaped, the water would rush in. On July 21st 1880, a serious leak occurred which resulted in the loss of twenty-one lives. *Peter Woodland* – one of the workmen, was the first to discover the leak. He was at the door of the air-lock giving warning to the other workmen rushing them through the exit. After eight men had escaped, Woodland saw that if the door were not quickly closed from the inside all would be drowned. To save the lives of those who had already passed through the air-lock, he closed the door and the water soon filled the chamber, drowning him and the others who had been unable to pass through the air-lock. Woodland could have saved his own life when he discovered the leak. Instead, he kept to his post and saved the lives of his fellow workmen. A monument commemorating the event (left) was erected over his grave in the *New York Bay Cemetery* in *Jersey City, NJ*.

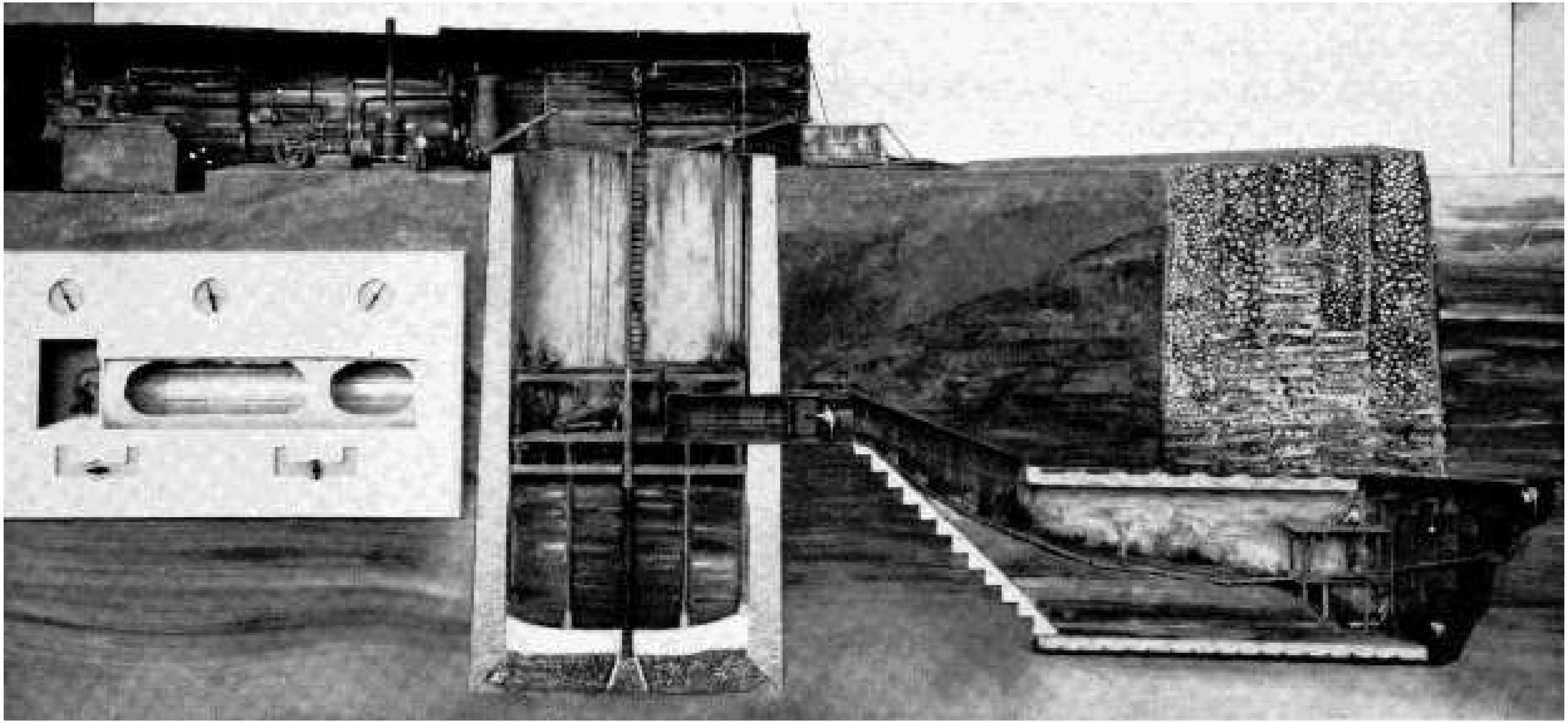
“The bodies were lying together in a bunch, as if the men had huddled together for mutual aid and comfort. Superintendent Anderson is of the opinion that the four men ran toward the air lock when Assistant Superintendent Woodland shouted to the men to save themselves, but being unable to get into the lock they ran into the north tunnel in the blind hope that some means of escape might be found there. Their agony was probably more prolonged than that of the others, who were crushed by the falling earth and iron plates. The bodies were in a very advanced state of decomposition - in fact they were little more than skeletons - and, as their clothing had nearly all rotted away, it was next to impossible to identify them…The head of the headless body among the last recovered was also found later and taken out”

***S.D.V. Burr*, Engineer**

RE: the discovery of the last four bodies in the north tunnel on November 29th 1880



When the first tunneling under the Hudson attempt was made, there was no excavation shield and no iron construction because Chief Engineer Haskin believed that the river silt was strong enough (albeit with the help of compressed-air support) to remain in-place until a brick lining (2.5-feet thick) was in place to support the tunnel structure without distortion. His plan was to excavate the tunnel using thirty-five pounds of air-pressure to expel water and hold the tunnel's iron-plate liners in-place (thin steel plates 0.18-inch thick) then sheathe the liners with a brick lining. He was able to build out about 1,200-feet from *Jersey City* until the July 21st 1880 blowout resulted in twenty-one deaths.



<u>Above</u>: caption: "Haskin's pneumatically driven tunnel under the Hudson River, 1880. In the engine room at top left was the machinery for hoisting, generating electricity for lighting, and air compressing. The air lock is seen in the wall of the brick shaft."

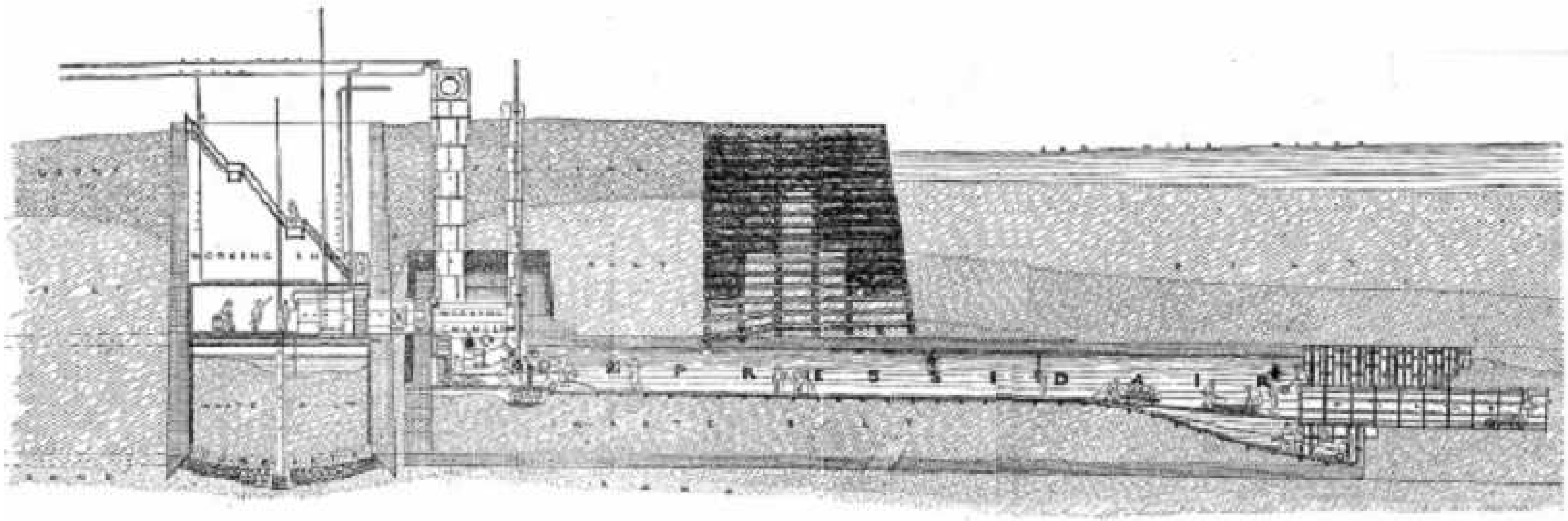
"…Colonel Haskin, having failed in his attempt to interest additional American capital in his enterprise went to England, where he succeeded in obtaining about two million dollars of English money, and a new company was organized to take over the franchise, and other assets of the old company. Colonel Haskin in resuming his self-imposed task of uniting New Jersey and Manhattan Island by a sub-aqueous route had in mind the establishment of a mammoth terminal station on a site in close proximity to Washington Square, where railroad trains from every section of the country could discharge passengers and freight…"

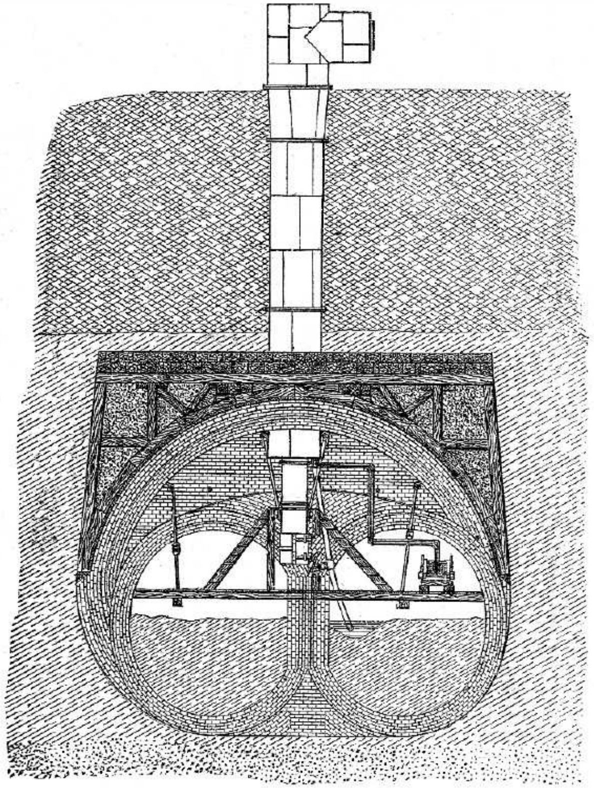
RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

“Opening this lock greatly facilitated subsequent movements, since it was both easier and quicker to lower supplies down the shaft, and pass them through the lock, than it was to admit them through the vertical lock in the caisson. It was decided to extend the two tunnels to the shaft, and not finish the upper half, but leave the whole as one large chamber uniting the two. Thus the caisson was converted into a large working chamber, connected with the outer world by three air locks. and wholly enclosed in masonry.”

***S.D.V. Burr*, Engineer**

RE: the *Hudson Tunnel Railroad Company* continued work for more than two years after the tunnel collapse in July 1880. The caisson in *Jersey City* reached its permanent depth in October 1880 and with the air-lock to the shaft open, more normal working conditions were gradually re-stored. As well, the caisson was strong enough to support the earth around it without air pressure. The intended floor level was 8-feet below the sides of the caisson so it was dug out carefully and finished in brick until the exposed section of caisson rested securely on the new brick foundation. At the same time, a masonry arch 3-feet thick was built across the top.





Upon opening the east-side of the caisson to the two tunnels, the water was pumped out of the north tunnel without incident then an opening was made from the caisson and the tunnel was found to be intact.

<u>Above</u>: caption: "How the tunnel was built after October 1880. The caisson now provided a safe 'working chamber' between the shaft and the tunnels. "

<u>Left</u>: caption: "Cross section showing how the caisson fit over the two tunnels. It was a little off-center so there was more brick lining on the north (left) side."

"The tunnel was then pushed forward until the advance plates struck the old wooden-crib bulkhead, when work on both tunnels was stopped, and operations were directed toward removing the temporary entrance, or connecting chamber, as this was too weak to stand the increased pressure necessary at the heading…It was through this old bulkhead that the water came at the time of the accident; it caused a great deal of trouble when recovering the bodies of the men and beginning anew…The south tunnel, through which water flowed from the river to the shaft, was filled with water, except a sloping bank next to the wall. It was impossible to finish this portion of the work until the inflow of water was effectively checked. When this plan would no longer work silt was rolled by hand into compact balls, which were dipped into water to make their surface slippery, and then placed in the pipe…"

***S.D.V. Burr*, Engineer**

RE: during the reopening of the south tunnel, it was found to be the source of the river water and the fish that had appeared in the shaft

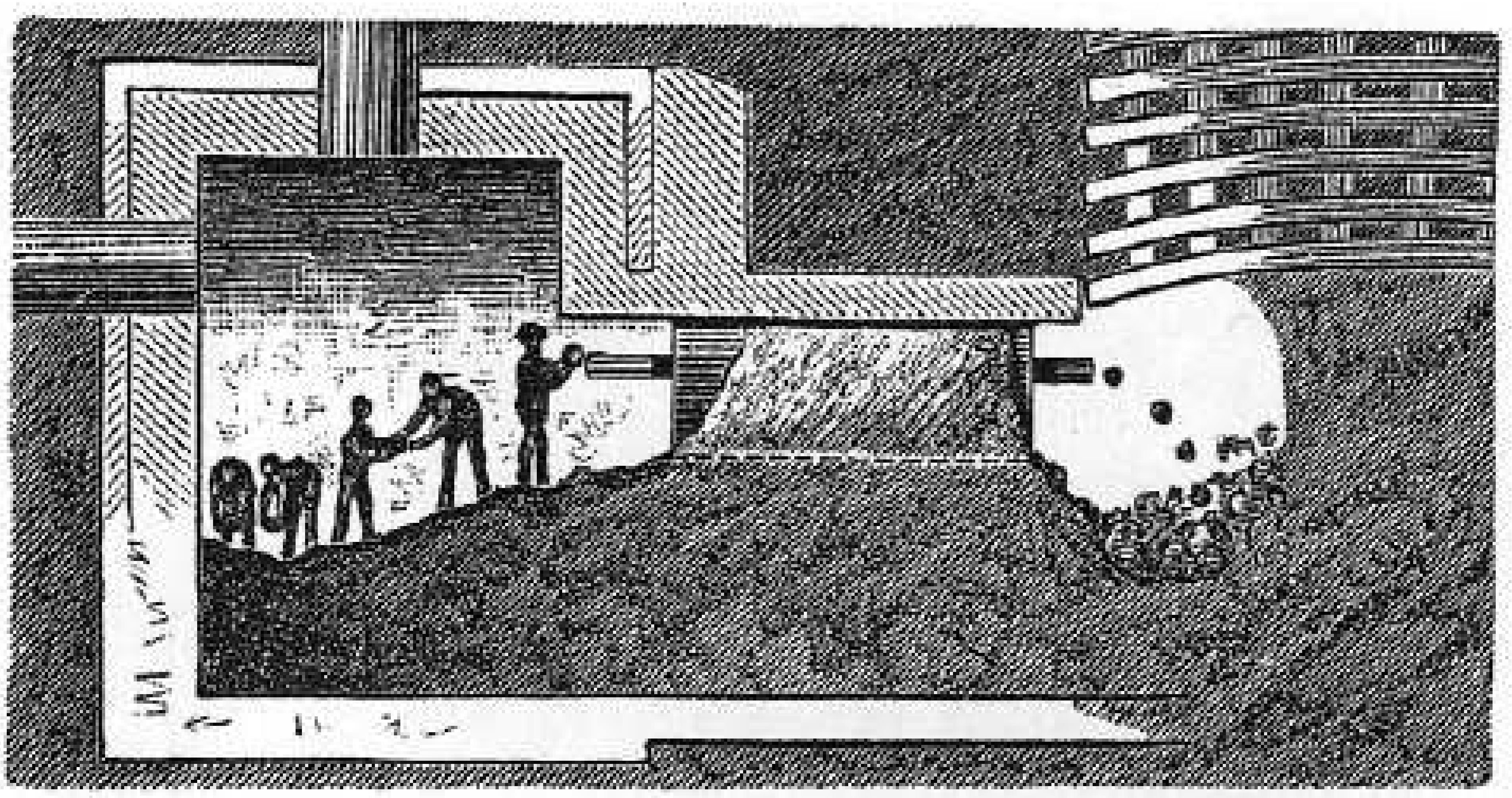
“When full a long ramrod, worked by four to six men, forced the load through. This pipe was supplemented by a 6-inch one, and silt rammed in until the near end of the tunnel was completely filled with a solid and tenacious mass. Then sections of the side of the caisson were cut out and a bulkhead put in.”

***S.D.V. Burr*, Engineer**

RE: to plug the tunnel with silt, a 2-inch pipe was tentatively inserted into the wall and a slurry of silt and water was pumped in by maintaining the air pressure above that of the water. When no more would go in, a 3½-inch pipe was pushed into the space, and the same repeated. It was hoped that the silt would hold back the air when an opening was made in the caisson to resume work, but the silt only extended so far. The river had come in right under the shoreline bulkhead.

"…It was discovered that the inrush of water through the loosely constructed crib-work had not only washed out much of the earth which had filled the spaces between the timber and stones, but had excavated the large hole shown in our engraving. Two serious hindrances were thus placed in the way of the work: the absence of support for the timbers of the crib on the original inclination caused them to drop below the upper line of the tunnel, necessitating their removal before the tunnel shield could be pushed forward, and the washing away of the protecting silt allowed the water to flow in, and the compressed air of the tunnel to escape. The cavity was discovered by sounding. Instead of clearing out the original tunnel at once, a small pilot tunnel, six feet in diameter, was first driven (from the caisson) through the washed-in silt almost to the cavity. Then a six-inch tube was thrust through the remaining wall of silt, and an attempt was made to pass through the tube a sufficient quantity of mud balls to fill the opening. It was thought that this had been acc-omplished, and the mud wall was removed only to discover a leak through the crib that defied the usual means of stoppage by the use of bags of bran and the like. At this stage the recent serious inflow of water occurred, compelling a change in the plan of procedure…"

Scientific American, **December 25th 1880**

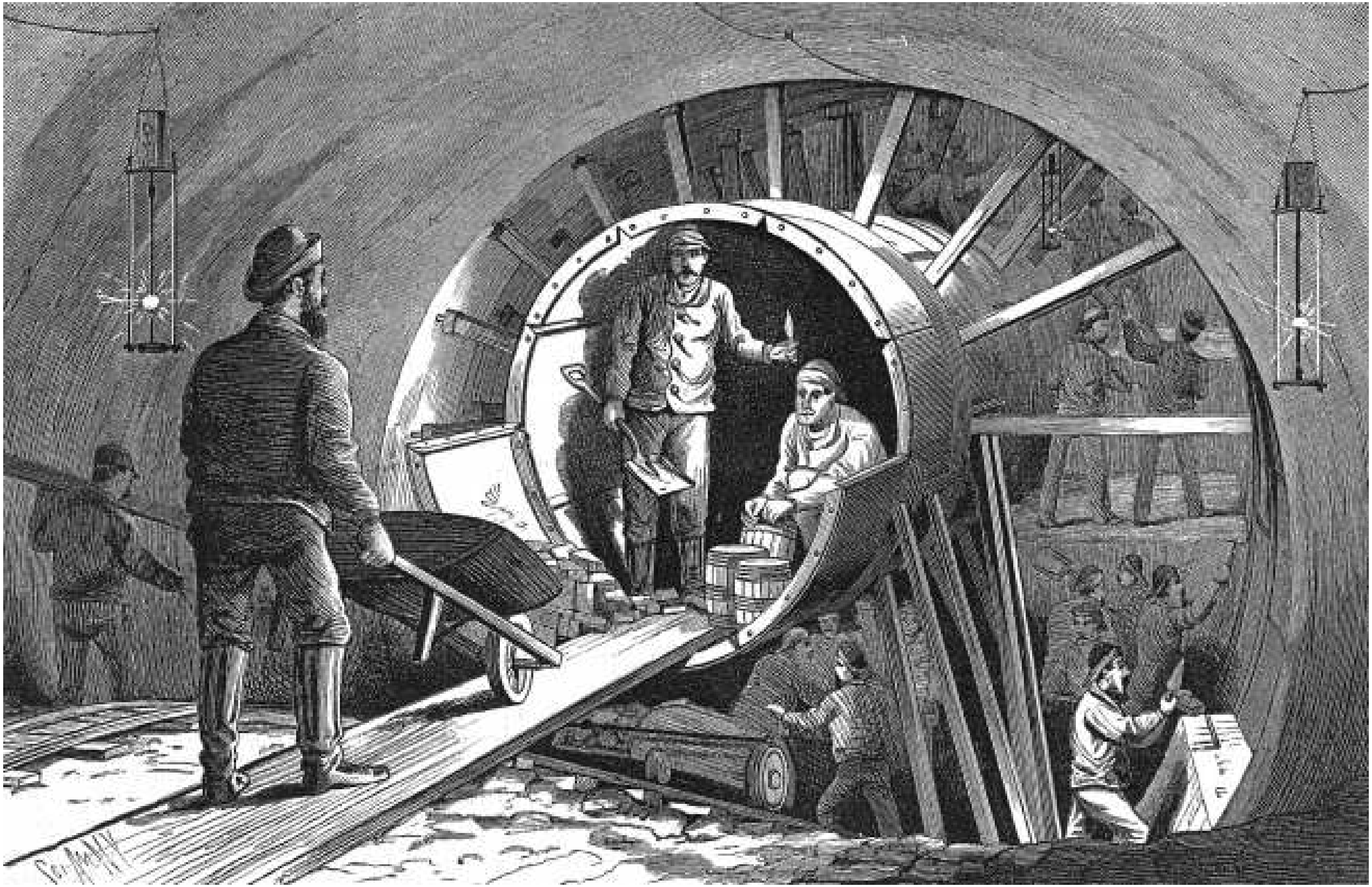


<u>Above</u>: caption: "The pilot tunnel and mud balls being forced into the cavity. From *Scientific American*, December 25, 1880."

"…This pilot tunnel was 6 feet in diameter, and made up of interchangeable plates, flanged so that they could be bolted together, and formed a central hub which extended a few feet into the silt in advance of the face, and also a few feet into the completed masonry of the tunnel. Being supported rigidly at both ends, the central portion of this pilot acted as a foundation upon which struts to support the plates could be placed…"

Scientific American, **June 4th 1881**

RE: pilot tunnel. The pilot tunnel was Chief Engineer John F. Anderson's idea (he used it exclusively). It would provide an idea of the ground ahead and also keep the tunnel in much better alignment. The pilot tunnel was like the hub of a wheel and the spokes radiating from it to the plates kept them from deflecting until the brick lining was in place.

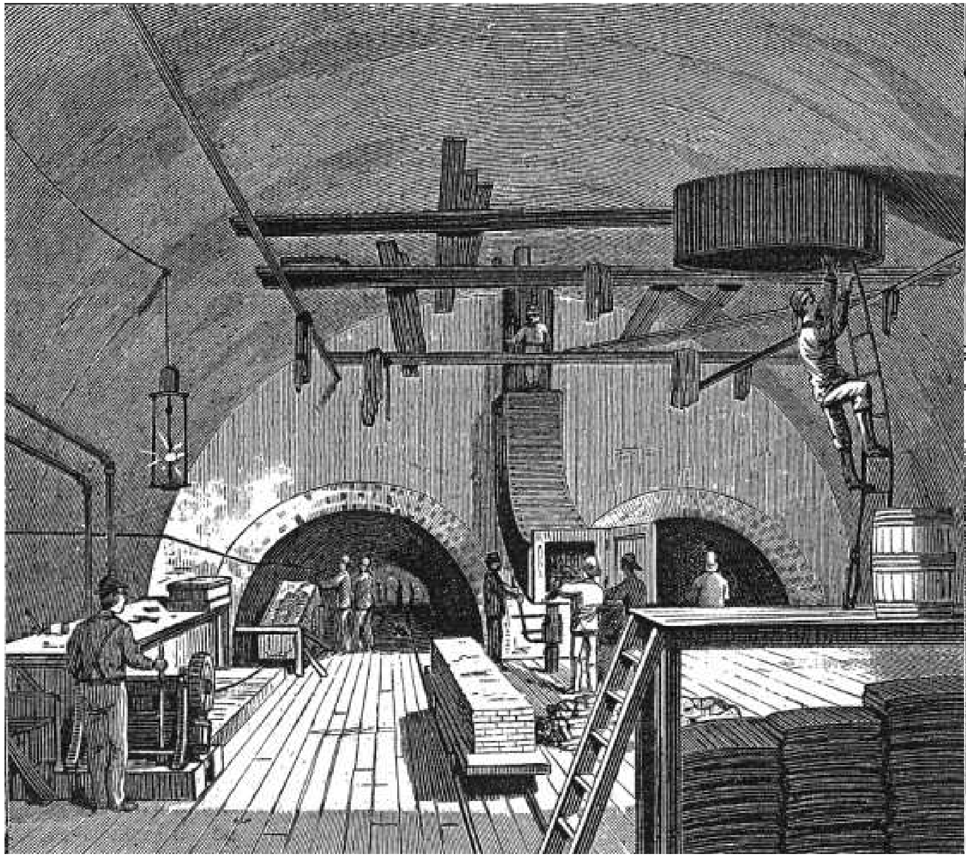


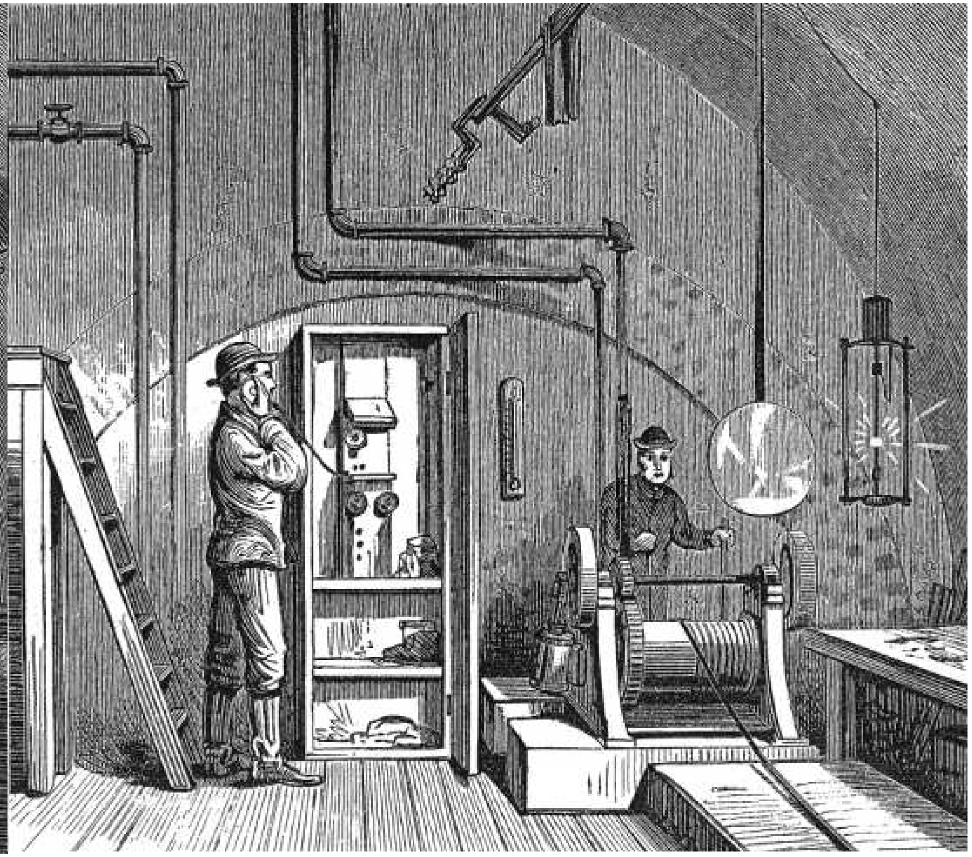
<u>Above</u>: caption: “The pilot tunnel, showing the spokes that kept it in place as the tunnel was built around it. From *Scientific American*, June 4, 1881.”

“The south tunnel is just emerging from under the bulkhead that gave so much trouble at the time of the accident, reported the Sun in the middle of 1881. The soil is so porous that the compressed air may be seen at the surface of the river as it escapes from the tunnel through the water, and bubbles up like a boiling spring. The work is progressing smoothly, and Mr. Andersen says that it is all now plain sailing”

***Sun,* 1881**

RE: on the *Jersey City* side, the problems in the south tunnel were solved by December 14th 1880 and work resumed in a more routine way. The company decided first to make the south tunnel as long as the north and put all the men to work there. The tunnel advanced about 4-feet per day, reaching 200-feet by July 1881. Meanwhile, the company began to prepare bulkheads in the tunnels so that compressed air could be confined to only the work area near the ends of the tunnels. This would keep the rest of the tunnel safe in case of trouble at the working face and for the safety of the laborers. The bulkheads were to have two locks (one was always open for the men to run into in an emergency). The tunnel was lit by electric lamps and a private telephone in the entranceway communicated with the office above.





<u>Left</u>: caption: “View inside the caisson looking east toward the twin tubes. The larger air lock is on the right, and the smaller one for materials is in the center background. From *Scientific American*, June 4, 1881)”

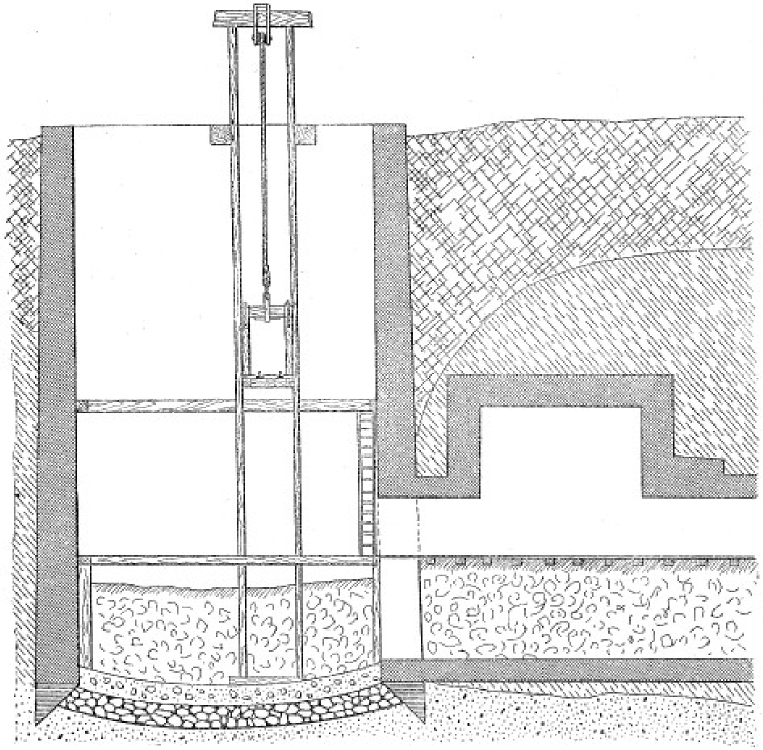
<u>Right</u>: caption: “View inside the caisson looking west. In the rear wall is one of two arches where the tunnels would later open through to the shaft. One man is using the telephone link to the surface. The air lock to the 15th St. shaft is just beyond the left edge of this view. From *Scientific American*, June 4,1881.”

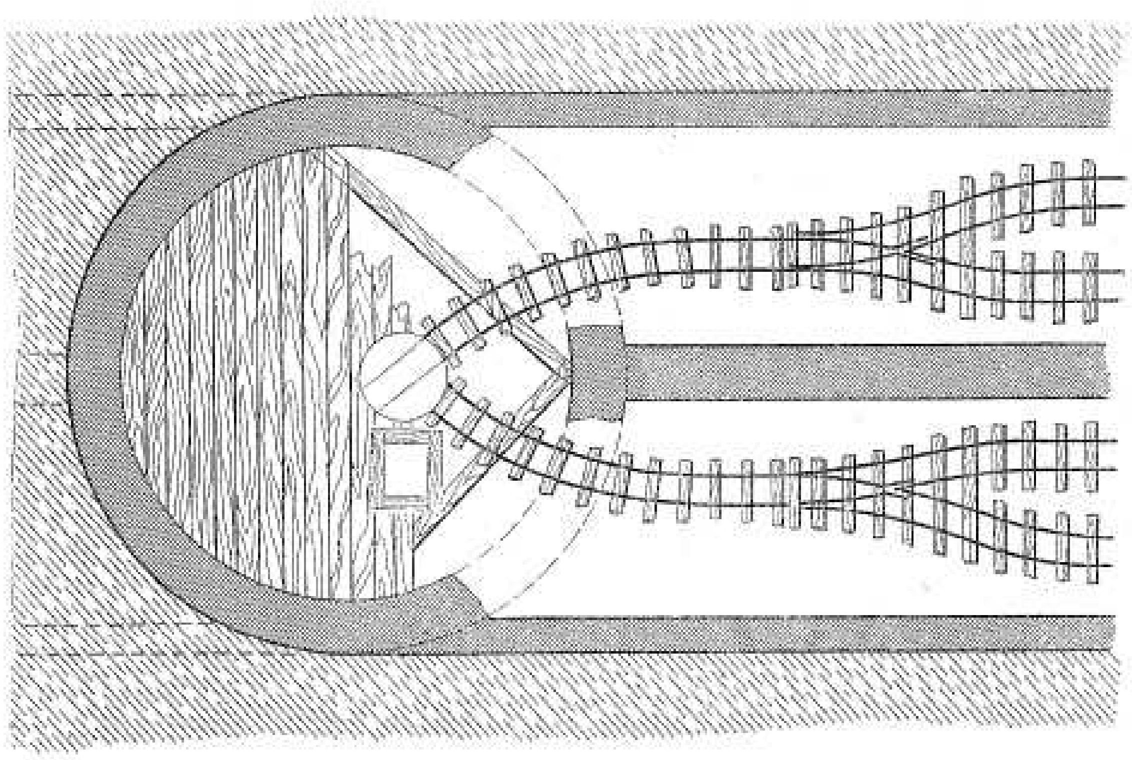
In 1881, *William Sooy Smith* became Chief Engineer of the tunnel company. With his appointment, the company finally had someone with experience working with compressed-air and caissons (mainly in the construction of bridge foundations). On the evening of August 11th 1881 (after the air-lock had been installed in the south tunnel) Smith tested the strength of the tunnel west of the air-lock by having the air pressure gradually reduced. The lock or bulkhead proved to not be air-tight and the end of the south tunnel lost pressure and began to fall in. But the new system did work as far as protecting the workmen; they all ran into the new air-lock and escaped uninjured. However, the last 30-feet of tunnel was crushed. By the start of November 1881, the air-locks in the tunnels had been properly installed and tested and air pressure was eliminated in the caisson and in a long section of the tunnels. The air-lock at the top of the caisson was removed and the roof completed and the wall to the shaft was opened. A reporter visiting the caisson on November 5th 1881 noted that it was now open to the fresh air. He also found there, to his surprise, a boy grooming the company horse that pulled the carts on temporary tracks laid between the caisson and the end of the tunnels, (he marveled at how they had managed to get a horse in through the six-foot high air-lock). The distance to the air-lock/s in both tunnels was now about 400-feet and the north tunnel extended 150-feet beyond that. Some changes in the work had been introduced as well. The silt was now being pumped out to the surface mixed with water using a system patented by Smith and the bottom half of the tunnel was now being built of concrete instead of brick. Smith reported an advance of 90-feet in October 1881 and with work about to begin from *New York*, he predicted the tunnel would be finished in 1885.

"Contrary to what we have been led to expect, a number of leaks were developed as the air pressure was removed, through one of which, in the north bore, the water is reported to have entered in such volume that it could only be stopped after much hard work. This explanation must strike the engineering mind as being highly unsatisfactory. This portion of the tunnel, it should be noticed, is reported to be finished - that is, the iron plates and masonry work are all in position, and yet its strength and stability are so inferior that on the withdrawal of the trifling excess of air pressure within (about 10 to 15 pounds to the square inch), it shows the effects of strain and weakness by allowing the water to pour in."

***Manufacturer and Builder,* 1881**

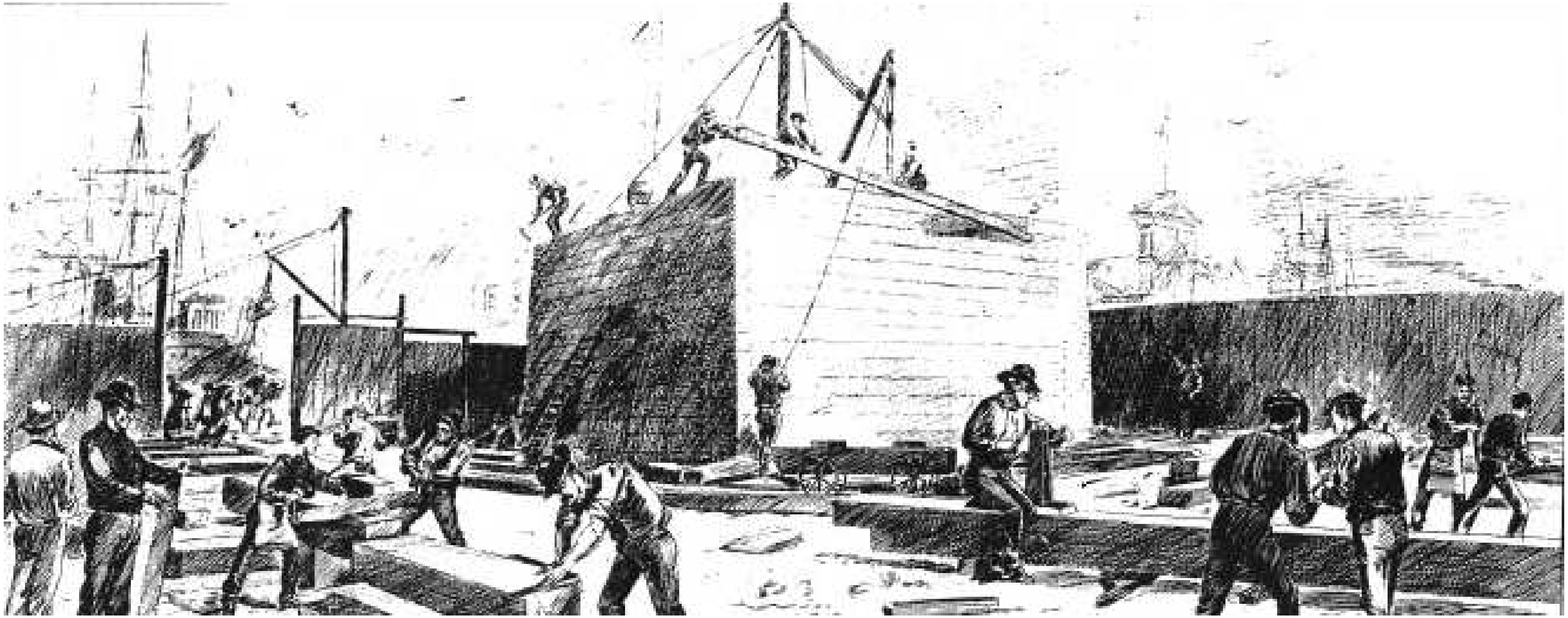
RE: the end of air pressure was not without incident. Colonel Haskin explained that the location of the leak was right under the crib-work at the edge of the river (with very little earth) and that the air pressure inside the tunnel had strained the brick lining outward and cracked it. In January 1882, touring engineers found the roof of the caisson to be "dripping in an unpleasantly suggestive manner."





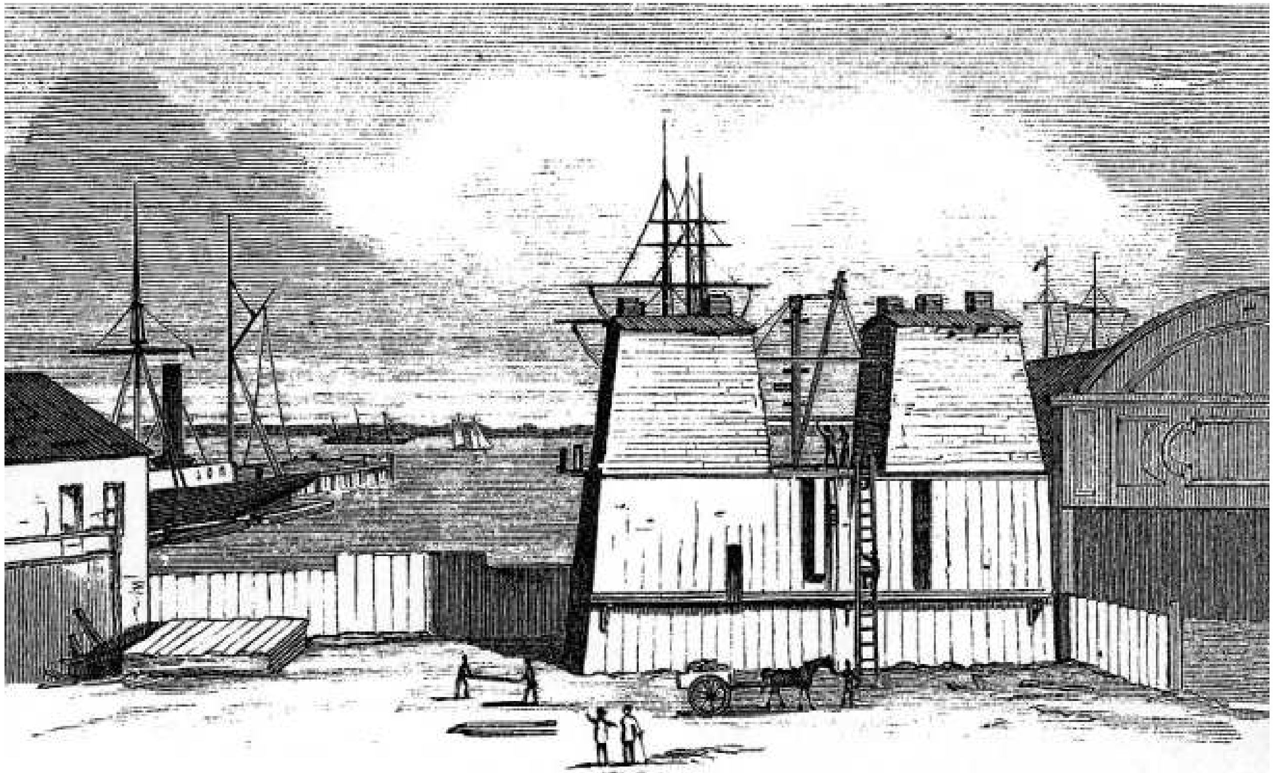
<u>Left</u>: caption: “The Jersey City shaft open to the outside after the air lock was moved farther into the tunnel. The short section of high roof to the right was the caisson. As usual about two-thirds of the tube was filled with excavated silt, and the diagram shows a side view of rails and crossties above it.”

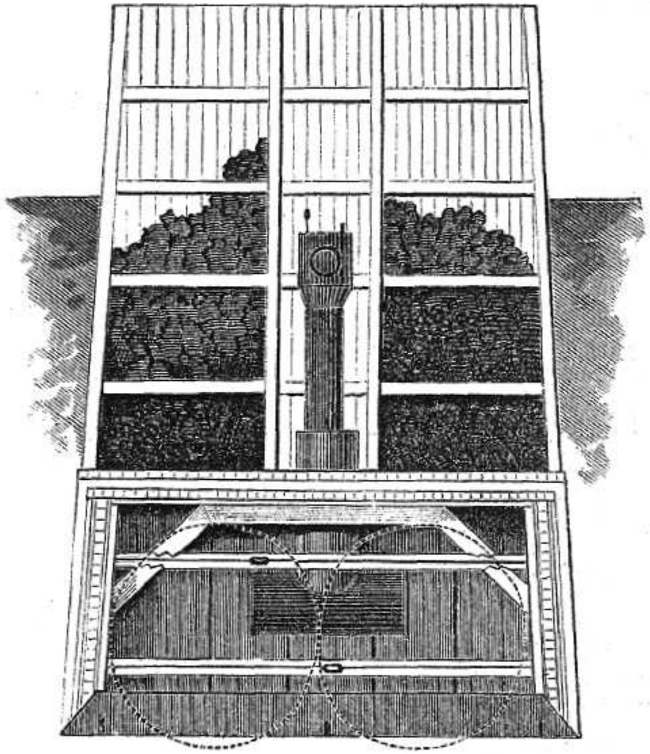
<u>Right</u>: caption: “Plan of the narrow-gauge railway tracks from a turntable in the shaft to the tunnels. The wall between the tunnels is shown here as starting at the shaft, so it had been carried through the caisson.”



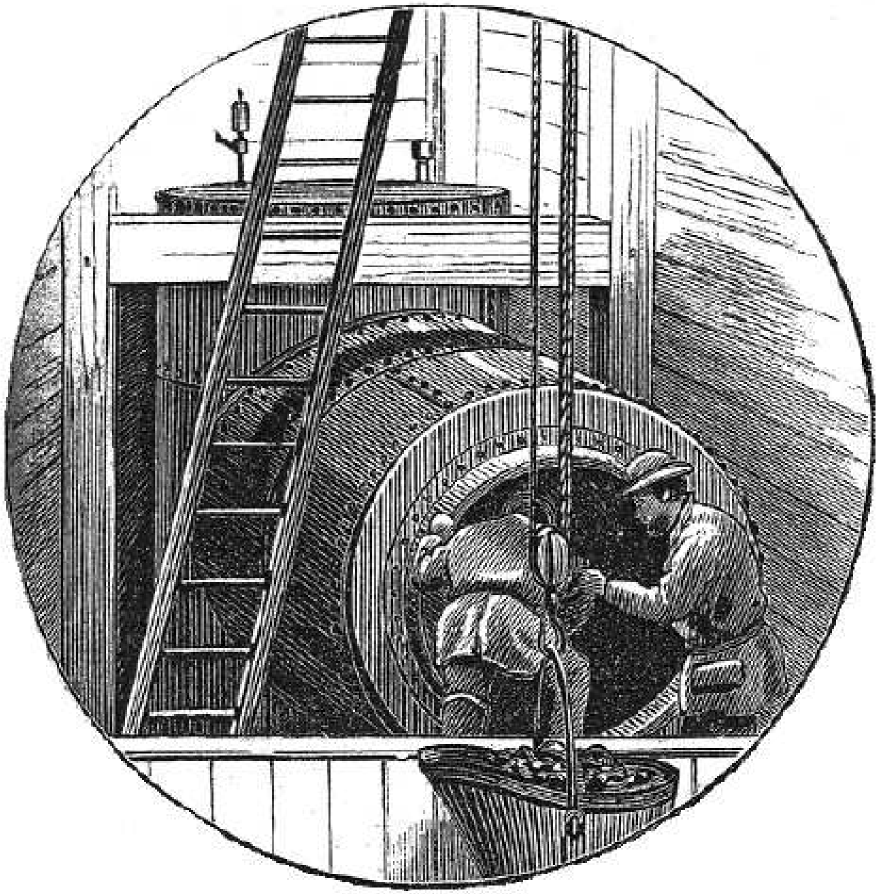
Construction in *New York* was begun by sinking a caisson, the method that most now felt should have been used to begin with on the *Jersey City* side. The caisson was completed on the surface at the start of November 1881 after about six months' work. The air-lock formerly at the top of the Jersey City caisson was carried across the river and reused. A report on November 18th 1881 said that compressed-air was turned on a few days before, electric lights were hung and work would now begin. Work progressed at about 2-feet per day thus, it took more than two months to reach the intended depth. On January 20th 1882, the caisson was reported nearly down. The ground at the bottom was not silt but sand and loose rocks. The finer sand could be blown out dry, but buckets had to be used to take out the gravel and rocks.

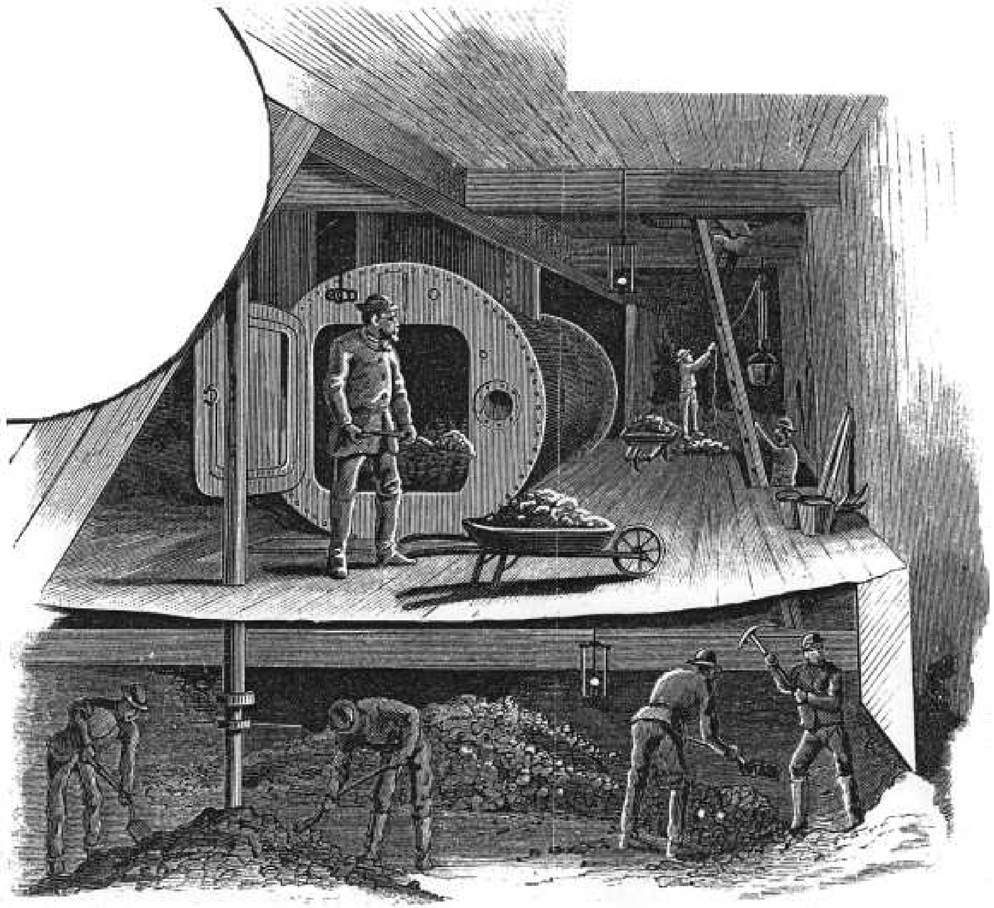
<u>Above</u>: caption: "The caisson on the surface on the New York side"





<u>Left</u>: caption: "The head building over the caisson and shaft. From Scientific American, February 4, 1882"
<u>Right</u>: caption: "Cross section of the caisson sunk to final depth, showing the rock ballast over it and the large air lock that was previously used on the Jersey City side. On this side, the top was below ground level, inside the head building. From Scientific American, February 4, 1882."





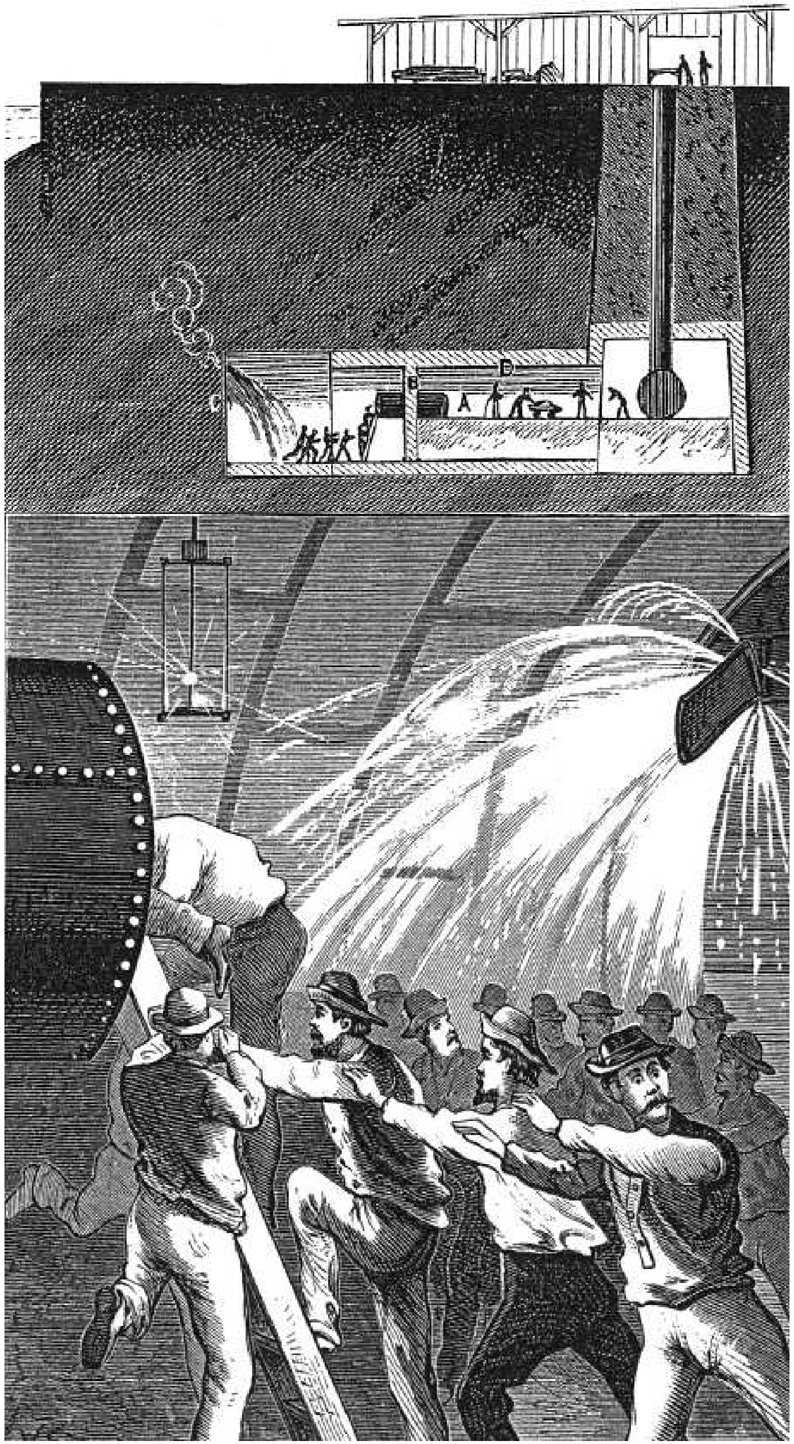
Above L&R: caption: “Views at the top and bottom of the air lock. From Scientific American, February 4, 1882.”

“…Instead, therefore, of prosecuting the work on the plan which Colonel Haskin, the chief promoter, had so enthusiastically favored from the first, he preferred other and more expensive, though safer, methods, which he claimed would also be more expeditious. Finding that Colonel Haskin and the directors insisted on proceeding as they had done from the first, he resigned his position and went West…”

***Scientific American,* June 1882**

RE: work on one of the tubes started in March 1882. Chief Engineer *William Sooy Smith* was concerned about the loose sand and gravel (he thought it would leak air and water). Smith’s concerns were well founded when on March 31st 1882 a blowout occurred. Air forced its way out the end of the tunnel and water rushed in, flooding the caisson. Fortunately, all the men got out safely.

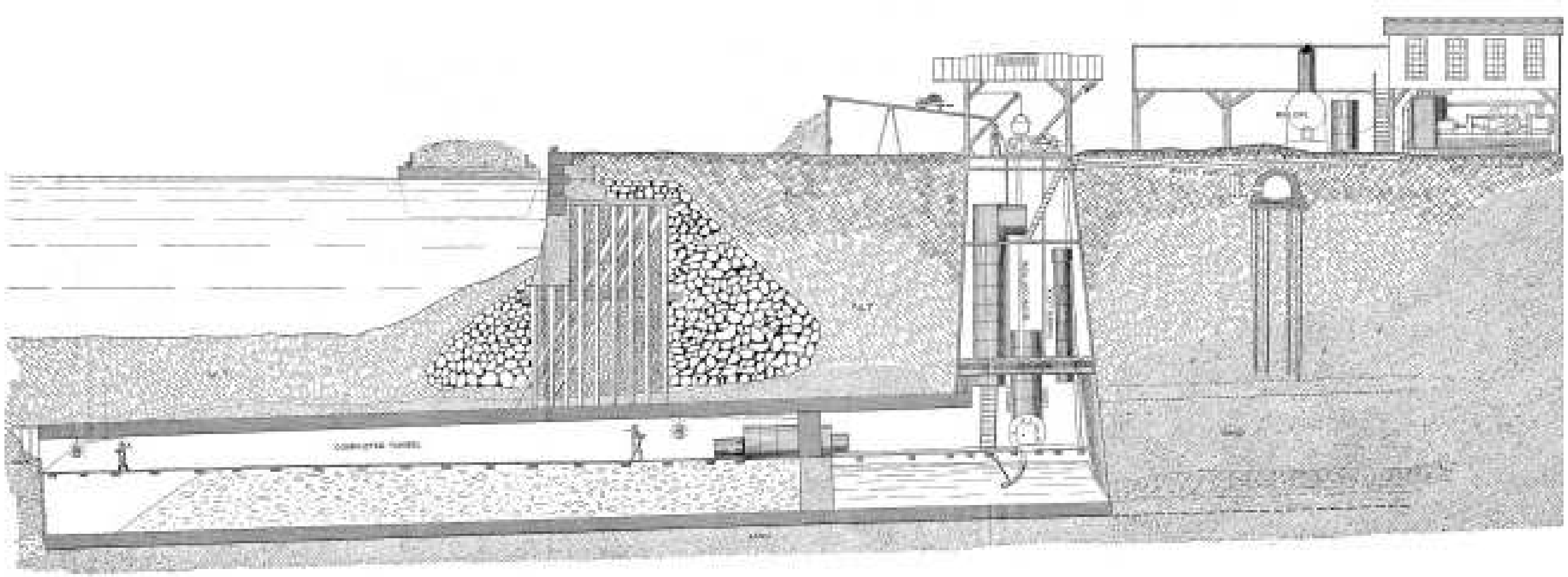
By the end of May 1882, the two tunnels had been completed inside the caisson. In the *Jersey City* caisson, one large arch had been built across both tracks but in *New York*, separate tunnels were built with a common center wall. From the caisson the north tunnel was started first and when it was 12-feet out, a temporary bulkhead of iron plates was built across it, braced against the end of the masonry. It was not a tunnel shield like those previously used by *Alfred Ely Beach* and English engineers; it had no hood, nor was it moved forward in one piece, so it was really no more than a temporary bulkhead. For the tunnel walls, shorter iron plates were used than in Jersey City and those against the roof were kept braced by timbers until the masonry was done (to keep them from deflecting). Laying of masonry was kept close to the working face and exposed earth was covered with silt brought over from Jersey City. By June 30th 1882, the north tunnel was 30-feet long and advancing. Work from Jersey City edged closer and by the middle of April 1882, the north tunnel was 839-feet long and the south tunnel about 500-feet. A new brick company opened in Jersey City, obtaining its raw material; Hudson River silt, from the tunnel excavation/s. By mid-May 1882, the north tunnel was 1K-feet long and 1,200-feet by mid-July 1882. Air pressure was now at 30psi. No more work was being done on the south tunnel. The New York side had advanced just 5-feet in two weeks. A report on August 15th 1882 gave progress for the week past of 20-feet in New Jersey and 15-feet in New York.



There was another blowout at the *New York* end on August 20th 1882, when part of the temporary bulkhead gave way. By this time the tunnel had an air-lock in it like those on the *New Jersey* side. The break was 65-feet from the caisson, but only 20-feet from the air-lock thus, all the men escaped. Oddly enough, this was followed ten days later by a blowout on the New Jersey side. Ferry passengers saw a waterspout shoot 10-feet into the air, about 1K-feet off-shore. The air had escaped from the unprotected heading of the tunnel and some of the iron plates fell at that point, but all the men got out safely. Colonel Haskin blamed it on insufficient caution on the part of the workmen. Water again invaded the New York end on October 9th 1882 (unfortunately, the tunnel had been located where a fresh water spring fed into the river). Now 70-feet in length, the tunnel filled rapidly. By the time they escaped, the workmen were up to their necks in water.

Left T&B: caption: "The blowout on August 20. From Scientific American, Sept. 2, 1882."

<u>Above</u>: caption: "Artist's conception of miners escaping into the air lock during the blowout in Haskin's tunnel"



"The work was never in as good shape as it is now. All there is of it is that the money that has been subscribed has been exhausted. The company does not propose to run in debt. Three-quarters of a million or more has been spent and a million or so more will be required to complete the north tunnel. If it had not been for my poor health, work would not have stopped at all. One thing is certain - the tunnel will be built. All the money that is needed can be obtained without any difficulty."

***Trenor Park,* November 1882**

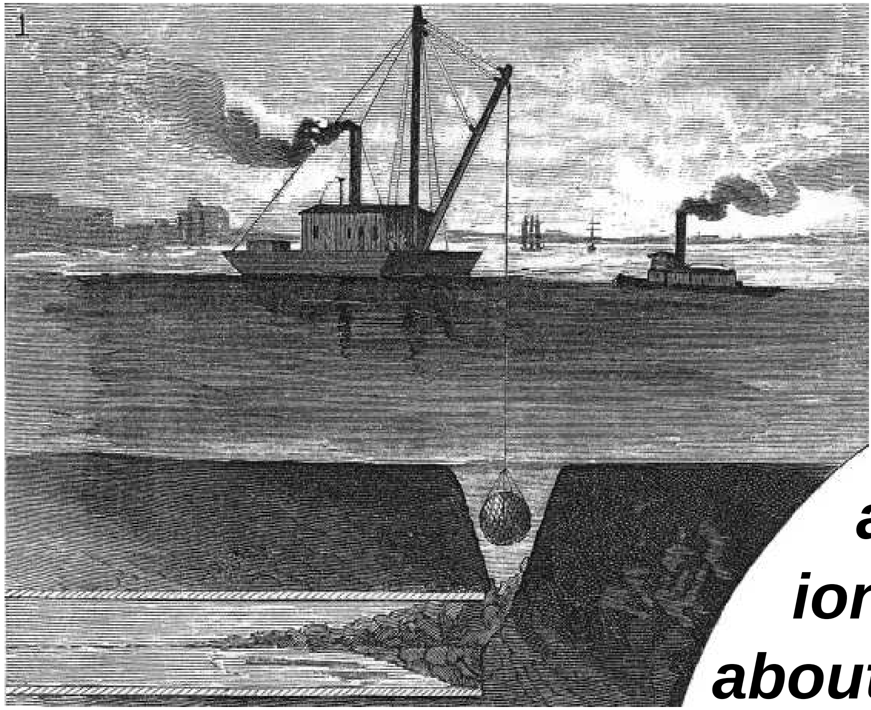
<u>Above</u>: caption: "The New York side by November 1882." Park was head of the construction company and the major fundraiser for the project. Work stopped on November 4th 1882; the tunnel company had run out of money. Almost all the men were discharged, but a few were kept on to build stone and wood bulkheads at the ends of the tunnel. The pumps were then shut-off and the tunnels were allowed to fill with water. Colonel Haskin gave the completed distance of the north tunnel as 1,542-feet from *New Jersey* and 75-feet from *New York* (out of a total 5,200-feet). The south tunnel ran 562-feet from New Jersey.

“The engine houses and workshops are deserted, the paint has become blistered by exposure to the sun and has fallen off in patches, giving the buildings the appearance of deserted barns.”

***The New York Times,* September 15th 1885**

RE: condition at *Morton Street*. Many accounts of the first Hudson tunnel attempt state that work stopped from 1882 to 1889, but there were two revivals during that time. Work was restarted at the *New York* side on April 22nd 1883. From this date, 72-feet was added to the north tunnel and the south tunnel was started for 23-feet. Work was suspended again on July 20th 1883 for lack of funds. A few watchmen were kept on. Colonel Haskin managed to raise some money and work started again on May 5th 1887, this time from the *New Jersey* side. The tunnels were pumped out and the air compressors were restarted and an elevator was installed in the shaft. Work was again in the north tunnel, at a pressure of 27psi. The tunnel was found intact after more than four years, but silt had forced its way in with the water and the pilot tunnel had drifted slightly northward. Exactly the same plan of work was resumed except that the masonry was now built four feet thick. Colonel Haskin predicted completion in 1889, but after 305-feet of tunnel had been built, money ran out again. Work stopped in September 1887.

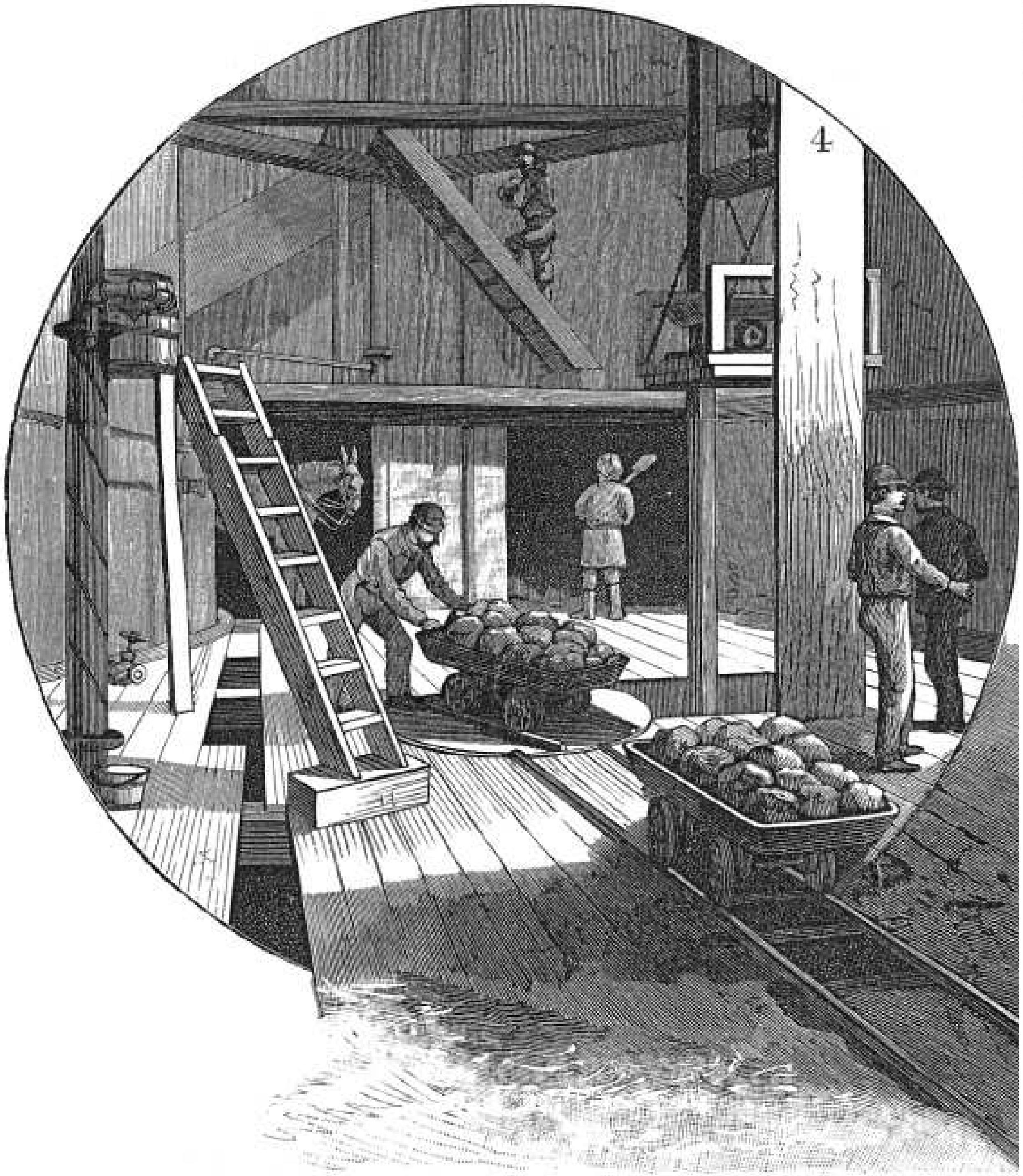
In 1888, Colonel Haskin interested some English investors in the project after having been reviewed favorably by the engineers of the *Firth of Forth* RR bridge (Fowler & Baker). A prospectus was circulated in *London* in February 1889 proposing to complete the north tunnel for £180K and the south tunnel for £250K, or a total of £550K for everything including the approaches and terminals. Plans were made for another start and in 1890 an English company was formed with *Sir John Fowler* and *Sir Benjamin Baker* as consulting engineers. The intention was to build two parallel tunnels. The original tunnel now was extended behind a shield eastwards towards *Manhattan* and work was begun on a twin (south) tunnel. An English engineer named *E.W. Moir* was assigned to the job by Baker in 1889. Construction had resumed, at first, following Haskin's old methods.

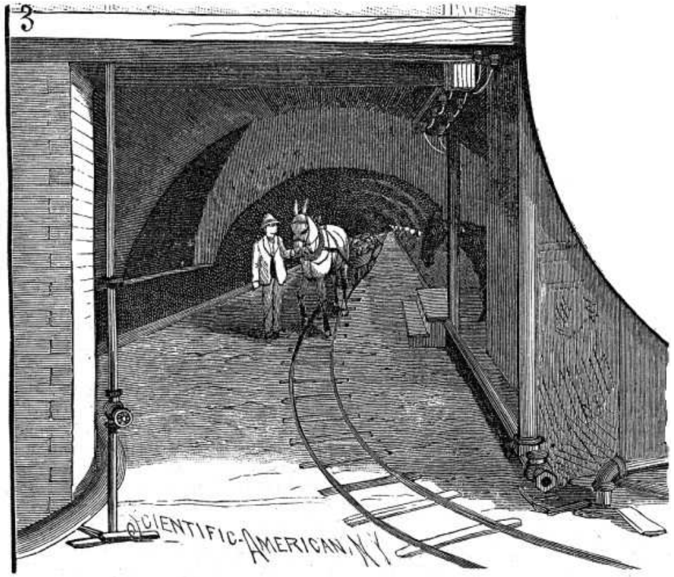


"Haskin continued for a short time after Sir Benjamin Baker made his report in 1888, in which Sir Benjamin staked his reputation on the completion of the work - a very bold thing to do for a man who had so great a reputation to lose…At that time there was about 200 to 250 feet of tunnel built beyond the last bulkhead, and Haskins had three collapses in 100 feet. The tunnel was full of something worse than slurry, the pilot tube was askew across the tunnel, and there was a hole 12 feet in diameter right through to the bed of the Hudson River. It was impossible to get near the face. After trying many expedients, a thing like a plum-pudding in a canvas cover, 12 feet in diameter, was put into the hole by means of a large floating crane."

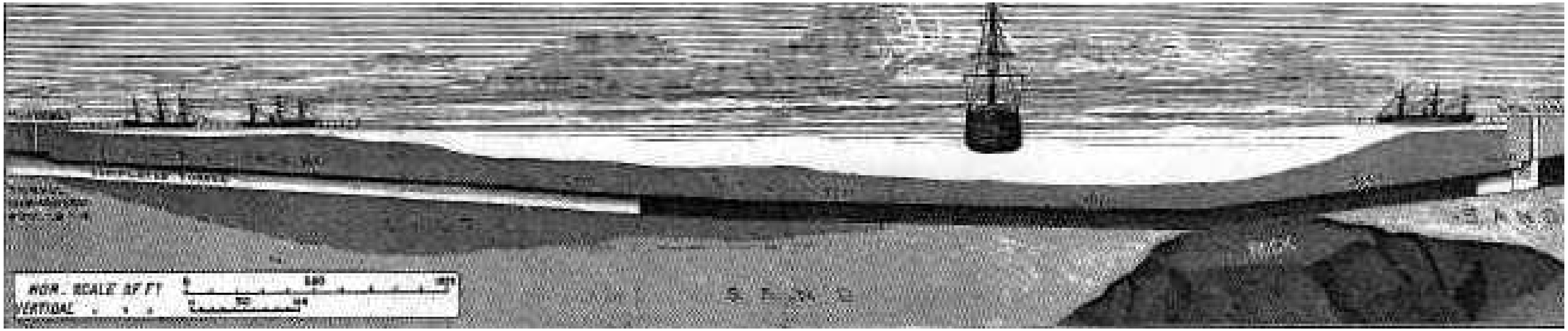
E.W. Moir, **Chief Engineer**

<u>Top Left</u>: caption: "Sinking the 'plum-pudding' to fill the hole. From SA, Sept. 7, 1889"





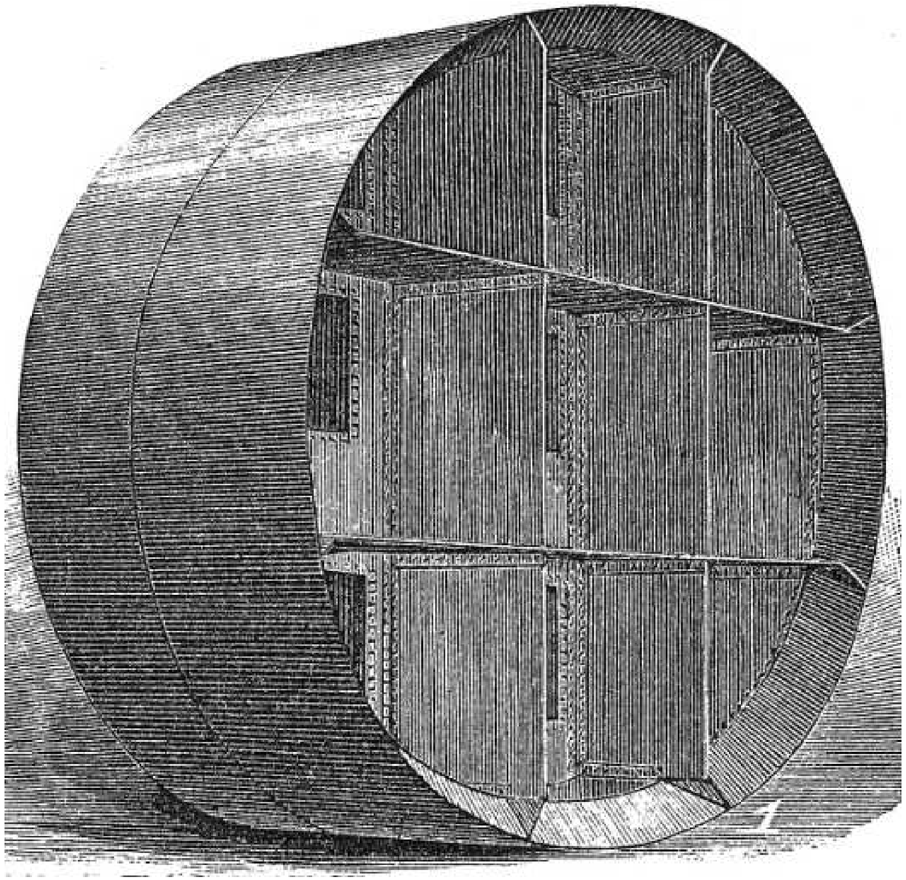
<u>Above & Left</u>: caption: "Views at the Jersey City shaft. From Scientific American, September 7, 1889."



"The erection of the shield began early in 1890, and by July, under a pressure of about 40 pounds per square inch, it had been riveted up and put through the temporary bulkhead…On first commencing to push the shield there was great difficulty in preventing the tunnel from becoming a shaft. The ground was exceedingly soft, due to the eruptions of air to the river and other disturbances, and the sinking of the shield was very considerable."

E.W. Moir, **Chief Engineer**

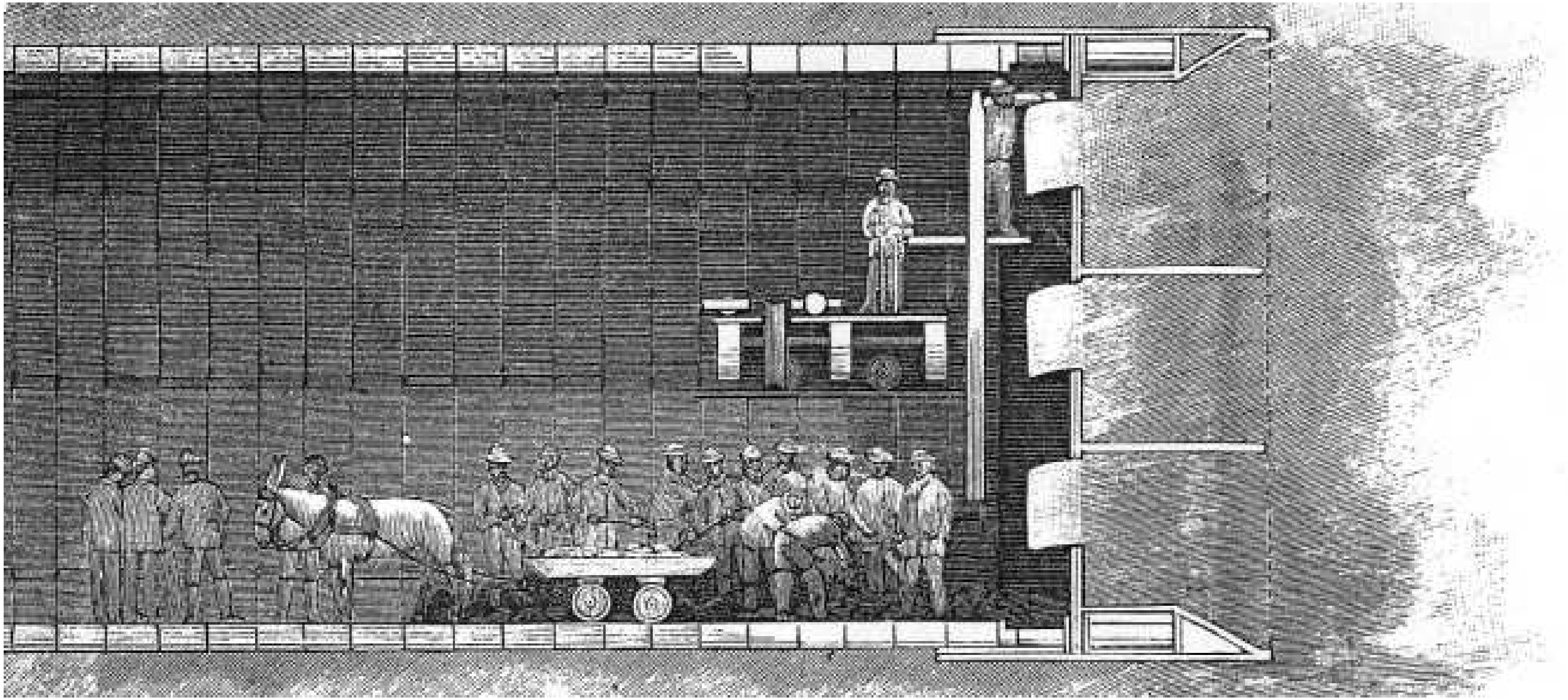
<u>Above</u>: caption: "Profile of the tunnel showing how much of the north tunnel was built by Haskins' method without a shield. From Scientific American, January 11, 1890." In November 1889, a contract was signed between Colonel Haskin and the English engineering firm of *Samuel Pearson & Son* to carry on construct-ion. Pearson cut away the bottom of the plum-pudding and there they made a chamber to put together a shield that was imported from *Scotland*. This work was done in December 1889.



"But as an engineering precaution, and to assist in the more rapid prosecution of the work, the Beach hydraulic shield has been introduced. Furthermore, iron plates much thicker and stronger than those before used have been adopted for the outer walls of the tunnel. Our readers are familiar with the history of this form of shield. It was designed and first constructed by Mr. A.E. Beach, one of the editors and proprietors of the SCIENTIFIC AMERICAN. It was first used in constructing a short section of the projected Broadway underground railway in this city, 1868-1869."

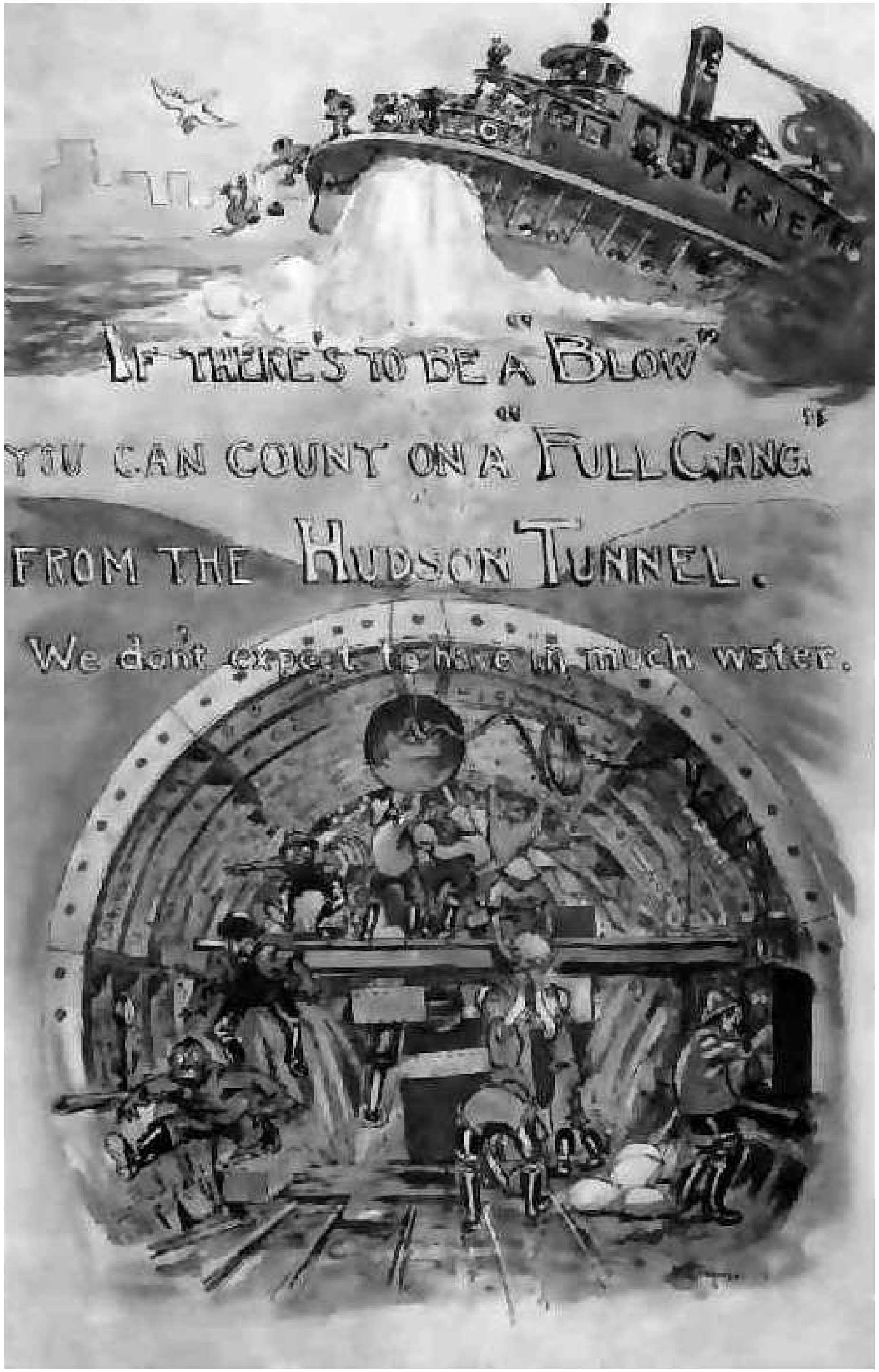
Scientific American, **January 11th 1890**

<u>Left</u>: caption: "A perspective view of the shield"



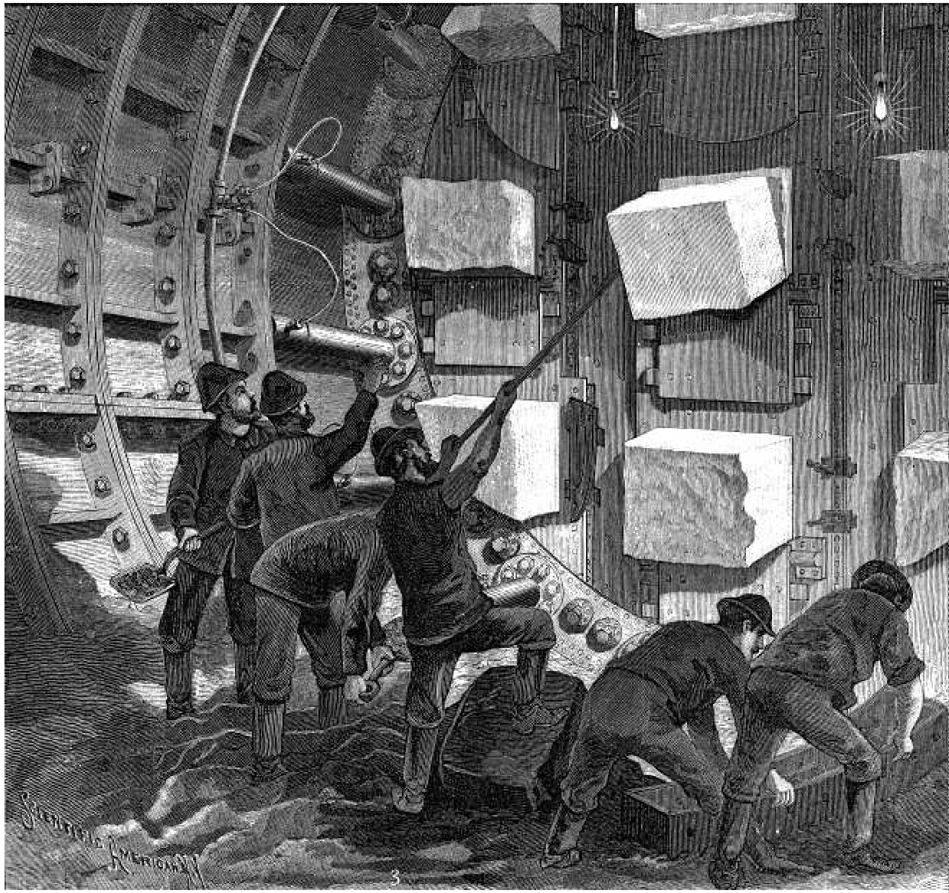
As in the *Beach Pneumatic Tunnel*, the hydraulic jacks could be worked separately to force the tunnel into the alignment desired. English sources called it a "Greathead Shield" (rather than a "Beach Shield"). *James H. Greathead* had been assistant engineer on the *Thames Tunnel* which was built about the same time as the Beach Pneumatic Tunnel in NYC. He developed what became known as the *Greathead Shield* in 1874, incorporating Beach's use of hydraulic jacks as well as additional patent devices for working under compressed air. However, the project for which he developed it (a Thames tunnel at *Woolwich*), was never realized.

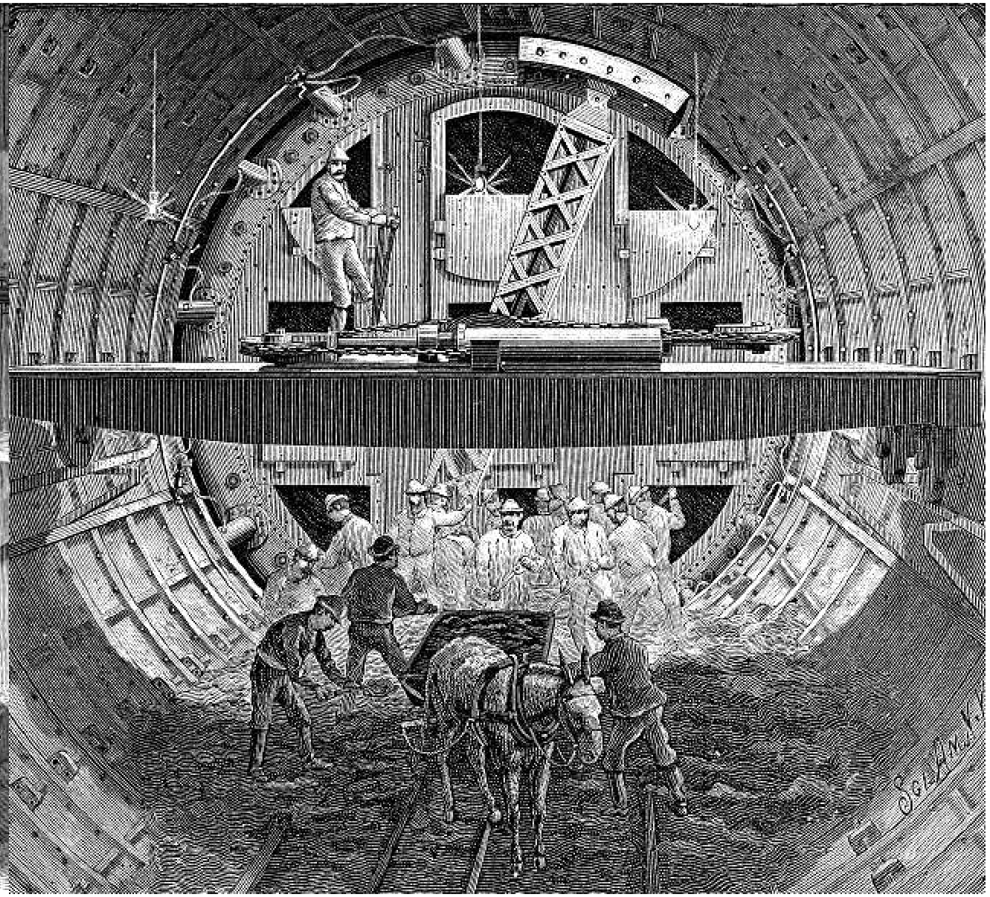
Above: caption: "Longitudinal cross section of the end of the tunnel with the shield in use. From Scientific American, January 11, 1890."



Thus, Colonel Haskin became the first person to build a major tunnel with compressed-air. At the time Pearson took over the *Hudson Tunnel*, Greathead was nearing completion of the first tube railway; the *City and South London*, built from 1886 to 1890 using the *Greathead Shield* for all of the work. Pearson's engineers found that the silt was so fluid that it did not have to be dug out. When the six hydraulic jacks forced the shield forward, the silt flowed through the doors in the shield, extruded in the shape of the doors for a few feet before it broke off and fell to the floor. The workmen had only to cart it away. After a years' work, by November 1890 the north tunnel ran for 1,250-feet outside the first air-locks and about 1K-feet beyond.

<u>Left</u>: caption: "If there's to be a 'Blow' you can count on a 'Full Gang' from the Hudson Tunnel. We don't expect to have in much water."





<u>Left</u>: caption: "The silt being extruded through the doors as the shield is pushed forward. Fine detail here of the pipes to the hydraulic jacks around the edge of the shield, the doors opening downward, and the heavy iron plates of the finished tunnel on the left. Light bulbs had replaced the arc lights. From *Scientific American,* January 11, 1890."

<u>Right</u>: caption: "A wider view shows the complete shield and the work platform that rolled on temporary rails mounted on the tunnel sides. The mule is ready to take a cartful of silt away on the work railway. Both from *Scientific American*, January 11, 1890."

“…the Beach hydraulic shield is advanced the width of one of the rings in eight minutes, a progress formerly requiring from 2 to 4 hours. Formerly, the great trouble was in getting the shield ahead; at present the great obstacle is getting away the excavated silt fast enough. A system of chutes is soon to be tried…The company hope to record ten feet a day when these changes are completed.”

***Scientific American,* January 3rd 1891**

RE: at the start of 1891, the north tunnel was 2,720-feet long and progressing at about 7-feet per day. By June 1891, the north tunnel was about 3,800-feet in length. By this time, the company’s president was *William Sooy Smith*, the engineer who had quit in 1882 because Colonel Haskin had ignored his advice. The company’s attorney; *John Dos Passos*, predicted completion in 1893. The tunnel was now at the middle of the river and getting closer to the riverbed. On June 18th 1891, Pearson requested permission of the *War Department* to dump clay into the river to make sure that there was at least 20-feet of solid material over the top of the tunnel (the tunnel profiles indicated as little as 5-feet of earth over the tunnel). The plan was approved in July 1891.

“The question of motive power to be used in the tunnel has been one of the most important which we have been called upon to solve. In connection with the railroads, we have considered every conceivable plan of motor, and we are now convinced that we will be able to use electricity.”

***John Dos Passos,* Tunnel Company Attorney**

RE: the first main-line railway electrification; the *Baltimore & Ohio’s* tunnel at *Baltimore*, opened in 1895. It proved the viability of the use of electric motive power for trains in tunnels.

"…In 1890 the new company, after pushing the tube one thousand, eight hundred feet further along toward New York, fell into bankruptcy, and work was again stopped. Colonel Haskins, unable to secure more capital for his enterprise, abandoned the project, and the unfinished work lay all but forgotten under the waters of the majestic Hudson…"

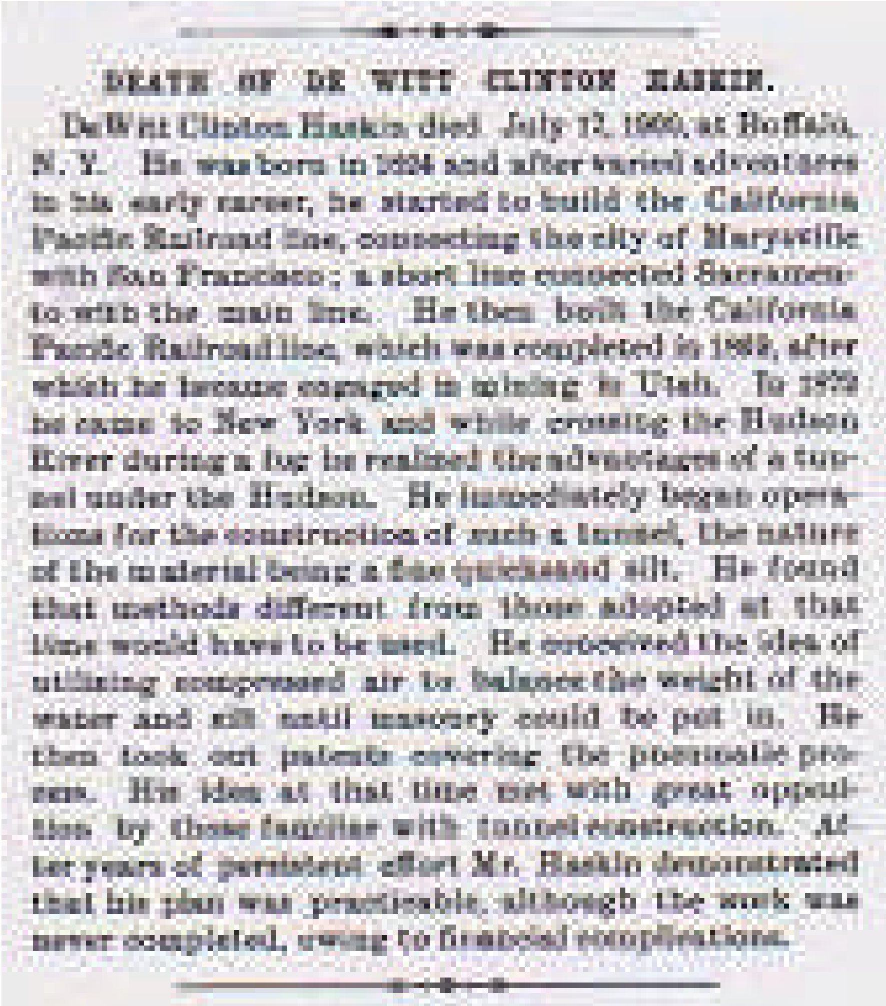
RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story.* After building 1,800-feet additional, the company again failed (in 1892) This tunnel was eighteen-feet in diameter, one-half brick and one-half iron. At the time the work commenced, there had been little experience in the construction of such a tunnel and with the difficult conditions that existed, the work was inherently dangerous and expensive. Over $4 million was spent in the prosecution of the work. A panic and financial crisis turned off the flow of investment from European capitalists and the trans-Hudson tunnels were again abandoned after the north tube had reached 3,916-feet from the *Jersey City* shore and an additional 160-feet from the *Manhattan* shore. Its twin (south) tube had reached a length of 570-feet.

"It's all bosh. It doesn't amount to a snip of the finger. The whole trouble is caused by these Englishmen. They have tried as usual to grab everything in sight…Their greediness in connection with the Hudson Tunnel Railway Company has brought the company to its present unfortunate position. They've mismanaged things and squandered money and quarreled among themselves."

Colonel Haskins, October 1891

RE: after going well, worked had stopped in October 1891 when the collapse of the *Barings Brothers* banking firm in *England* caused the panicked English investors to drop out. Contractor *Pearson & Son* put a mechanic's lien on the company's property, but Haskins claimed that they owed the company for work not performed. In any event, the work had come to a complete halt. For several years (starting in late 1891) the Hudson Tunnel was in litigation. The holders of the first mortgage met in *London* in April 1893 and decided that if they raised $1 million they could complete the tunnel. The north tunnel was about 4K-feet long from *New Jersey* and needed just 1,500-feet to reach the 150-feet built from *New York*. However, this last part included a section through rock near the *Manhattan* shore.

In July 1893, *Pearson & Son* asked the *Court of Chancery* in *London* to appoint a receiver. In the meantime, in 1895 Pearson sent engineer *Charles M. Jacobs* to evaluate the tunnels and, at that time, they were pumped out. Jacobs reported the north tunnel to be in good condition. At the end of 1895, attorney and financier *John Dos Passos* suggested to the press that the company might soon be reorganized and work restarted. The suits continued to wind through the courts in *New Jersey*. Finally, the New Jersey property was foreclosed on June 15th 1899 to the only bidder; *Frederic B. Jennings* of *Stetson, Jennings and Russell* (attorneys for the American bondholders) for just $300K (subject to a lien of $62K by Pearson &Son). The next day, the *New York* property was foreclosed to Jennings for $100K. Jennings paid Pearson the lien amount and ownership was now secure. *DeWitt C. Haskin* died on July 17th 1900, never to see the completion of the *Hudson Tunnel*.



DEATH OF DE WITT CLINTON HASKIN.

DeWitt Clinton Haskin died July 17, 1900, at Buffalo, N. Y. He was born in 1834 and after varied adventures in his early career, he started to build the California Pacific Railroad line, connecting the city of Marysville with San Francisco; a short line connected Sacramento with the main line. He then built the California Pacific Railroad line, which was completed in [illegible], after which he became engaged in mining in Utah. In 1872 he came to New York and while crossing the Hudson River during a fog he realized the advantages of a tunnel under the Hudson. He immediately began operations for the construction of such a tunnel, the nature of the material being a fine quicksand silt. He found that methods different from those adopted at that time would have to be used. He conceived the idea of utilizing compressed air to balance the weight of the water and silt until masonry could be put in. He then took out patents covering the pneumatic process. His idea at that time met with great opposition by those familiar with tunnel construction. After years of persistent effort Mr. Haskin demonstrated that his plan was practicable, although the work was never completed, owing to financial complications.

"…DeWitt Clinton Haskin died July 17 1900, at Buffalo, N.Y…In 1872 he came to New York and while crossing the Hudson River during a fog he realized the advantages of a tunnel under the Hudson. He immediately began operations for the construction of such a tunnel, the nature of the material being a fine quicksand silt. He found that methods different from those adopted at that time would have to be used. He conceived the idea of utilizing compressed air to balance the weight of the water and silt until masonry could be put in. He then took out patents covering the pneumatic process. His idea at that time met with great opposition by those familiar with tunnel construction. After years of persistent effort Mr. Haskin demonstrated that his plan was practicable, although the work was never completed, owing to financial complications."

Scientific American, **August 18th 1900**

Part 3

Hudson & Manhattan

Master Mind

"…In 1901 there came from Chattanooga, Tenn., to New York a young man who had been born in Marietta, Ga., thirty-eight years before. He was unknown to fame, to finance, to engineering, and he, at that time, had no intention of abandoning his career in the practice of law. But one day William Gibbs McAdoo being called to Hoboken on business, was much vexed by the delays occasioned by a river full of craft of every conceivable description trying to feel their way through an almost impenetrable sea of fog. Thus delayed his thoughts were turned to the necessity for some more safe and rapid method for transacting business across the Hudson. So in his moments of leisure – perhaps at first from a mere sense of curiosity – he began to investigate the now abandoned tunnel…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

"…He found that its franchise had yet about twenty-five years to run, and that both franchise and uncompleted tunnel could be bought for a song. The more he considered the project, the more convinced he became that the tunnel was an absolute necessity; that it should be completed; that the public demanded just such relief as it and it alone could afford. He also realized that it was a stupendous engineering feat the difficulties of which could only be surmounted by modern methods. In a casual way from time to time, he consulted with the master minds of the engineering world, and found that, if the necessary capital was supplied, the tunnel could be completed…"

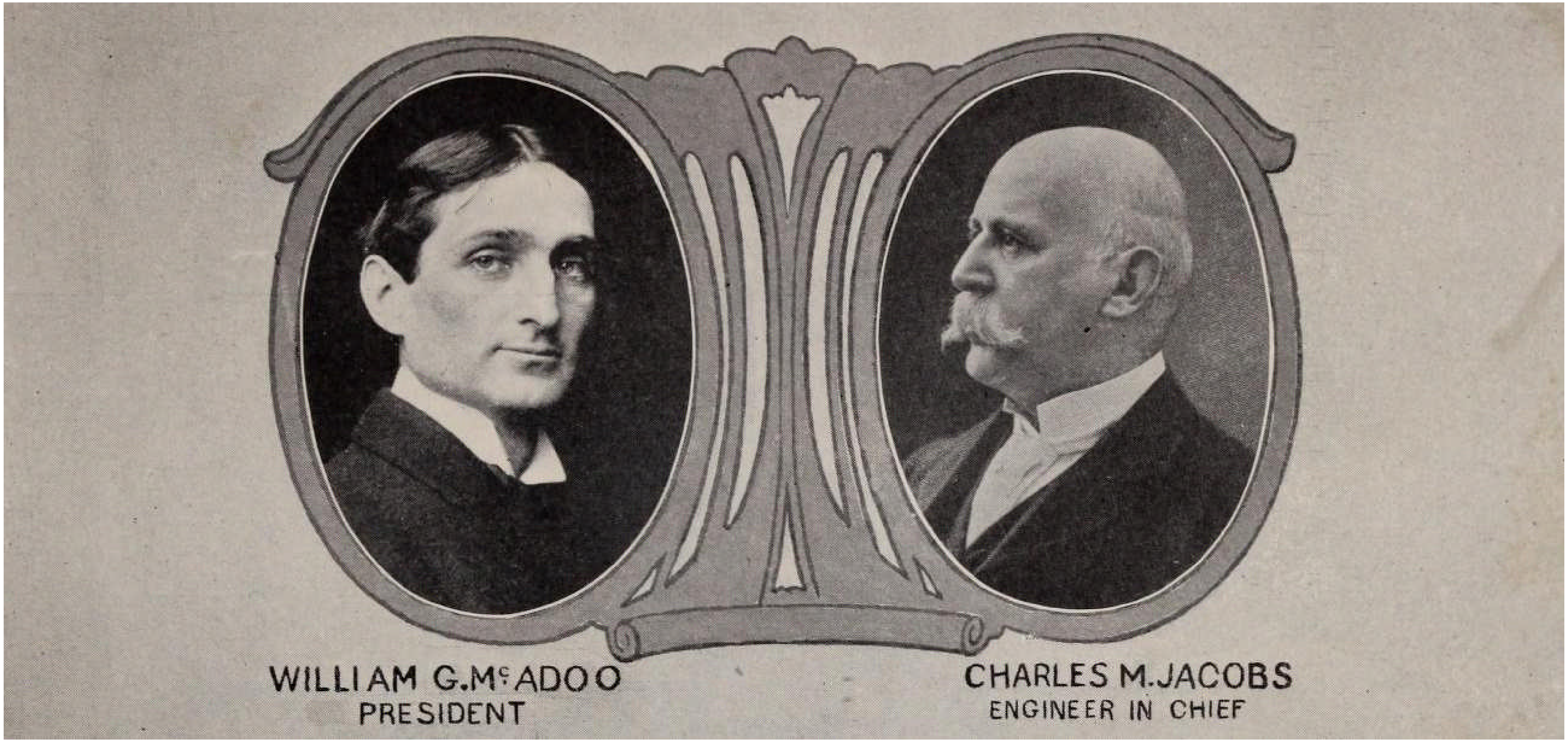
RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

Left: *William Gibbs McAdoo*

"…Then this master mind set about to interest capital to complete the tube, but the capital he sought was not to be of the 'high-finance' kind. He believed his enterprise to be a legitimate, conservative business proposition, and therefore endeavored to interest only conservative capitalists and investors in the undertaking. He unfolded his plans and needs to Pliny Fisk and William M. Barnum, of the financial firm of Harvey Fisk & Sons in such a straightforward and business-like way as to win the confidence and cooperation of these masters of conservative banking, among whose clients are numbered many of the country's richest conservative investors. The young lawyer convinced the bankers of the possibility, the urgent necessity, and the profitable income to be derived from an investment in these tunnels and they undertook the financing of the enterprise…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story.* In 1901, *W.G. McAdoo* entered into negotiations with the *Bondholders Re-Organization Committee*. McAdoo presented a plan for the completion of the single eighteen-foot diameter tunnel, which was to contain two tracks and be operated with narrow-gauge cars of special design and was to run from the *Lackawanna Station* in *Hoboken, N.J.* to a terminal at *Ninth Avenue* and *Christopher Street, New York.*

The Tunnel Companies



"…The New York and New Jersey Tunnel Company was organized in February, 1902, to take over the title, franchise and other interests in and to the long-defunct preceding companies. The new company purchased new and modern machinery and equipment, secured the services of the best engineering talent the country could afford, and quietly but honestly set to work to finish the tunnel under the Hudson from Hoboken to Morton Street, New York…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story.* Upon the organization of the tunnel company in 1902, *W.G. McAdoo* was elected President, *Walter G. Oakman* was elected VP and *Charles M. Jacobs* was elected as Chief Engineer.

In February 1902, construction resumed on the tunnels; now designed for electric-powered trains. In addition to the twin tubes already begun (the "Hoboken-Morton Tunnels" which, upon completion, were 5,650-feet in length and 97-feet below the river surface), there was also a new and expanded system planned including three additional pairs of tube tunnels:

• A second set of twin tubes running under the *Hudson River* from lower *Jersey City* to lower *Manhattan* (a.k.a. "Montgomery-Cortlandt Tunnels" - 5,976-feet long and 92-feet below the river surface;

• A pair of tube tunnels in *New Jersey* connecting three major railroad terminals in *Hoboken* and Jersey City; (the *Central Railroad of New Jersey/B&O/Reading Terminal*), and;

• A tunnel extension in Manhattan to both *Grand Central Terminal* and *Pennsylvania Station* (which was still under construction and which was to replace the *Jersey City Pennsylvania Station* as the PaRR's principal *New York* station) along with a spur to the just-opened IRT subway.

As well, there was to be an above ground segment running westward from Jersey City to *Manhattan Transfer* and *Newark* for connections with the PaRR's lines to *Chicago, St. Louis* and *Washington D.C*.

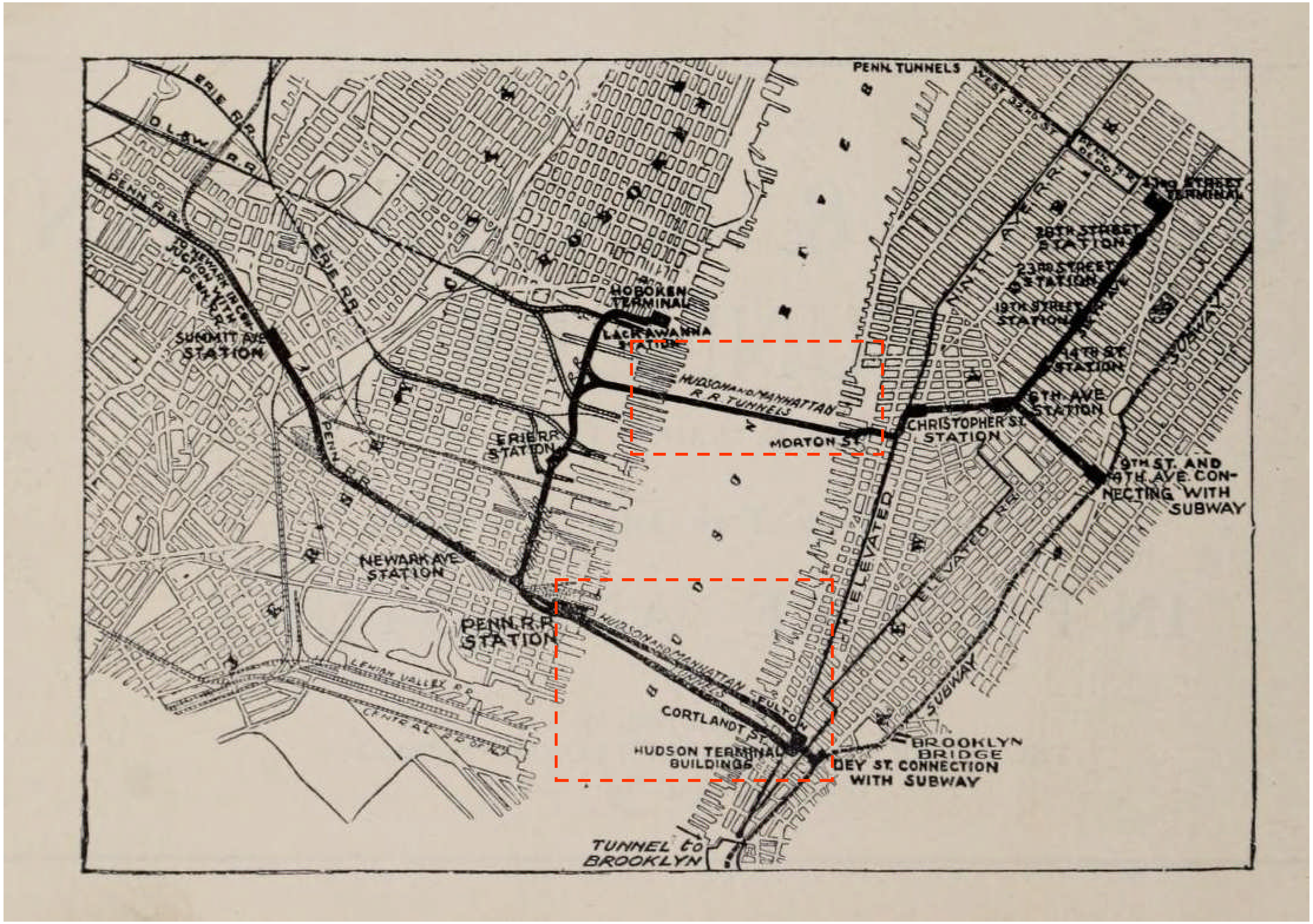
"…The New York and New Jersey Tunnel company was organized and financed merely to complete the old tunnel, so for the construction of additional tunnels and terminals, a new company had to be formed, and that company was the Hudson and Manhattan Railroad Company, which was organized in May, 1904, with William G. McAdoo, as president…"

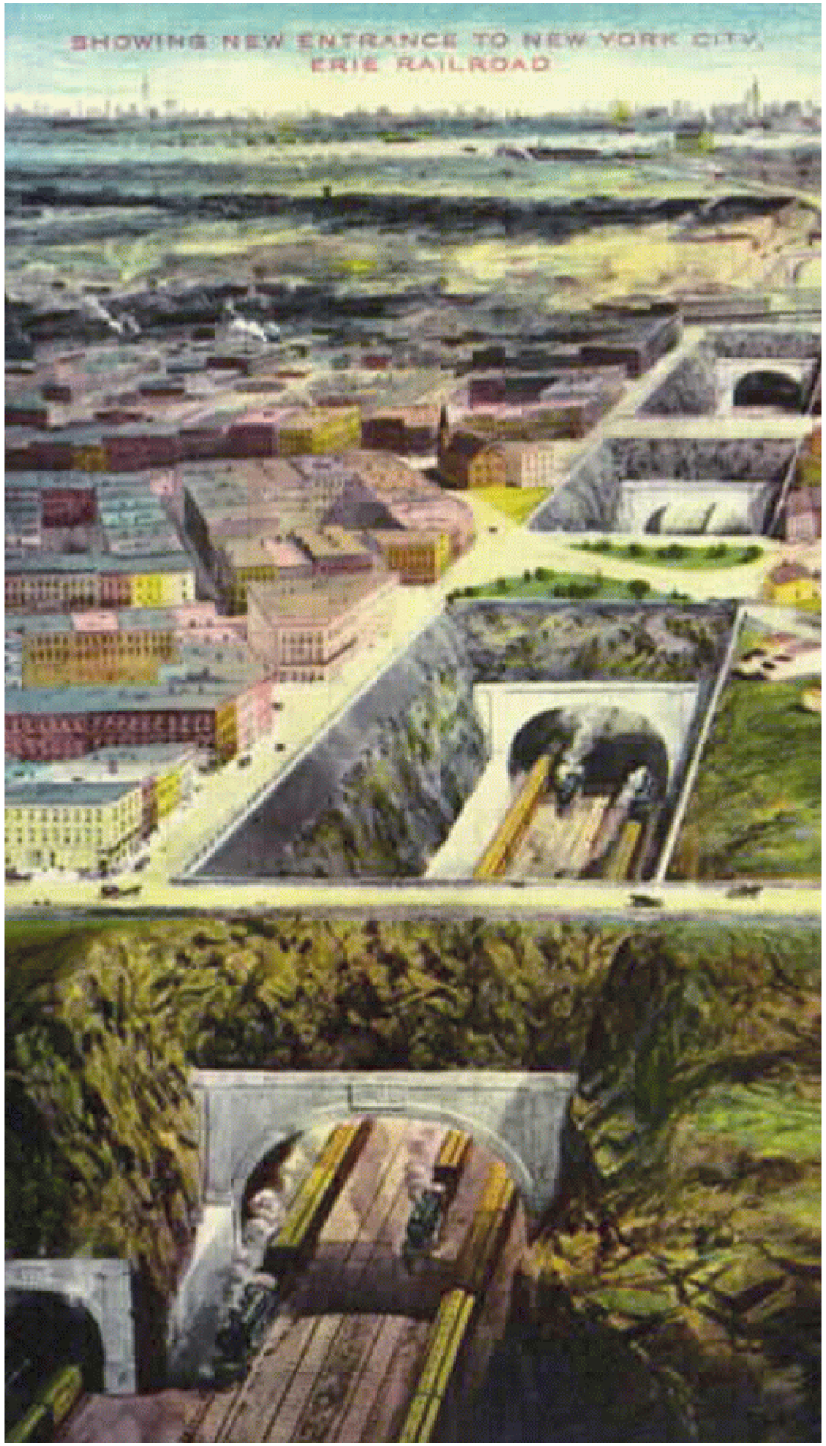
RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story.* The H&MRR's promoters noted that there would be a major economic gain for *New Jersey* in residential real estate. Because of the geographic and financial constraints of *Manhattan Island,* less than 5% Manhattan of residents owned their own home. As such, it was believed that the H&MRR, with its connections to commuter railroad lines, would open home ownership to thousands of Manhattan workers creating a residential land boom in New Jersey.


2943
100
HUDSON & MANHATTAN RAILROAD
COMPANY

These McAdoo Tunnels

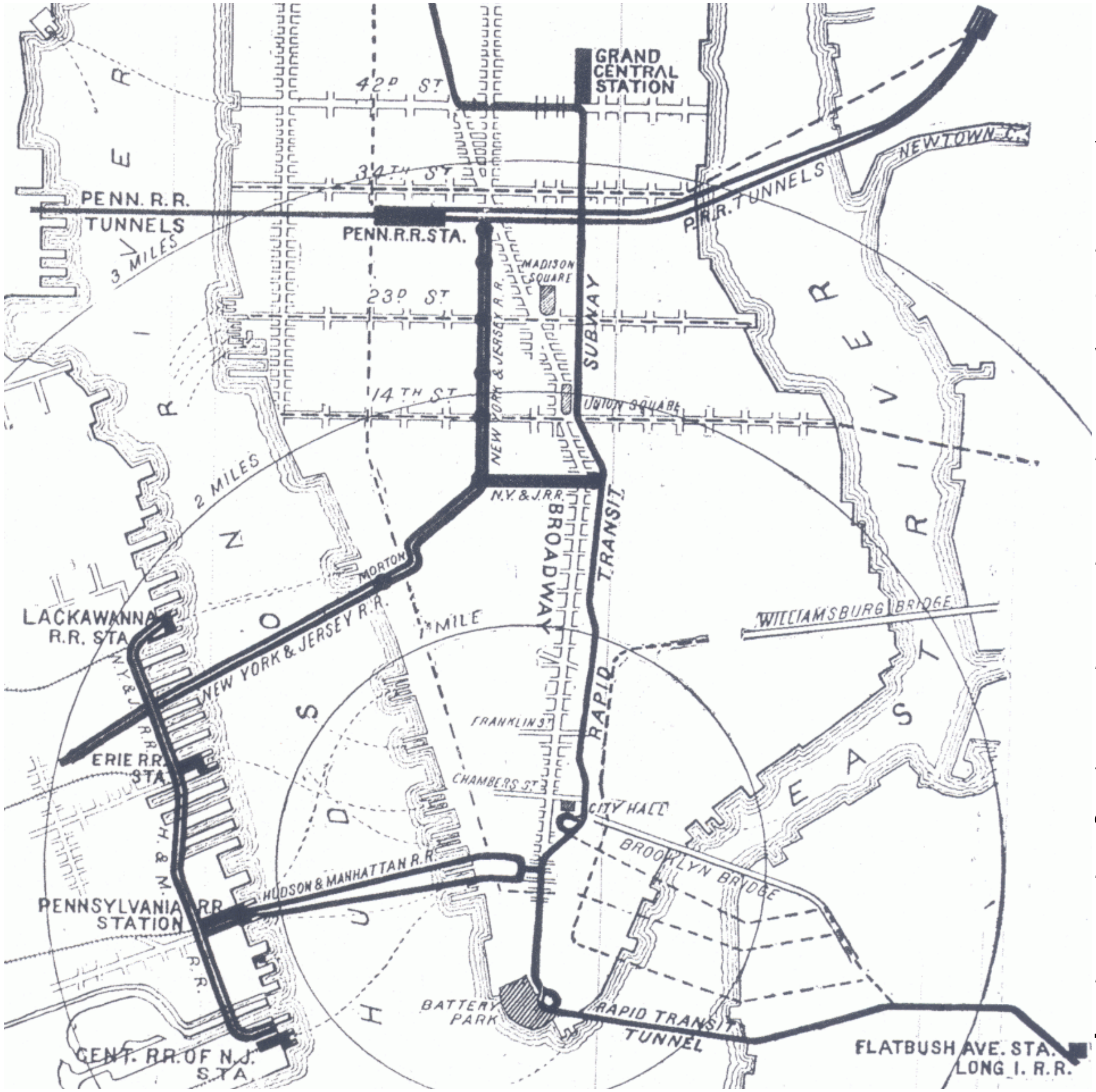
The tunnel, as originally planned, was to have been a single tube from *Hoboken* to *Christopher Street* and *Ninth Avenue* in *New York* - a distance of two miles. The original plan was for the *Hudson Companies* (one of the group of McAdoo firms involved in building and operating the H&MRR) to take over operation of the *Jersey City* PaRR station when *Pennsylvania Station* in *Manhattan* went into operation. Under these plans, (from ca. 1903), PaRR traffic to downtown would transfer at *Harrison* to the Hudson Companies' H&MRR tubes and the Hudson Companies were to operate all conveyances (ferry, trains etc.) between lower Manhattan and *Newark, NJ*. By the time *Penn Station Manhattan* opened (1910), the plans had been changed. The PaRR kept operating to lower Jersey City and kept running its *North* (*Hudson*) *River* ferries. The route between *Summit Avenue/Journal Square* and *Newark* became a joint operation of the H&MRR and the PaRR.


PENN. TUNNELS
ERIE R.R.
D. L. & W. R.R.
PENN. R.R.
SUMMIT AVE STATION
HOBOKEN TERMINAL
LACKAWANNA STATION
HUDSON AND MANHATTAN R.R. TUNNELS
MORTON ST.
CHRISTOPHER ST. STATION
ERIE R.R. STATION
NEWARK AVE STATION
PENN. R.R. STATION
LEHIGH VALLEY R.R.
CORTLANDT ST.
FULTON
HUDSON TERMINAL BUILDINGS
DEY ST. CONNECTION WITH SUBWAY
BROOKLYN BRIDGE
TUNNEL to BROOKLYN
33RD STREET TERMINAL
28TH STREET STATION
23RD STREET STATION
19TH STREET STATION
14TH ST. STATION
6TH AVE. STATION
9TH ST. AND 4TH AVE. CONNECTING WITH SUBWAY
ELEVATED
SUBWAY



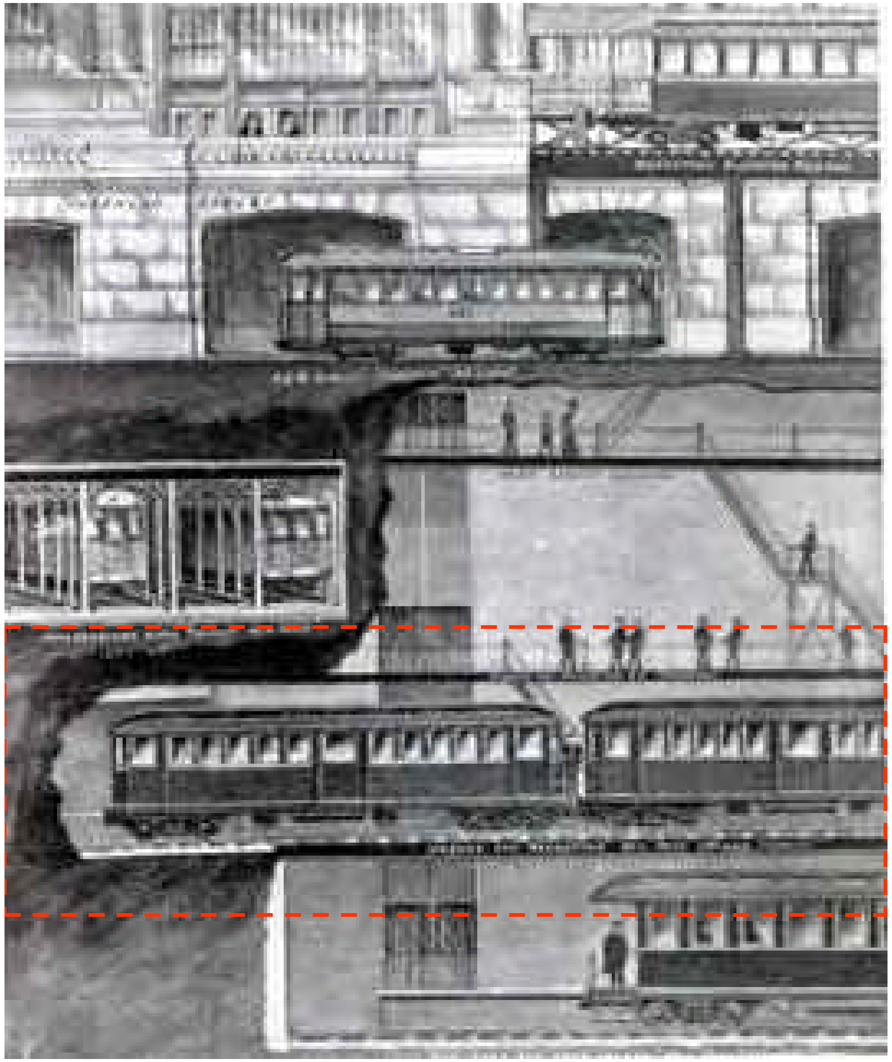
A short time after the *NY & NJ Tunnel Company* was formed in 1902, McAdoo became convinced that the operation of a single tunnel (with narrow-gauge cars) would be insufficient. Thus, a second tunnel; parallel to the first, was undertaken. He also became convinced that tunnels under the *Hudson River* would be not be satisfactory unless a system was provided by which the passengers could be landed into the downtown district of *New York City* as well as the uptown district. With this in mind, a new tunnel system was planned to extend from *Hoboken*, through the *Erie* and *Pennsylvania Railroad* stations in *Jersey City*, then cross the river to a terminal station at *Cortlandt* and *Church Street/s, New York*. It was also planned to extend the uptown tunnels from *Ninth Avenue* and *Christopher Street* to *Sixth Avenue* and *Thirty-Third Street* (also from *Ninth Street* and *Sixth Avenue* to a connection with the Subway at *Fourth Avenue*).

Left: caption: "Showing New Entrance to New York City, Erie Railroad"



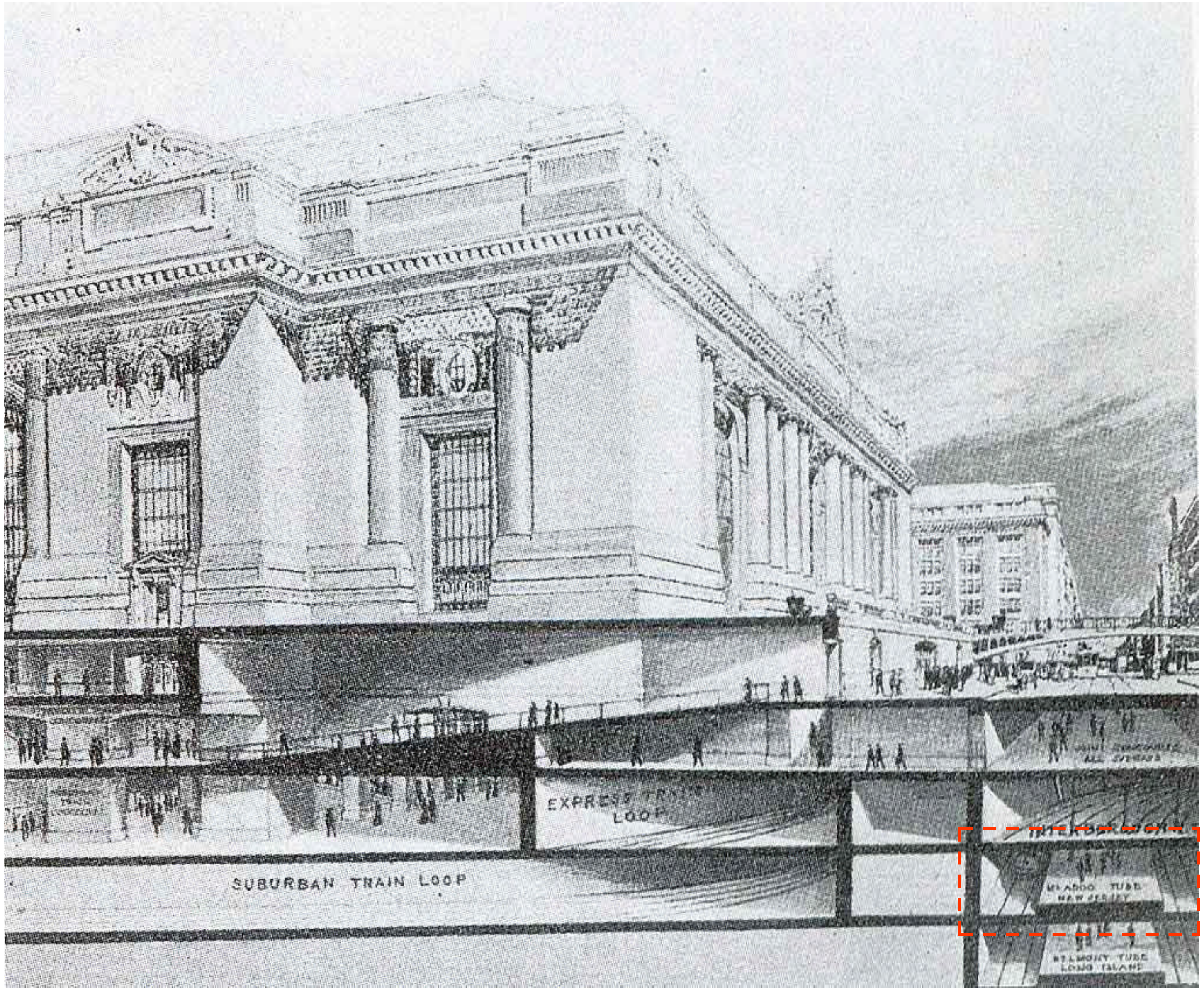
"…These 'McAdoo' tunnels enter Manhattan Island at the foot of Christopher street, where they connect with a subway constructed and operated by the Hudson and Manhattan company, extending up Christopher street to Sixth avenue, thence north to Thirty-third street, where connection will be effected with the mammoth terminal station now in course of construction for the Pennsylvania and Long Island System. There are way stations on Christopher street at Ninth and Sixth avenues, allowing close connection with the west-side elevated systems of the metropolis…"

<u>Left</u>: caption: "Map showing the New Jersey Tunnels and Subway and their Relation to the Rapid Transit Subway"



McAdoo organized the *Hudson & Manhattan Railroad Company* to build the downtown tunnels and entered into an arrangement with the *Pennsylvania Railroad Company* for terminal facilities in *Jersey City* and for the Pennsylvania Railroad Company's cooperation (without which the downtown section could not have been constructed). An extension from *Thirty-third Street* and *Sixth Avenue* to *Grand Central Station* was planned and a franchise obtained for its construction, but it was never realized.

<u>Left</u> : caption: "Sketch plans for Grand Central Terminal show the Hudson and Manhattan Rail Road and the 'McAdoo Tunnels' on the second underground level below its own concourse, above the 'Belmont Tube' / Steinway Tunnels (later the IRT Queensboro line)"


SUBURBAN TRAIN LOOP
McADOO TUBE
BELMONT TUBE

Uptown Tubes

The shield used by *Pearson & Son* (in the first tunnel attempt) was still at the end of the north tunnel and it was used to complete the job. The tunnel began to advance in October 1902 and reached the reef of rock (on the *Manhattan* side) in November 1902. During blasting there were two blowouts. They were stopped by dropping clay over the tunnel from scows in the river. After the rock was passed, the tunnel entered a very fluid area of silt. Five barges of clay were dumped over it and the clay was fired from within the tunnel to bake it hard. Finally, on March 11th 1904, the tunnel met the bulkhead of the short tunnel built years earlier from the *New York* side thus, the first tunnel under the *Hudson River* had been completed. A party of twenty officials walked through from *Jersey City* to New York by way of the shafts and the air locks (parts of the tunnel were still under air pressure). In the ceremonies that day, H&MRR President McAdoo thanked the two-hundred workmen and gave them two days off with pay in gratitude for their efforts.

"At the deepest part of the river near the New York side a ledge of rock was encountered at the bottom of the river. This ledge was only twelve feet high while the tunnel was eighteen feet. The problem that was presented was having to build the bottom of the tunnel through rock and the top through silt and at the same time support a river more than one mile wide and sixty-two feet deep, with a cover of only fifteen feet of silt between the top of the tunnel and the bottom of the river. It was necessary to blast the rock in the bottom and hold the silt at the top. This problem was considered so serious that for many years doubts have been entertained by eminent engineers as to whether or not it was possible of solution. This was, however, solved by the chief engineer, Mr. Charles M. Jacobs, and inside of a year the eight hundred feet of rock had been blasted out and the successful construction of the tunnels under the Hudson River was assured."

W.G. McAdoo

<u>Left</u>: caption: "Where the north tunnel holed through, under the river near the New York side. In the foreground is the end of the short tunnel built west from the Morton St shaft up to 1883. Beyond is the tunnel completed in March 1904 from Jersey City. The alignment had to be projected from a mile away and is almost perfect. The shield has just been removed, but the work platform is still in place. The men are cutting back some of the brick lining to complete the joining (this space was still under pressure)."

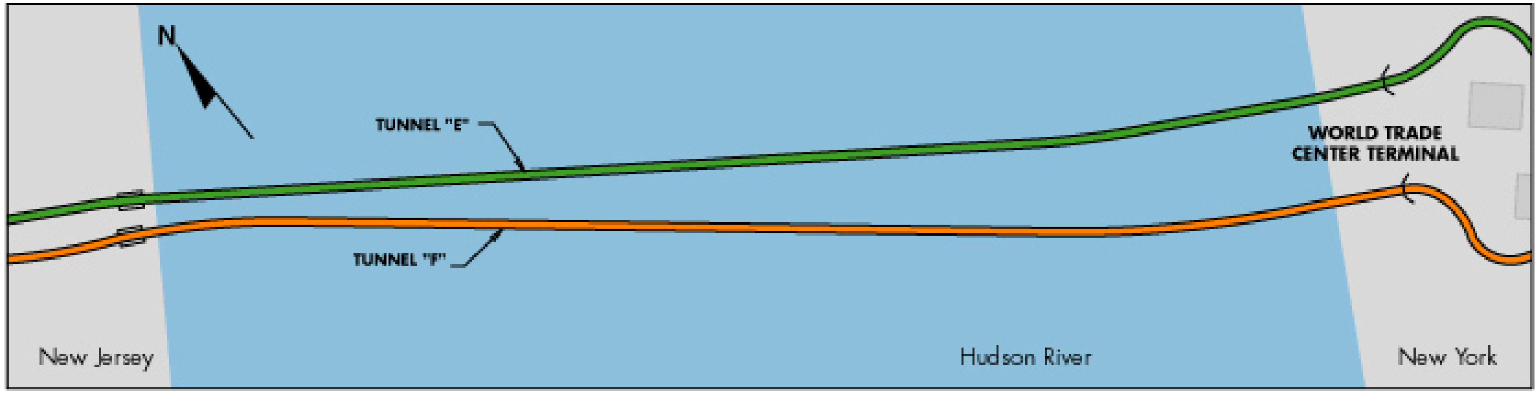
On January 4th 1908, the first special train ran through the H&MRR's uptown (original 1874) brick-lined tunnel between *Hoboken* and *Christopher Street*. On Saturday, January 25th 1908, there was a test-run through the southern uptown tunnel (a.k.a. "Hoboken to 8th Street Tunnel") which was made of tubular cast-iron. At midnight on Friday, February 25th 1908, the H&MRR ran its first service through the uptown pair of tunnels to the temporary end-of-the-line at *19th Street* in *Manhattan*. Using a telegraph connection, POTUS *Theodore Roosevelt*, from the *White House*, turned on the power at 3:30PM. Simultaneously, one train started out from *19th Street* carrying the *New York State* governor while another train started from *Hoboken* carrying the *New Jersey State* governor. The subway system was officially open to the public. When the uptown tunnel/s, each of whose two tubes had a diameter of 15-feet 3-inches, was finally completed, it was a double tube 5,650-feet long (between shafts) and reached a maximum depth of 97-feet below the *Hudson River*. The estimated cost of the project was $55 million, but, in the end, turned out to be closer to $60 million.

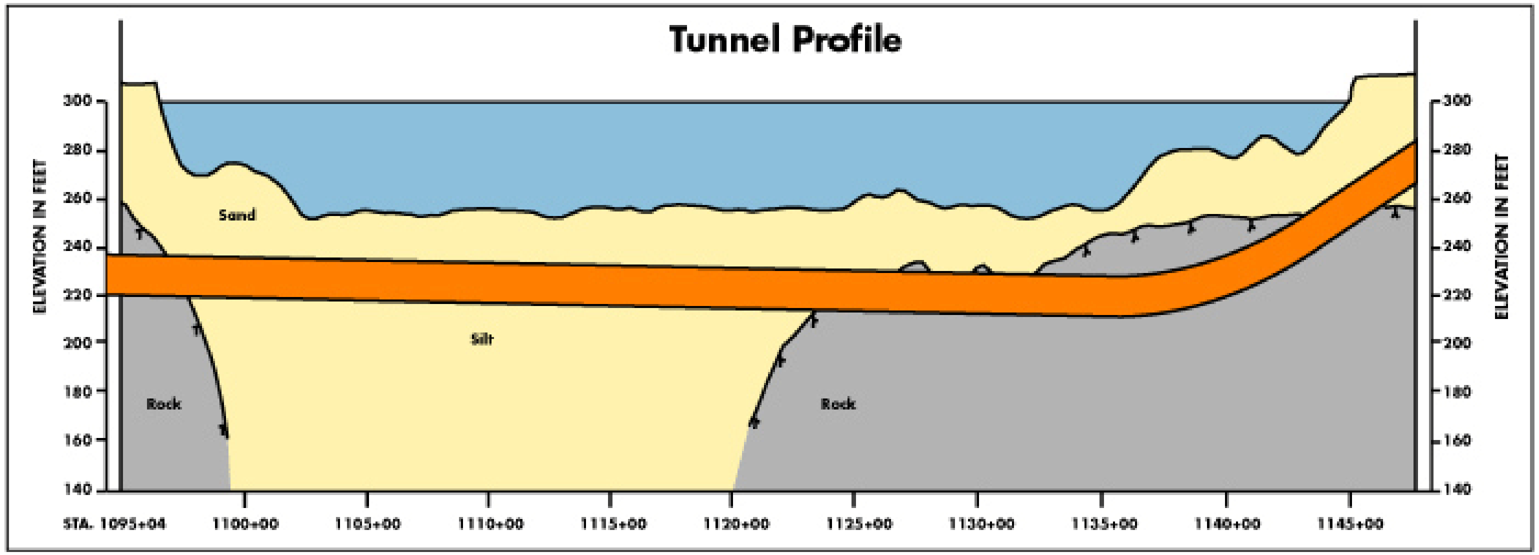
Downtown Tubes

"…Each tube is fifteen feet three inches in diameter, and lies from sixty to ninety below the surface of the water, or from fifteen to thirty feet below the bed of the river. The total length of the sub-aqueous portion of the tube is app-roximately five thousand seven hundred feet, or about two and a half miles…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story.* The "Montgomery-Cortlandt Tunnels" - between *Cortlandt Street* (at *Church Street*) in lower *Manhattan* and *Montgomery Street,* in lower *Jersey City* (where the PaRR's main *New York* station was located) varied from sixty to ninety-feet below the surface of the *Hudson River*. The distance between the roof of the tunnel and the bed of the river varied from fifteen to thirty-feet. The tubes averaged about thirty-feet apart from one another.

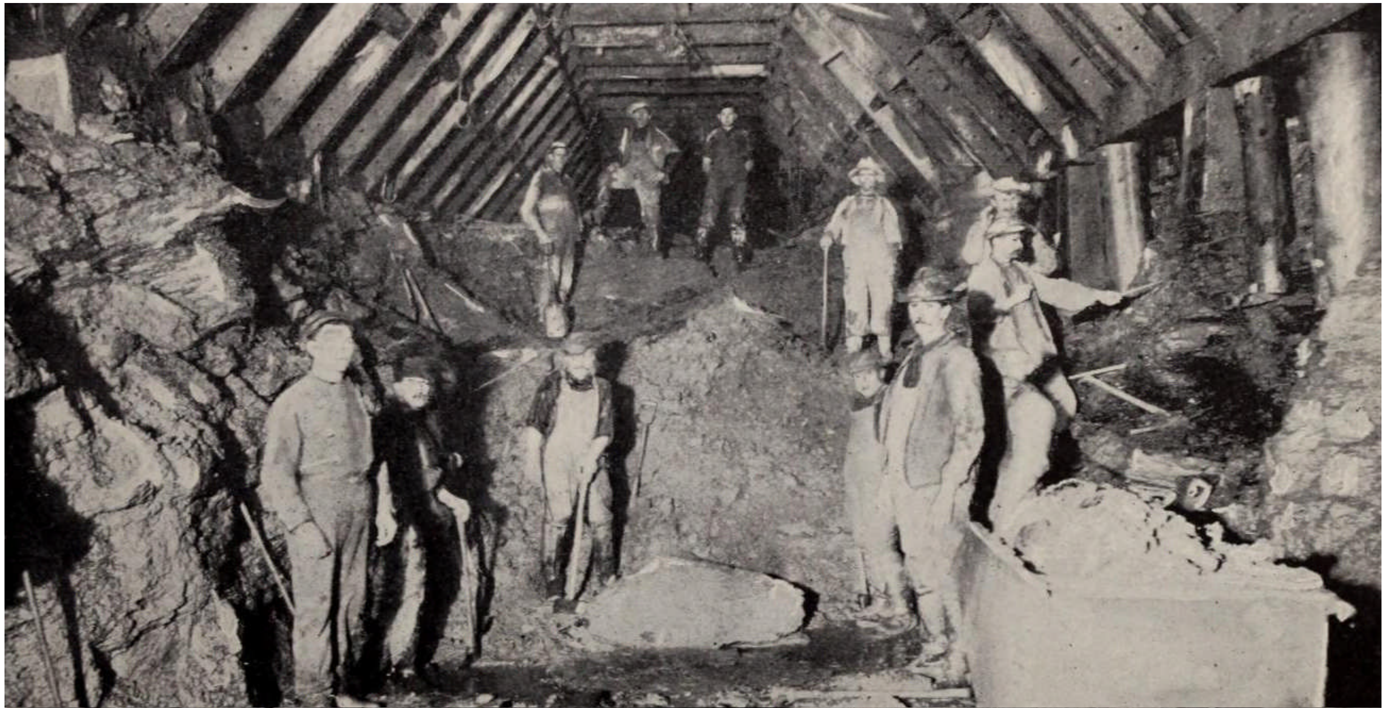
Tunnel Plan

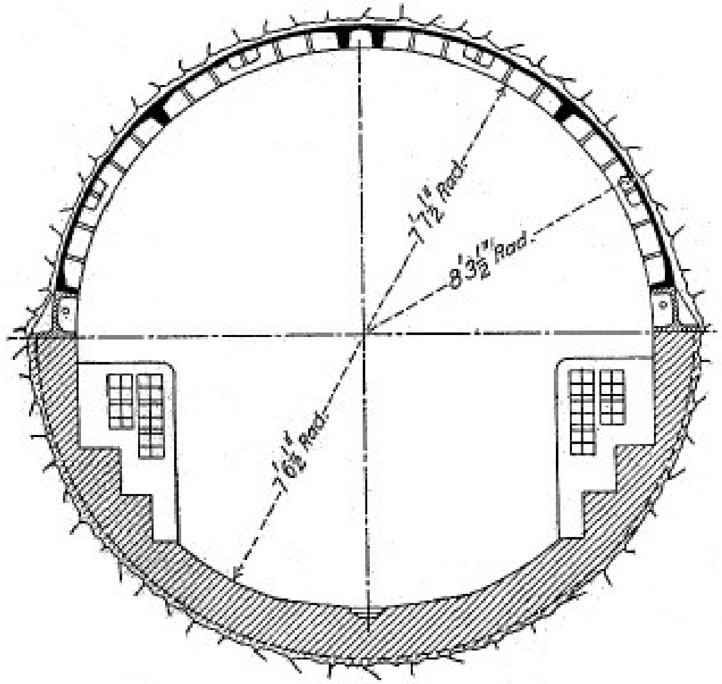

N
TUNNEL "E"
TUNNEL "F"
WORLD TRADE
CENTER TERMINAL
New Jersey
Hudson River
New York


Tunnel Profile
ELEVATION IN FEET
300
280
260
240
220
200
180
160
140
Sand
Silt
Rock
Rock
STA. 1095+04
1100+00
1105+00
1110+00
1115+00
1120+00
1125+00
1130+00
1135+00
1140+00
1145+00

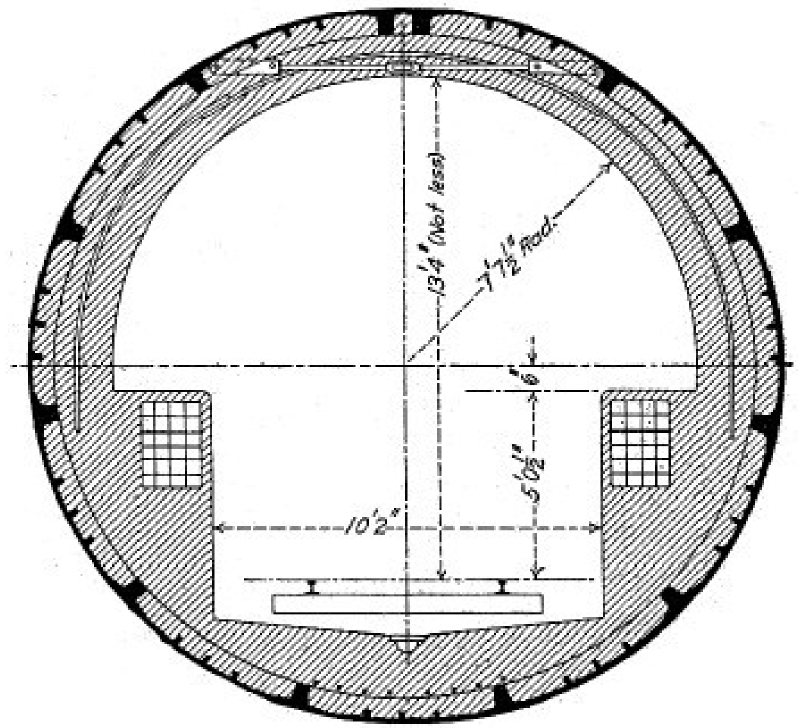
"…In the original work upon this tunnel, under Colonel Haskin, compressed air was first used in construction, when its aid and usefulness in subterranean construction was clearly proven. Haskin even used compressed air as a means of removing from the tunnel the sand and silt, first having mixed them with water. Since those days, however, the use of compressed air in sub-aquatic engineering has made great, important and rapid strides toward the perfect system used by the Hudson and Manhattan company in the construction of these tubes…From the time when Haskin drove a pilot tunnel (six feet six inches in diameter, thirty or forty feet in advance of the main works, enabling him to lay stronger foundations for the roofing irons and brick and masonry of which he was constructing his tunnel), to the introduction of the high-pressure air chambered shield used by the Hudson company, there has been a wonderful advance in engineering science. Behind this shield men can labor without fear of cave-in as the high pressure in the chamber holds the mud, sand, and silt in place until loosened and removed with pick, shovel or dynamite…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*





Tunnel with Cast Iron Roof Lining.

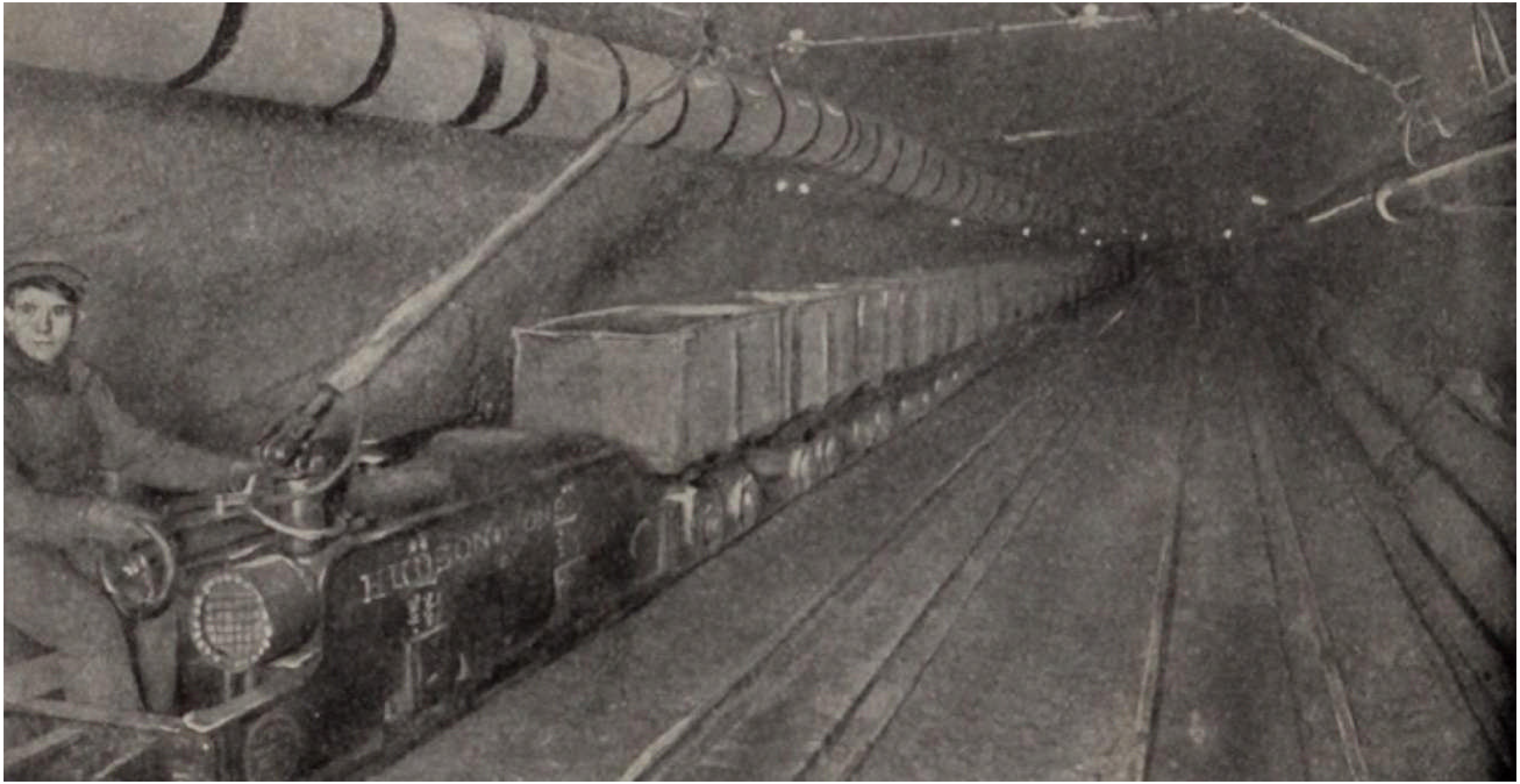


North Tunnel as Lined with Concrete.

"After this tunnel was completed…it was internally lined with concrete to the same internal diameter as the other tunnels throughout, and this difference in size enabled many of the irregularities in the earlier construction to be straightened out and adjusted."

J. Vipond Davies, **H&MRR Engineer**

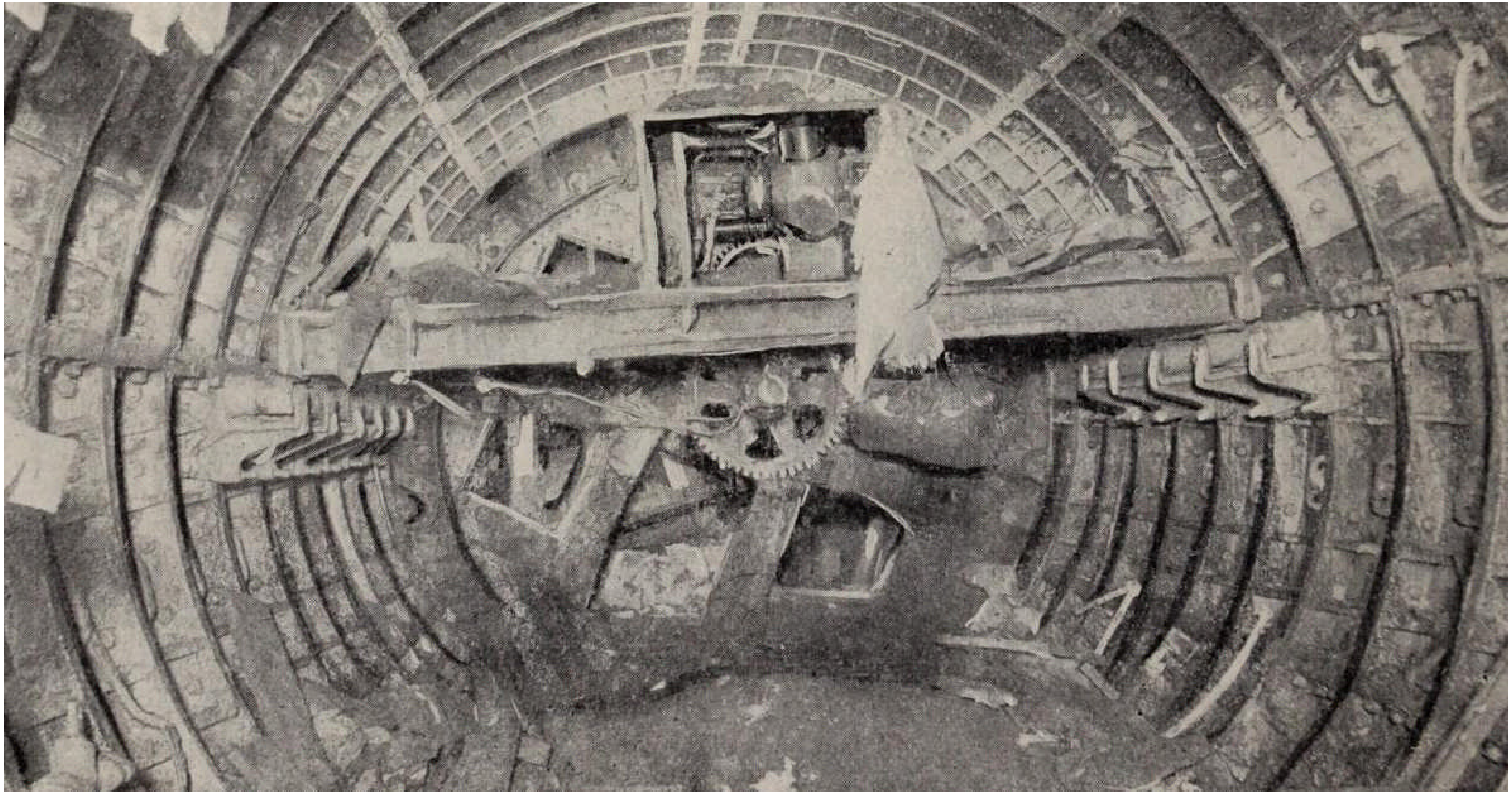
<u>Above L&R</u>: caption: "Profiles of the north and south tunnels." The original *Pearson & Son* shield was about 18-feet in diameter; 3-feet larger than what was now needed for rapid transit trains. Chief Engineer Jacobs stated that the defective iron lining installed in the early stages of the work was rendered efficient by the reinforced concrete lining.



"…Electricity was also used as a means of both light and power in the construction work, greatly facilitating the speed and accurate completion of the undertaking…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

<u>Above</u>: caption: "Electric train pulls ore cars filled with sand, gravel[154] **and stone"**



"…The shield is forced forward into the soil by huge jack-screws, and its correct path is maintained to the fraction of an inch by careful mathematical calculation…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

<u>Above</u>: caption: "View of Shield and completed iron rings forming the tube behind its forward progress"

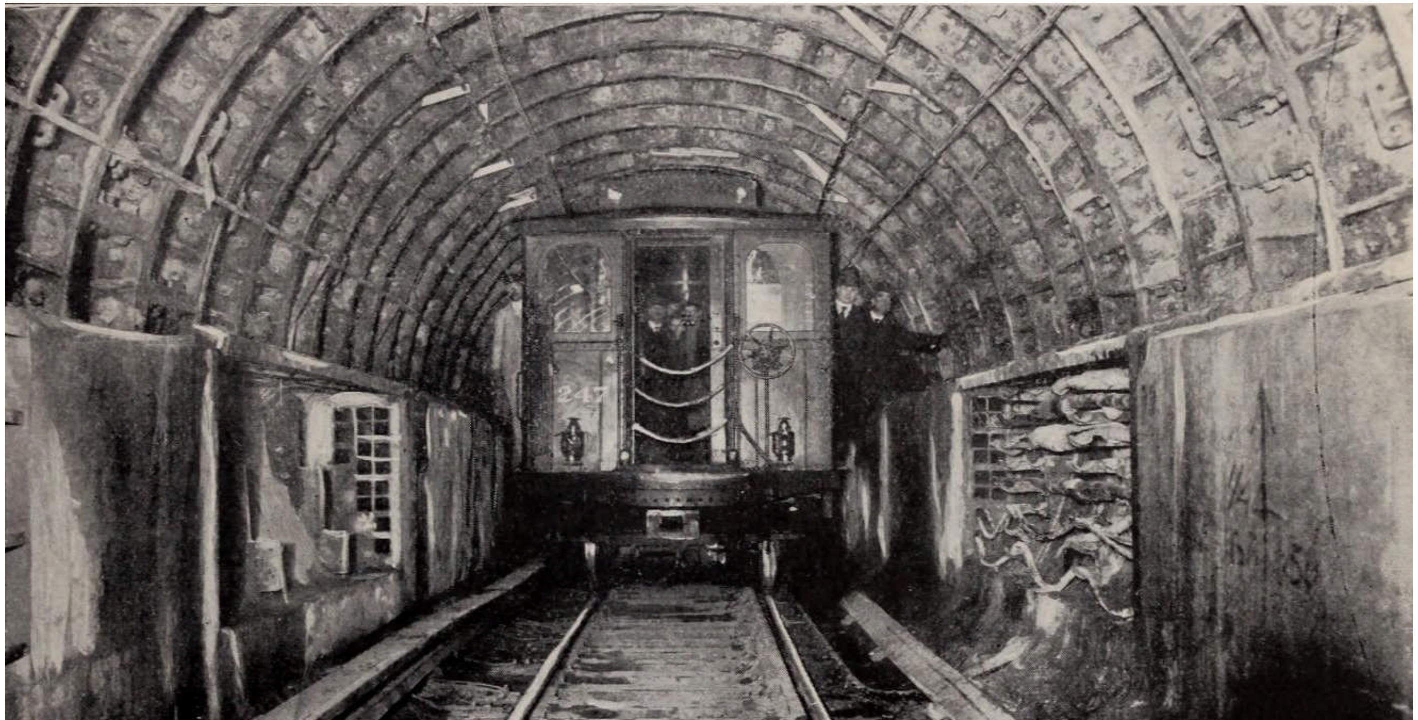
A shield was installed for the first time in the south tunnel at the *Jersey City* end in July/August 1903 and it began to move on September 22nd 1903. Because of *Pearson & Son's* experience in pushing forward through the silt without digging in the first tunnel attempt, the new shield was made even stronger and with more hydraulic jacks; sixteen, in order to push aside as much silt as possible. Amazingly, the engineers found that they did not need to open the doors at all; the silt moved aside as the shield was pushed forward. With no need to dig or even remove waste silt, the heading advanced more than 60-feet per day, an incredible rate compared to Colonel Haskin's 3-feet. Work was stopped from April to August 1904 while the company negotiated with the *Board of Rapid Transit Railroad Commissioners* over an extension of the line through *Christopher Street* and *Sixth Avenue*. Then, after another year's work, the tunnel was holed through into the *Morton Street* shaft on August 25th 1905.

Above: caption: "The south tunnel holed through, breaking into the brick bulkhead at the Morton Street shaft. The newly completed tunnel is in the foreground." 157

"…The shield is several inches larger than the diameter of the completed bore, thus allowing room for the placement of the construction materials. In the present tunnels, these are huge rings of steel securely cemented and bolted together, and sheathed with concrete either all or a part of the way around the circle…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story.*

<u>Left T&B</u>: the tunnels were constructed as a series of rounded segments made of cast-iron rings (weighing five-tons each) securely bolted together thus forming a "tube" sixteen-feet in diameter. This design is in evidence at the *Christophe*r *St.* and *Ninth Ave.* station (bottom).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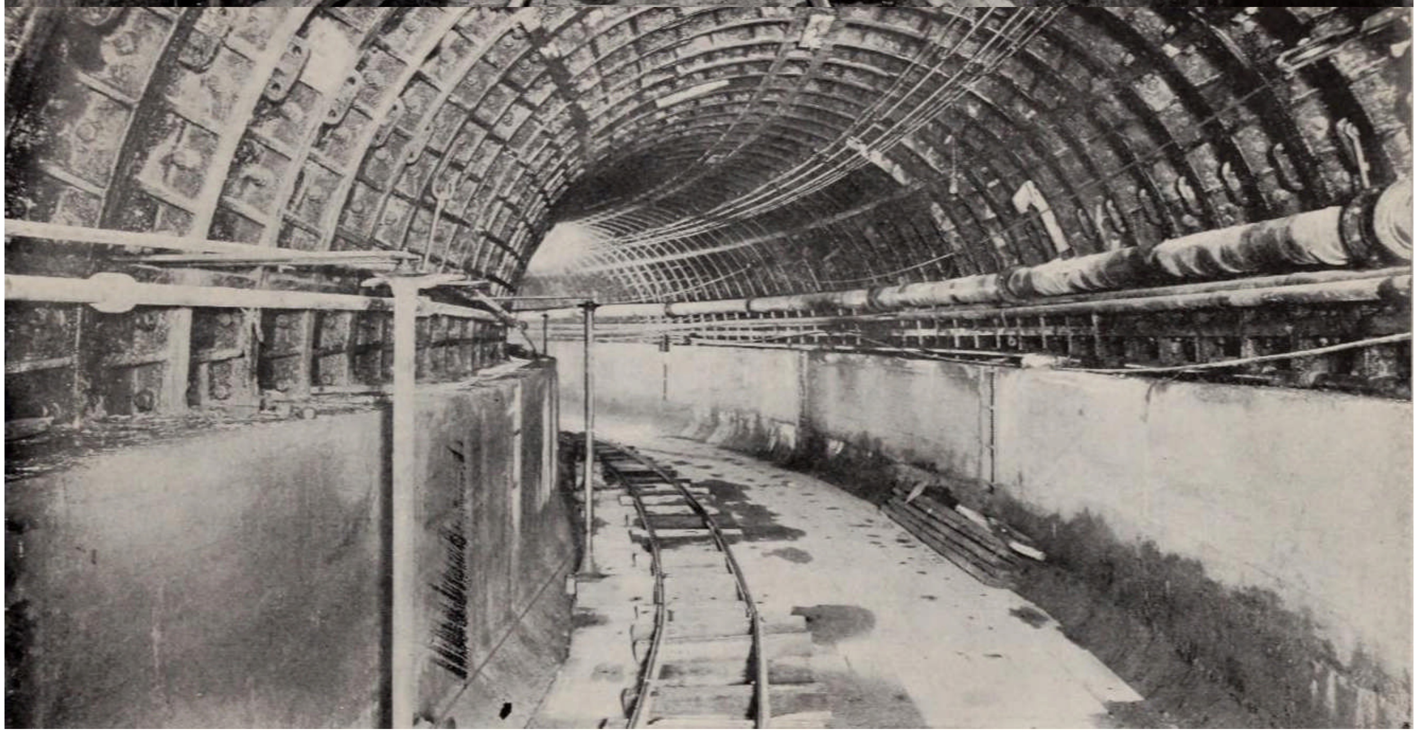
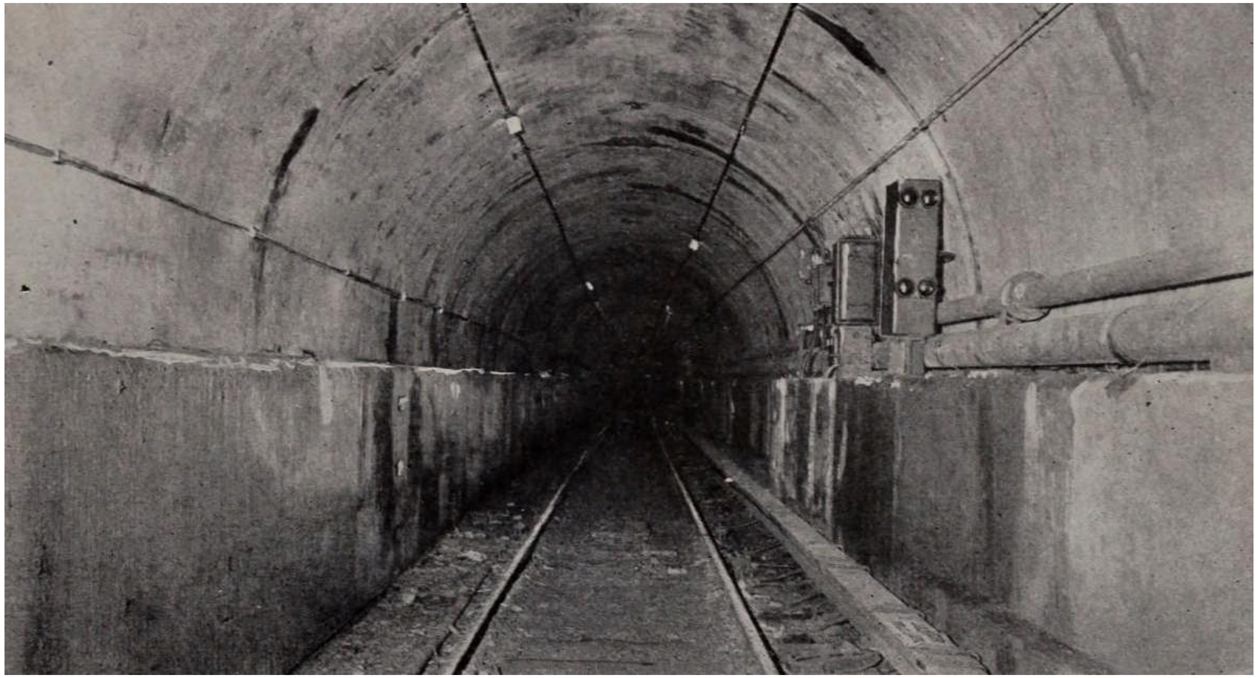
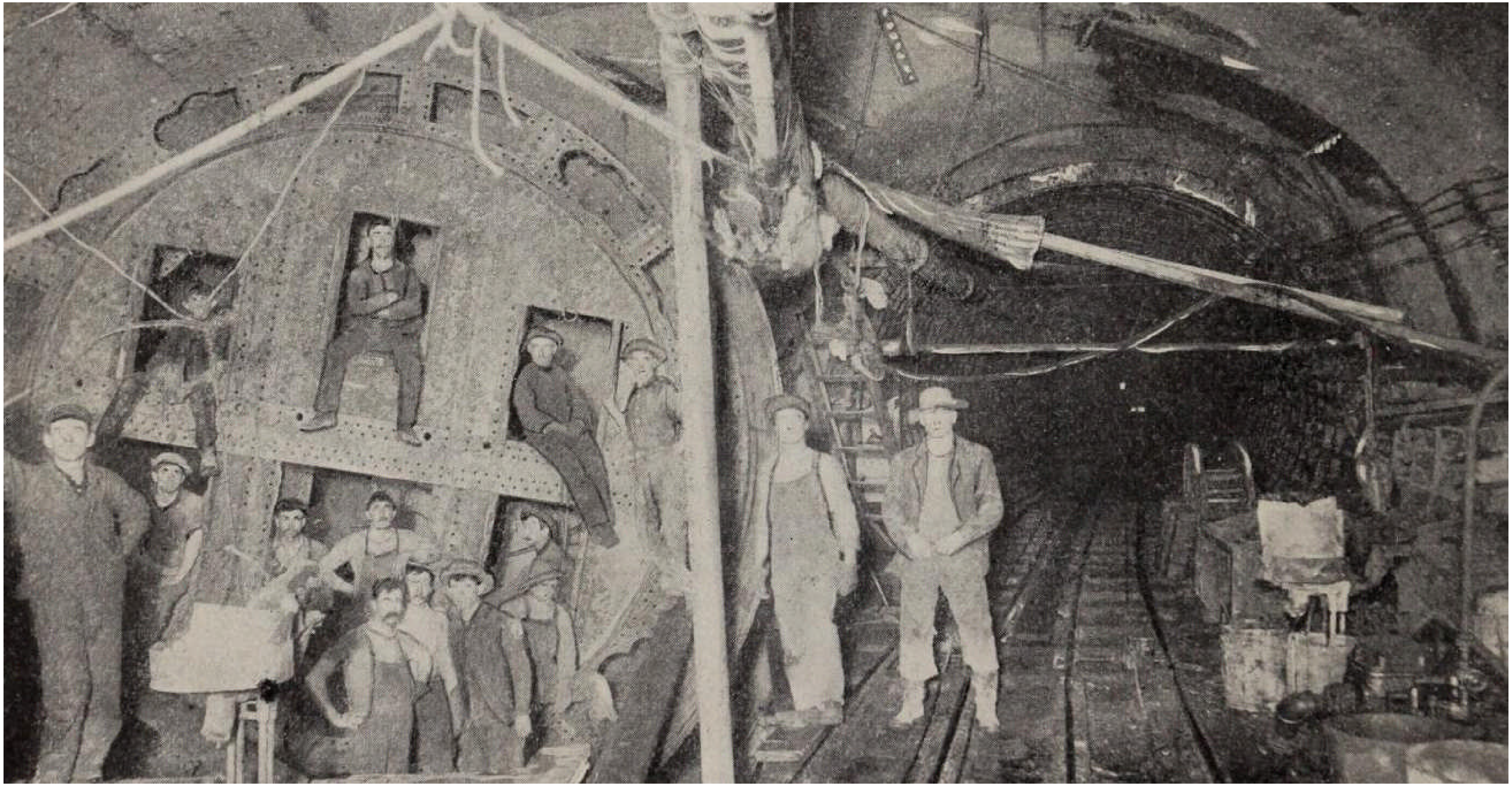
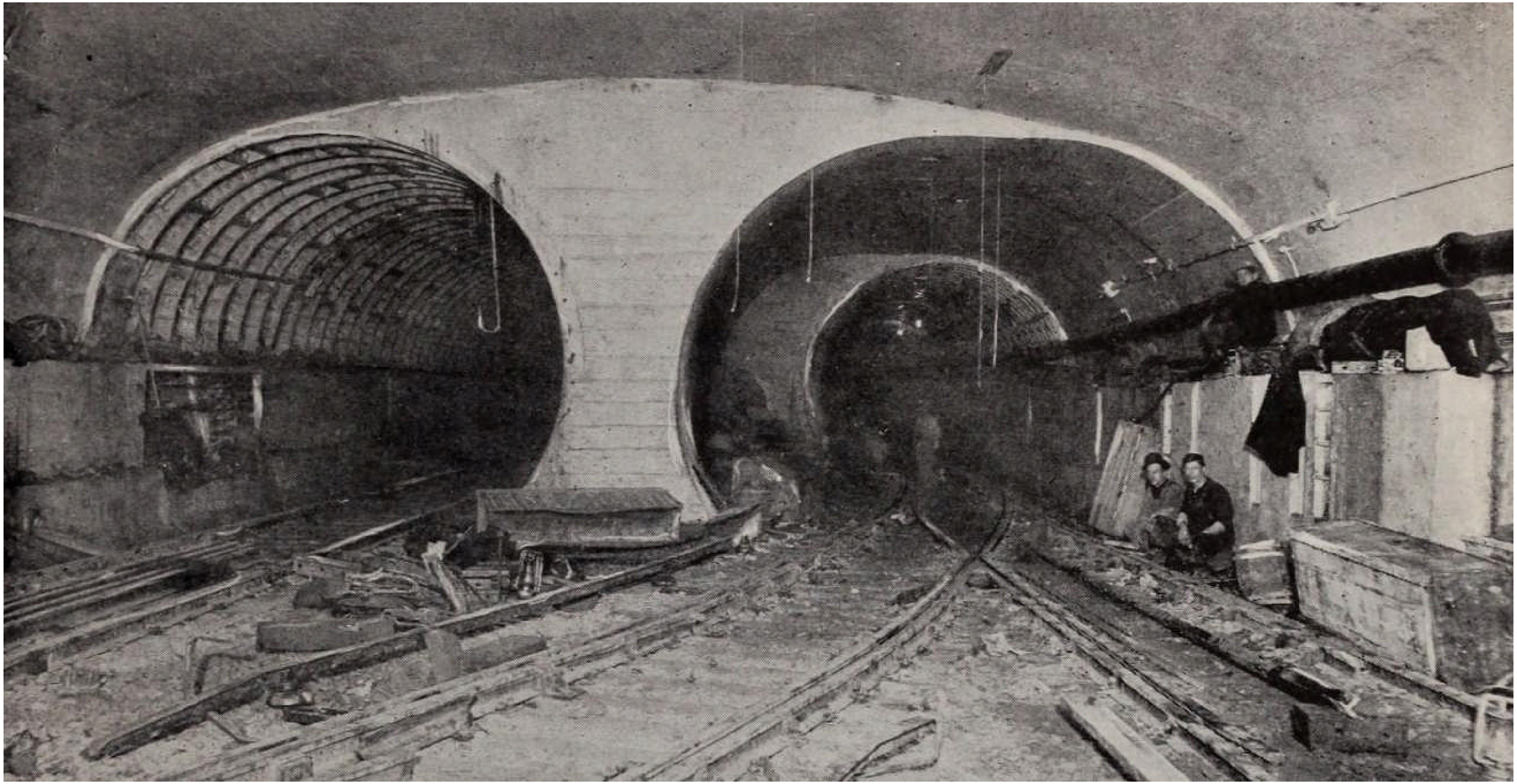




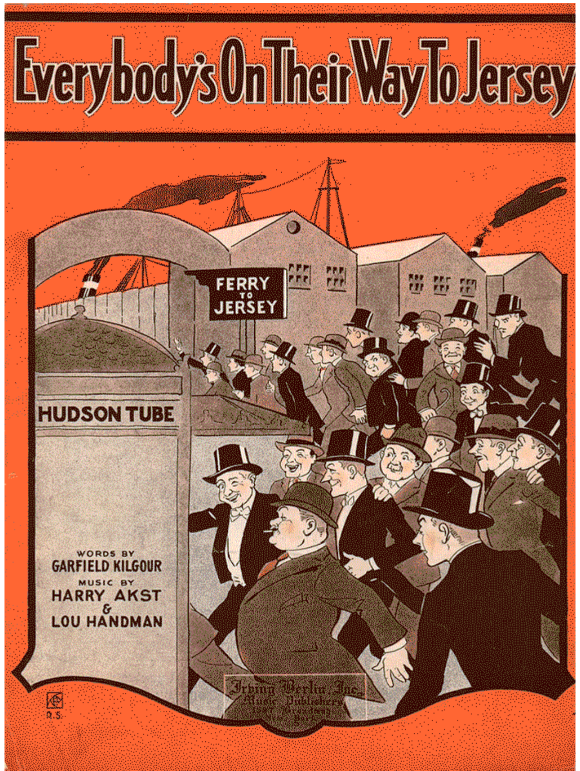
<u>Left</u>: in subterranean locations, the "cut & cover" technique of tunneling was used and the tunnel/s were encased in concrete making the interior of the tube/s smooth



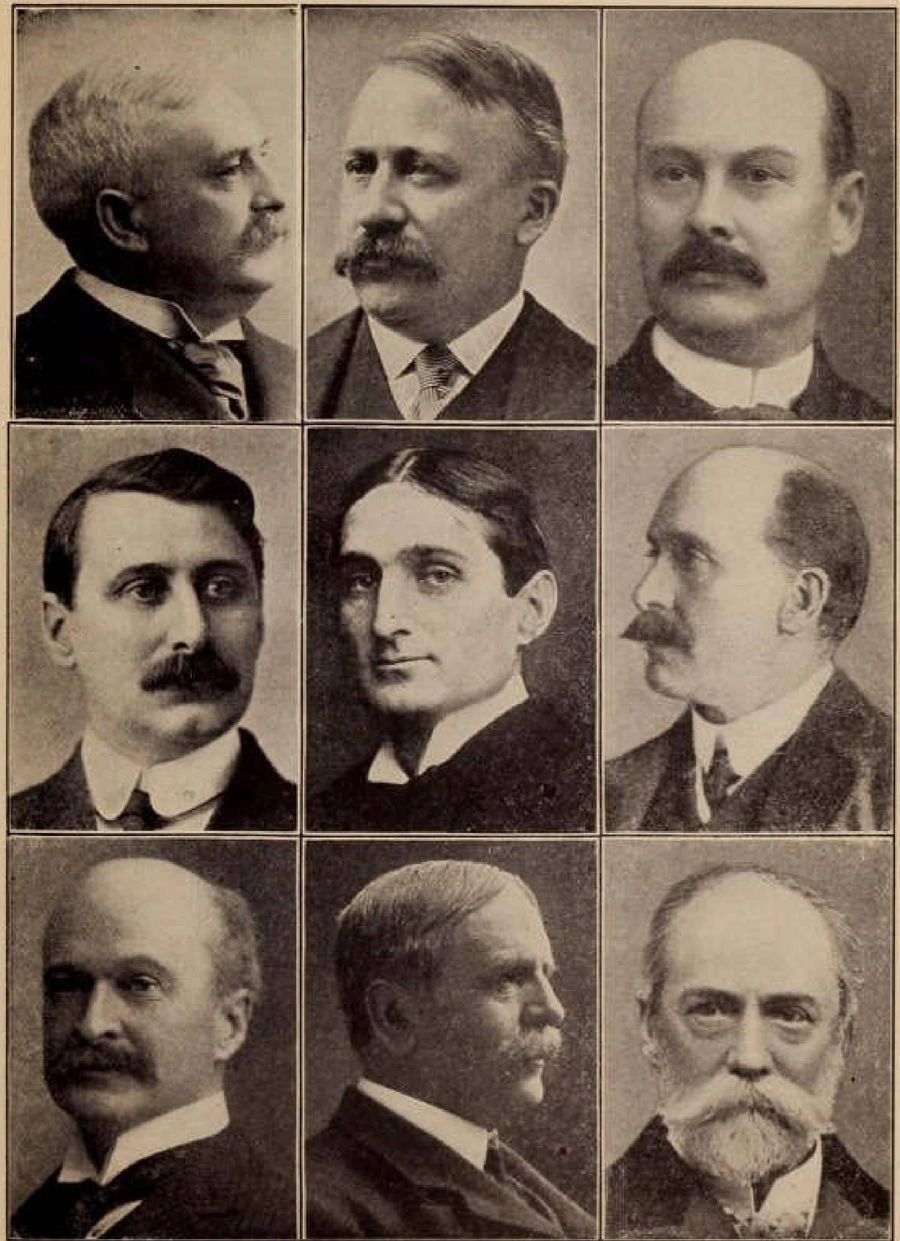
<u>Above</u>: caption: “Having arrived at the terminal, here we see another shield (at left) about to begin its mission for the betterment of transit facilities between the two states”



<u>Above</u>: caption: “The crossover, or mouth of the two tunnels”



On April 4th 1909 *Hudson Terminal*, the twin 22-story office buildings built over the downtown terminal of the *Hudson & Manhattan RR*, opened at its location on the west-side of *Church Street* between *Cortlandt* and *Fulton Street/s*. It contained 815K square-feet of office space and was proclaimed the world's largest office building. On July 19th 1909, operations began between lower *Manhattan* and lower *Jersey City* through the *Montgomery-Cortlandt Tunnels* (located about 1.25 miles below the uptown pair of tunnels). At the time, the H&MRR's "Tubes" were going into service, composer George M. Cohan's "Only forty-five Minutes from Broadway" was one of the big hits of the day. To celebrate the opening of the trans-Hudson tunnels, Broadway's "Tin-Pan Alley" celebrated the event in song (top). The twenty minute *North River* ferry crossing was reduced to just three minutes by tube train, as highlighted in the cartoon at bottom. With the completion of the uptown *Manhattan* extension (to *Penn Station*) and a westward overland extension to *Manhattan Transfer* (opened October 1st 1911) and then to *Newark-Park Place* (opened November 26th 1911), the H&MRR was finally complete. Considered an engineering marvel of the first order, the H&MRR's *Hudson River* sub-aqueous tunnels were the first to be constructed under a major river, pre-dating those of both the *New York City Subway System* and the PaRR's direct entry into Manhattan.



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.RR. C. W. CLINTON, architect H.R. Term.

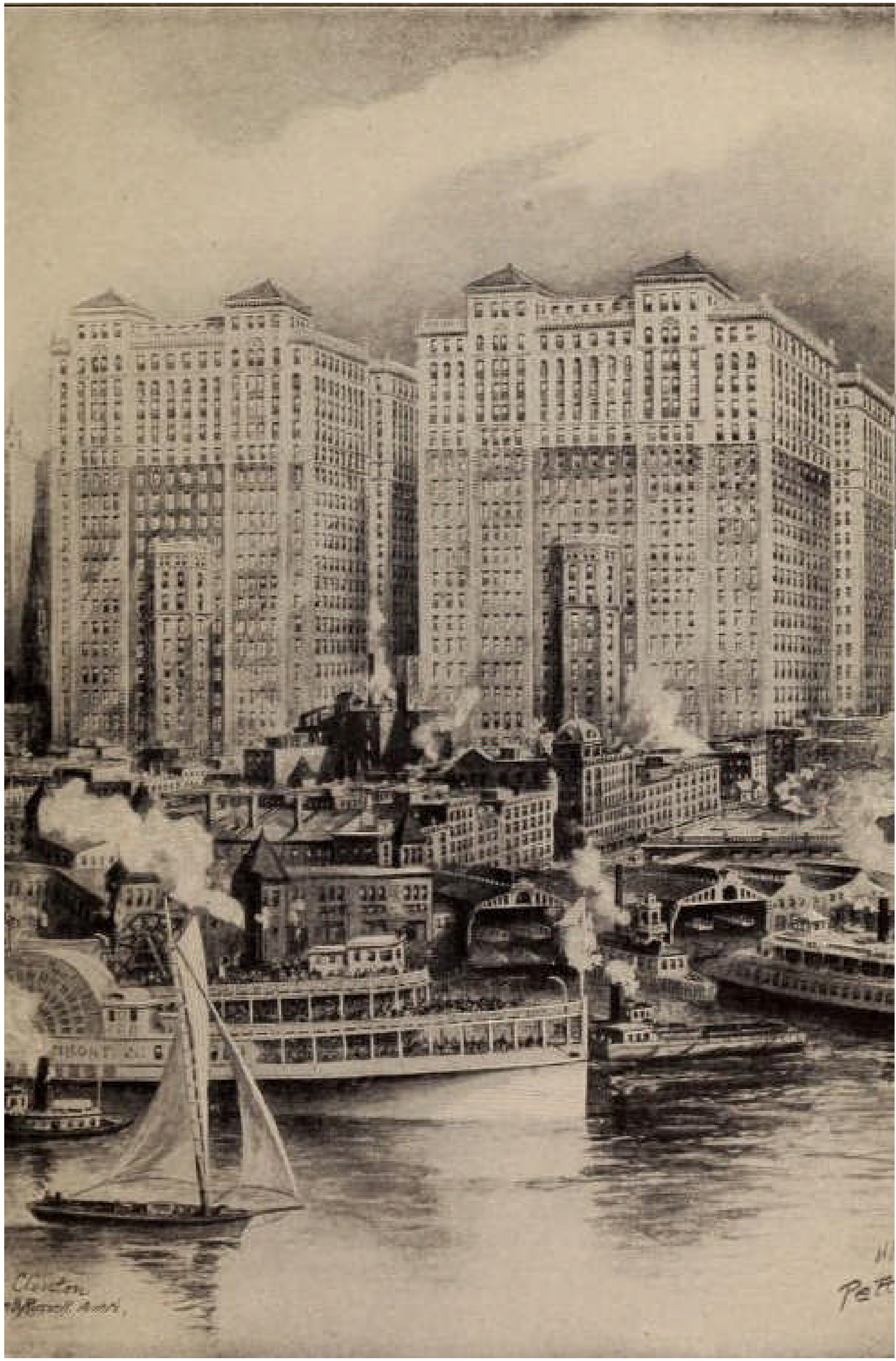
Above: caption: "Here we look upon the giant minds who have made possible the tunnel: McAdoo, Jacobs, Davies and associates"

Left: H&MRR President, Directors, Chief Engineer, Assistant Chief Engineer and Architects

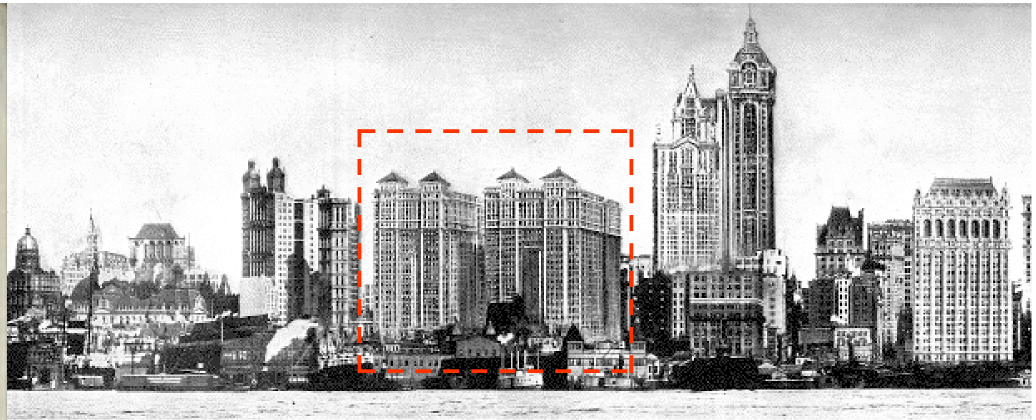
Hudson Terminal

"…There has been reared, also, two twenty-two story buildings, known as the Hudson Terminal Buildings which are of fire-proof twin construction, and cover nearly two city blocks at Cort-landt, Dey, Fulton and Church streets. Here are located the terminals of the two great southern twin tubes to Jersey City...This building goes on record as the largest office structure in existence, containing as it does, in its twenty-two stories, eighteen and a half millions of square feet (or more than twenty-nine acres) of floor space, affording com-fortable accommodations for over ten thousand office tenants. These twin buildings are respectively officially des-ignated as the Fulton, and the Cort-landt, and are joined by an iron bridge across Dey street…"

RE: excerpt from *The Hudson & Manhat-tan Tunnels in Picture and Story*

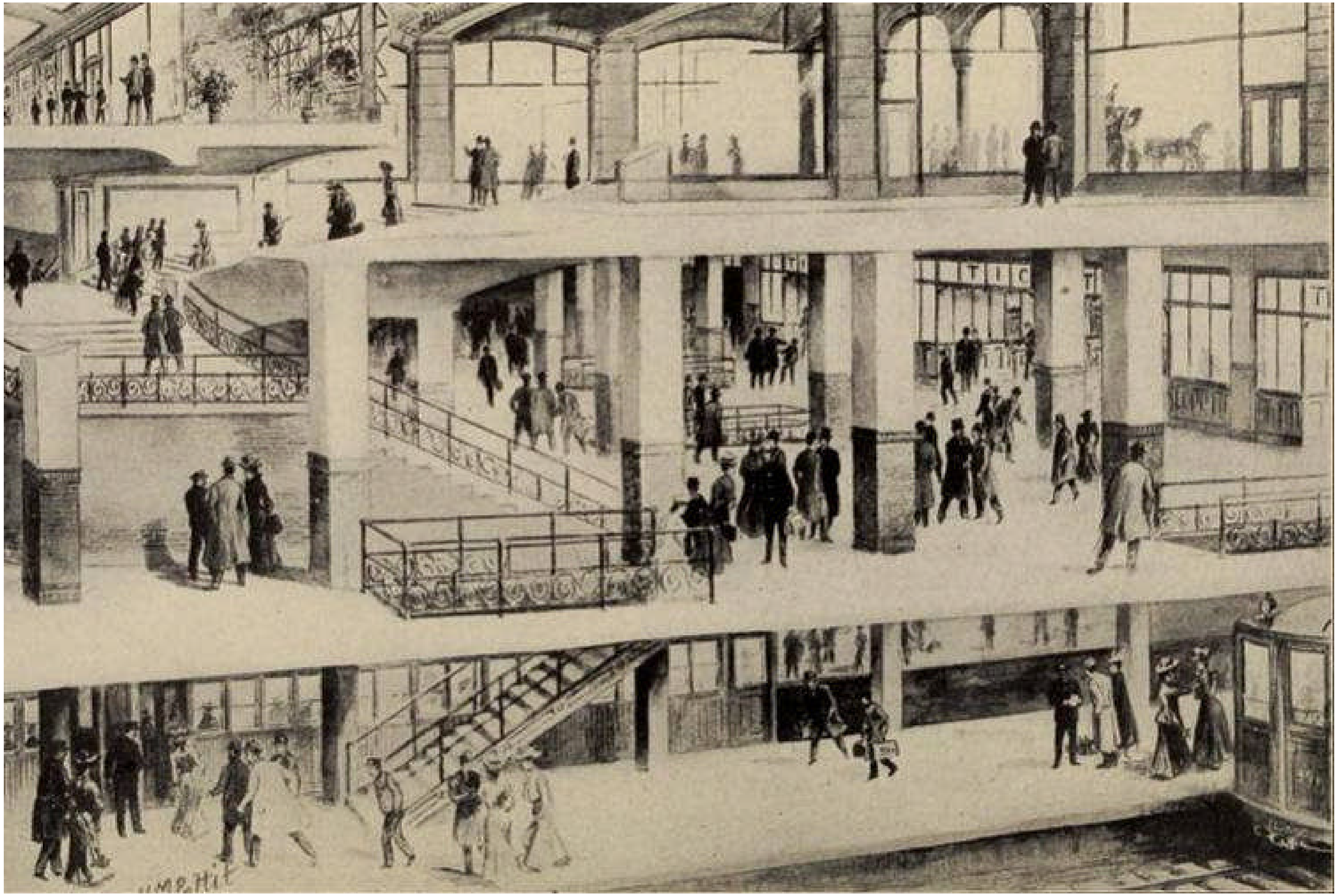


<u>Above</u>: caption: “This is the Hudson Terminal Buildings, wherein are located the stations of the south twin tubes”
<u>Left</u>: caption: “Church St. Terminal, largest and heaviest building in city; 200,000 tons, including 24,000 tons structural steel, 37,500 tons concrete, 16,300,000 bricks, 4,500 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.”

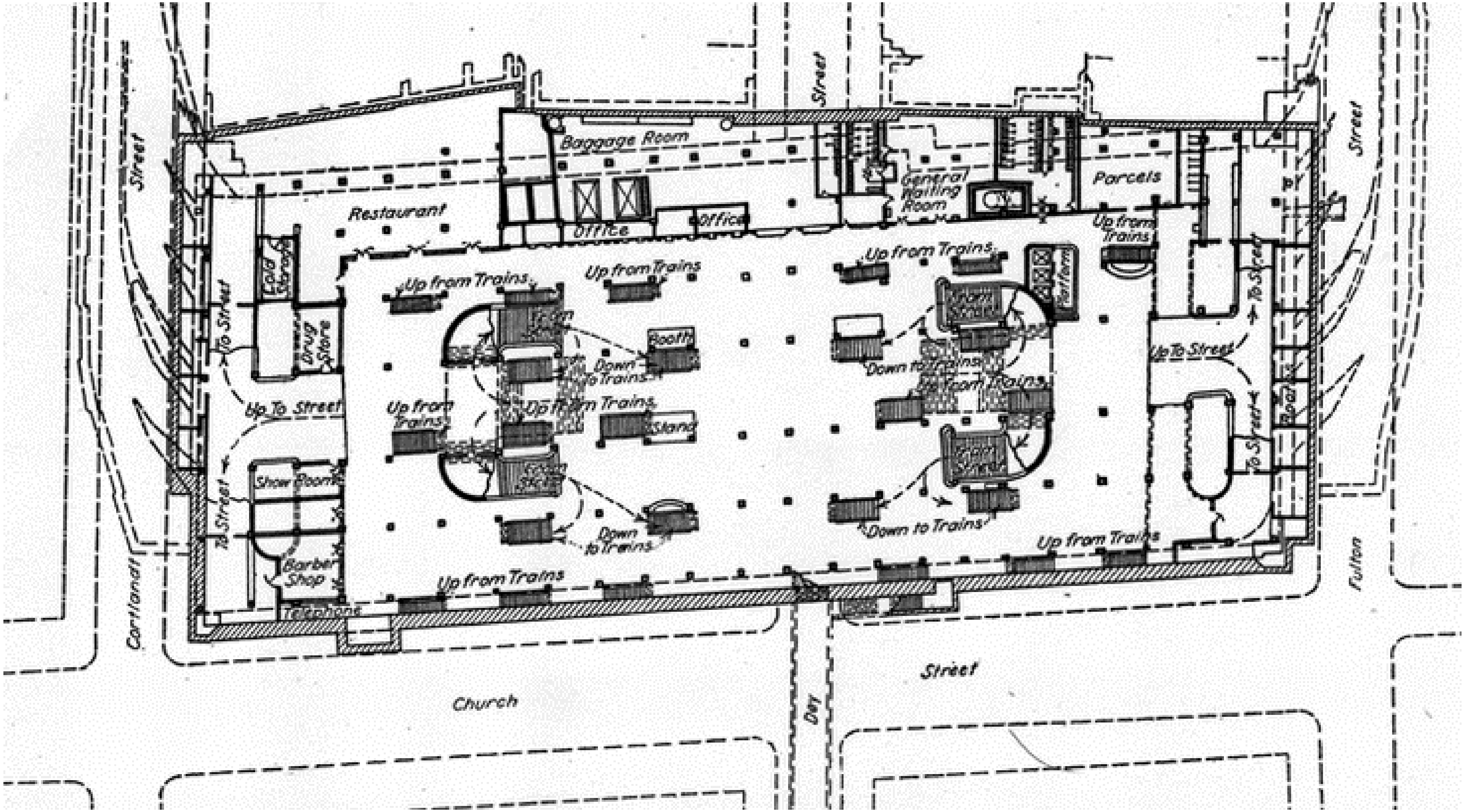



"…About thirty-feet below the street level are located the loop and station platforms where one thousand persons a minute, or five hundred thousand people a day can easily be handled. Just above this floor is located what is known as the 'concourse'…Fifty-two elevators afford prompt, comfortable, safe, and easy access to the various floors, already rented as offices to some of the largest of our American corporations…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

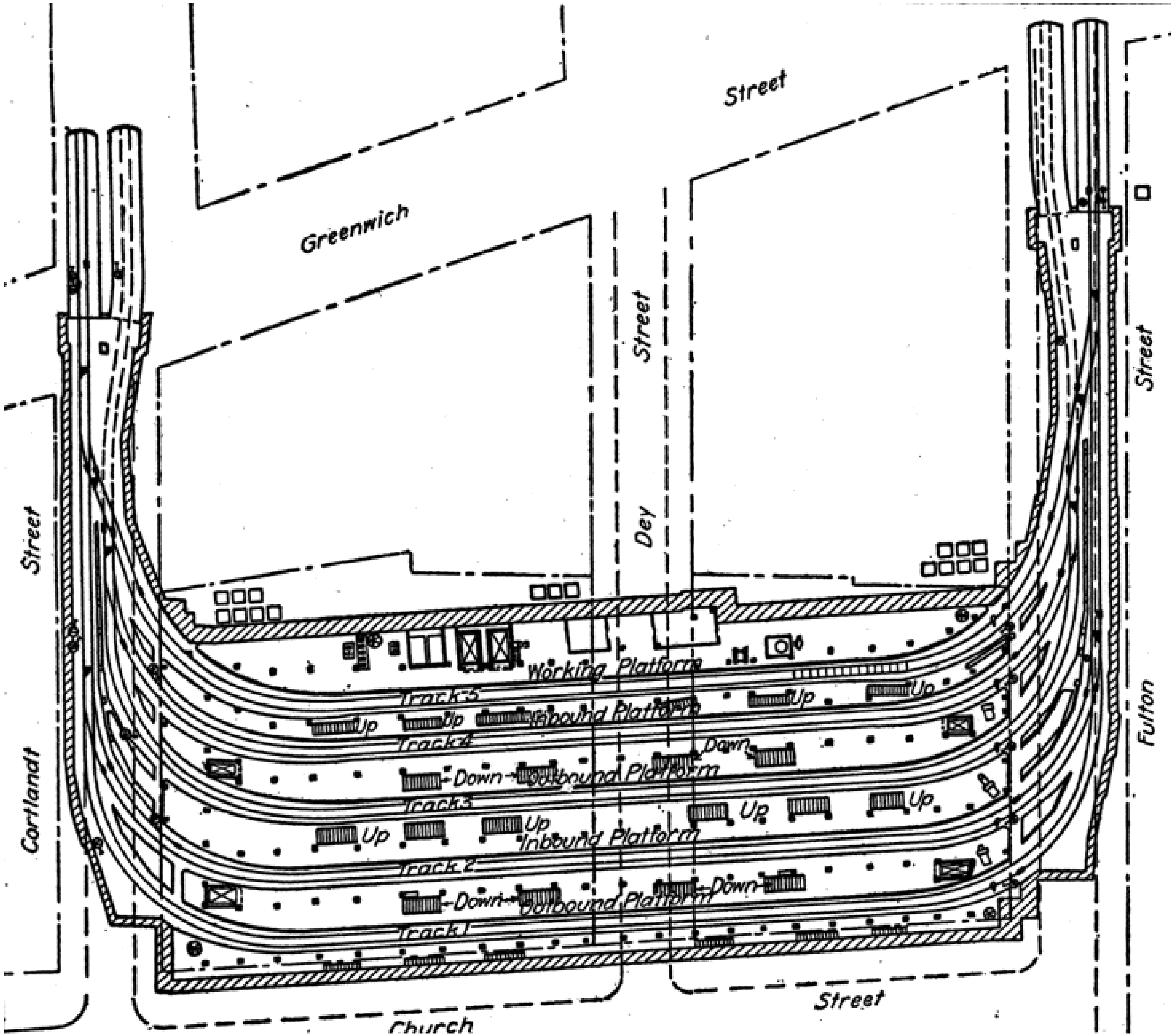


<u>Above</u>: caption: “Church Street Terminal, Hudson & Manhattan RR., Cortlandt to Fulton Sts., built on largest coffer dam in the world, 400 x 178 ft., 75 ft. deep, at one point 98 ft.; trains from Jersey enter coffer dam at Cortlandt St. 30 ft. below surface, emerging at Fulton St.; passengers ascend from 20-ft. platforms by stairway 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.”

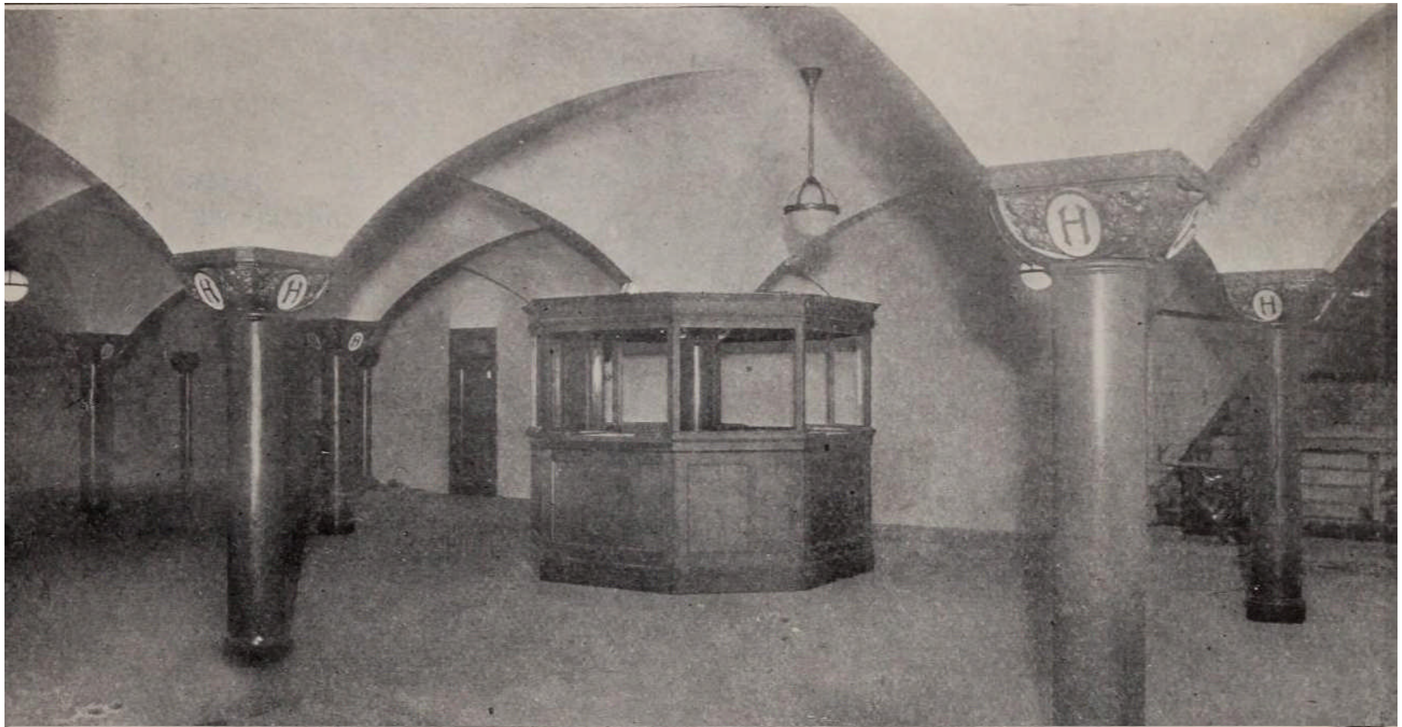


<u>Above</u>: caption: "Plan of Concourse – Hudson & Manhattan Station"


HUDSON & MANHATTAN R.R.
TRAINS TO
MANHATTAN TRANSFER
EXCHANGE PLACE
GROVE & HENDERSON STS.
AND SUMMIT AVE.
PENNSYLVANIA
LIMITED
PARK PLACE, NEWARK

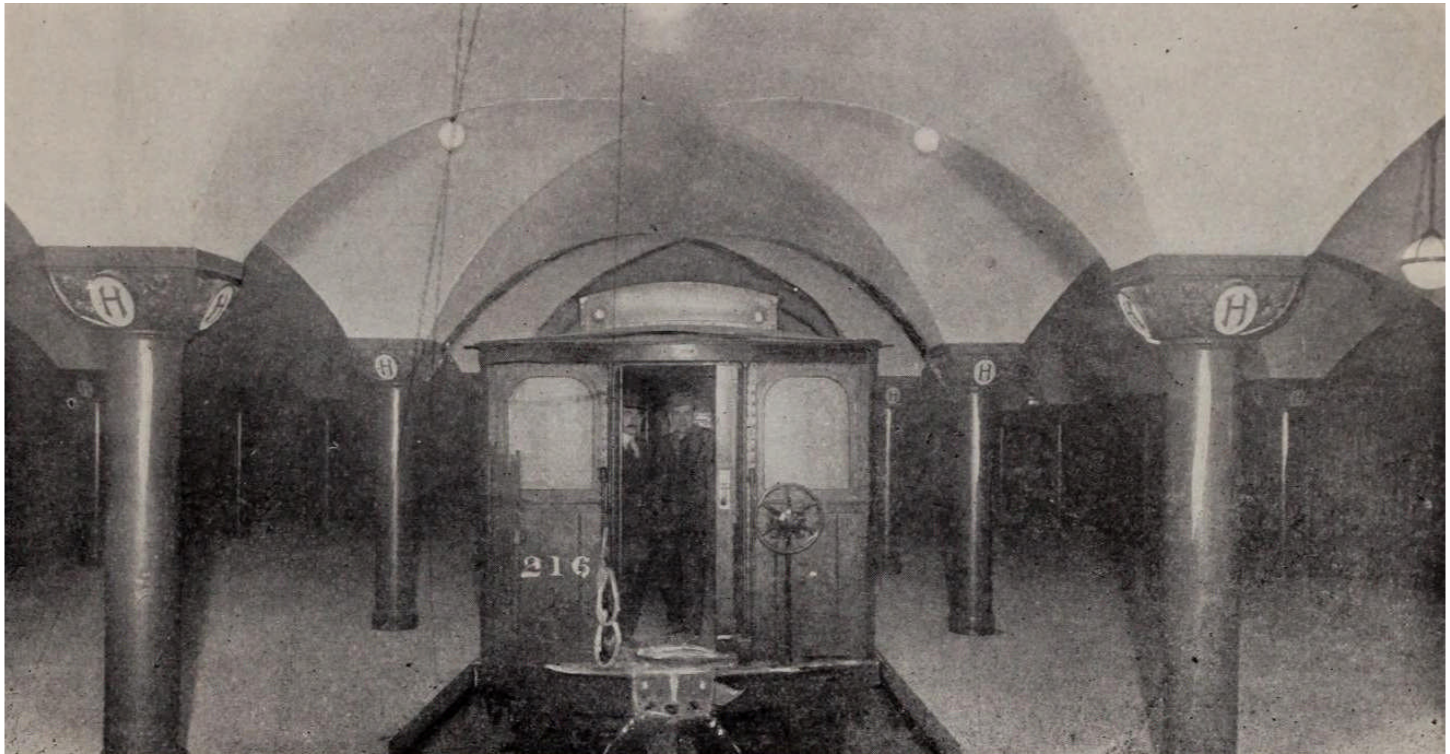


<u>Above</u>: caption: "Track Level of the Hudson & Manhattan Station"



"…The stations are built on what is known to the engineering fraternity as the tangent form, which means simply that the tracks in the station are perfectly parallel with the platforms, that there are no curves where the passengers are allowed to enter the cars, thus avoiding the dangers of the 'wide step' so often found in other transit systems of the great metro-polis…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*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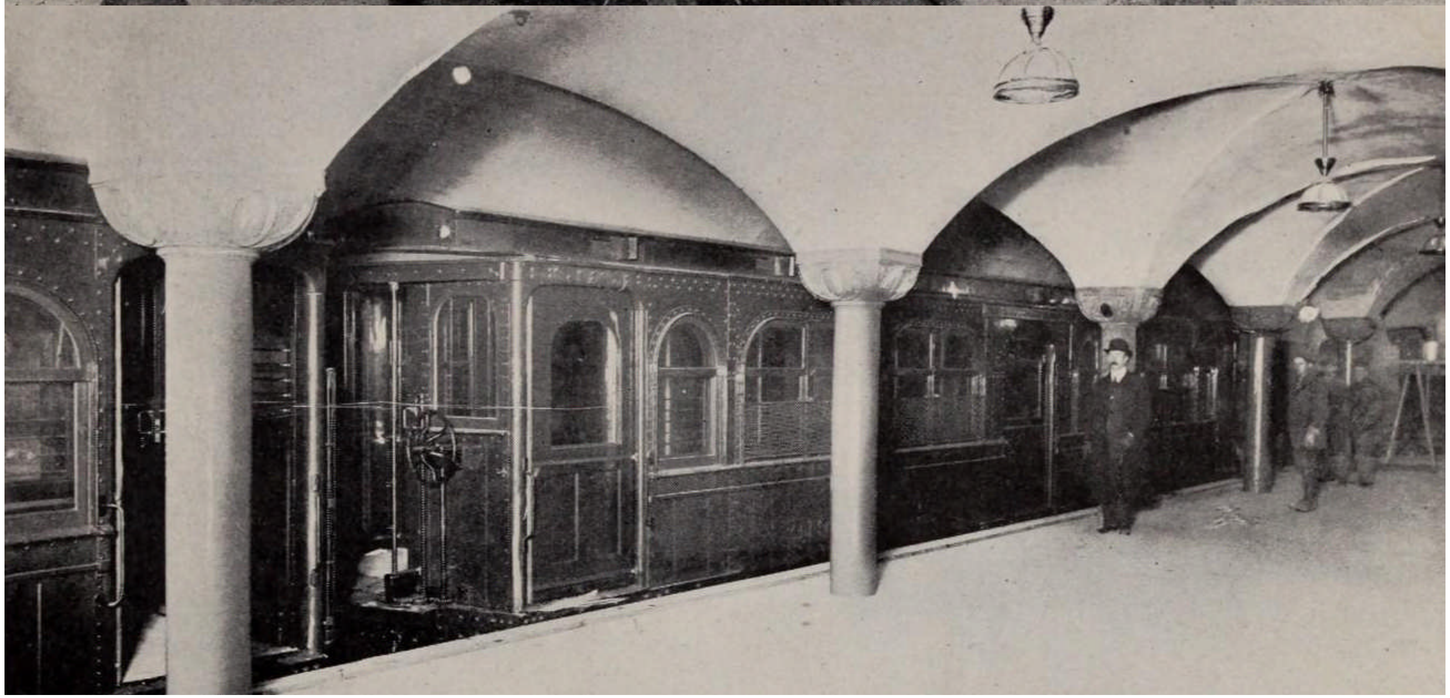
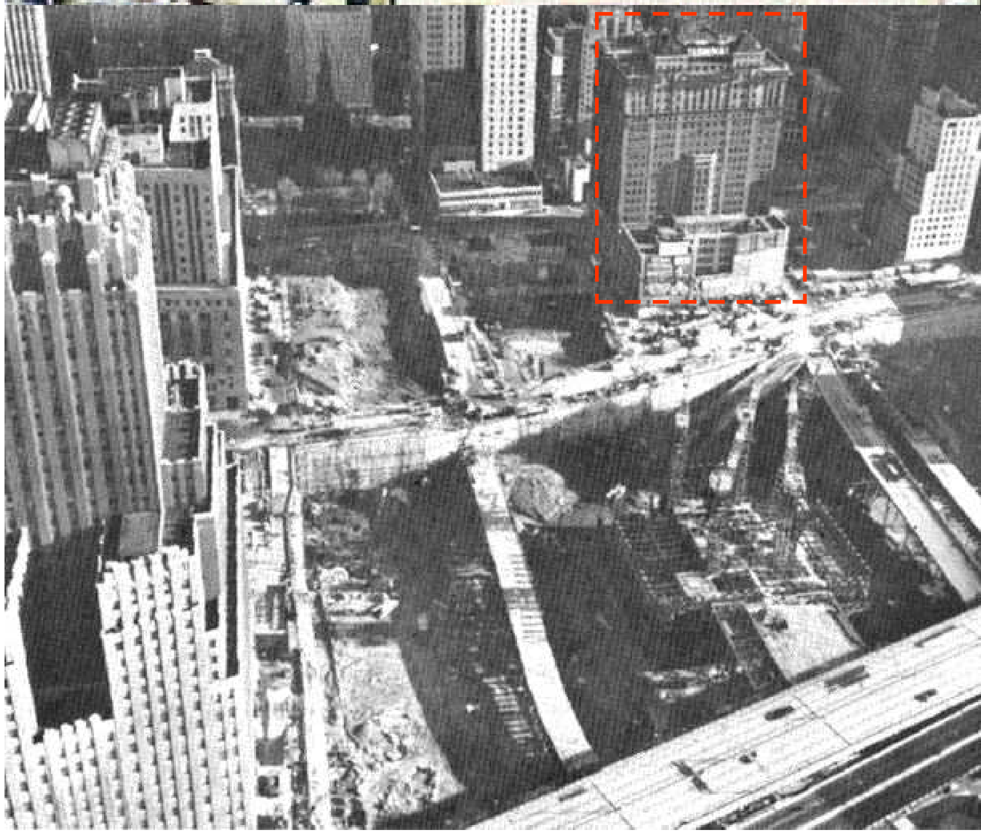



Journal Sq
Hoboken
33rd Street
EXIT



<u>Top Left</u>: caption: "Church Street Terminal – Sectional View From Street Level To Train Platform – Hudson & Manhattan R.R. Company's Terminal"
<u>Top Right</u>: caption: "The concourse at Hudson Terminal was filled with shops and services the commuters could use before descending to the platforms"
<u>Left</u>: caption: "View of the WTC complex under construction (ca. 1968). One of the original Hudson Terminal towers is in the upper center-right (highlighted, with 'Terminal' on the roof)."

<u>Left</u>: part of the "HUDSON TERMINAL" sign that once stood on the roof of the twin 22-story buildings is visible in this photograph of a workman painting the flagpole atop one of the buildings

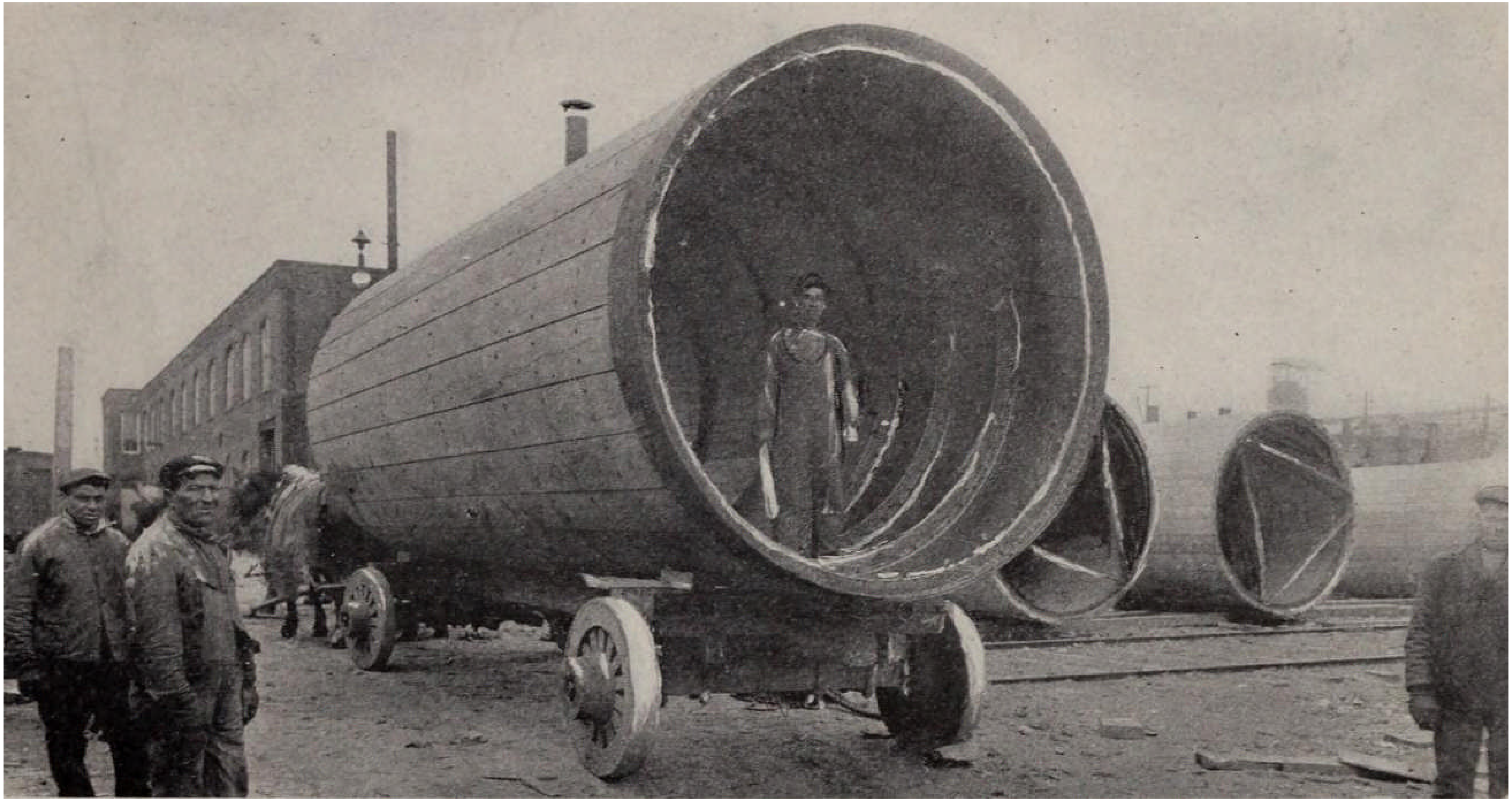
Flying Junction

"As there was not sufficient distance between the ends of the old tunnels at the Fifteenth Street shaft and the first switch enlargement, in which to separate the tunnels so that one could be carried above the other without the use of excessive gradients, it became necessary to rebuild the first 500 feet of the old south tunnel adjoining the shaft. This was acc-omplished by erecting a shield in the same shield-chamber that was built for the south-tunnel river-shield at the end of the old brick tunnel, and driving westward towards the shore, using a slightly descending gradient; as the old tunnel was on a very sharp ascending gradient, they quickly separated, the shield cutting through the bottom and sides of the old brick tunnel until the outside of the iron lining entirely cleared the invert of the old brick lining, and passed on under the bottom of the shaft."

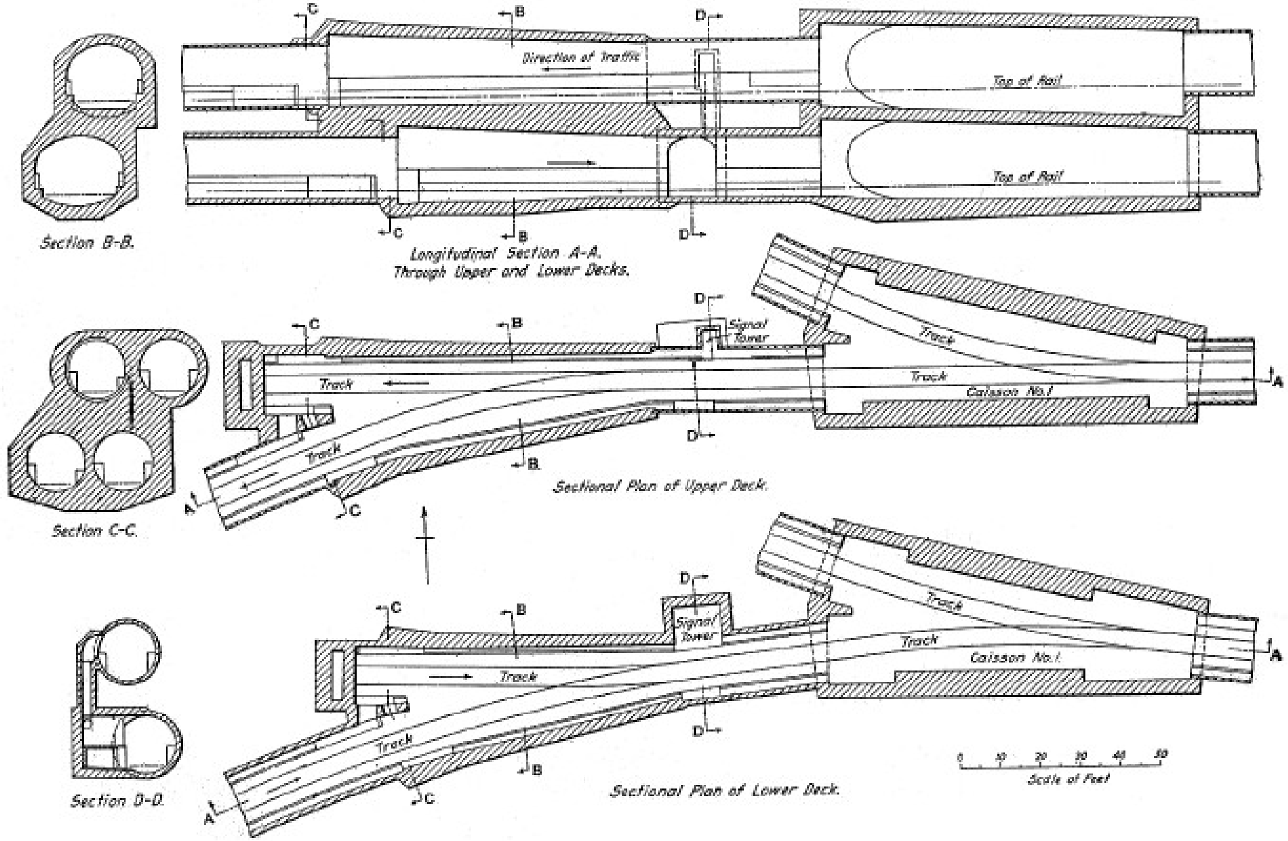
***Charles M. Jacobs,* Chief Engineer**

RE: on the *New Jersey* side, after passing the *15th Street* shaft, the route divided, running north to *Hoboken* and south to *Erie* (*Pavonia*). To avoid grade crossings, the junction was to be built on two levels. Two other junctions were needed nearby to connect the two branches to each other forming a triangle. To do this, a bulkhead and air-lock had to be installed (to keep the work under pressure while the south tunnel was partially opened) and access to all this was only from the *Morton Street* shaft a mile away. On the original level, the shaft was put under pressure so that an opening could be made in the west-side to extend the north tunnel by shield to the junction.

<u>Left</u>: caption: “View east in the old south tunnel not far from the 15th Street shaft, 1905. The shield is moving toward the camera and down, to establish the new lower level approaching the junction just west of the 15th Street shaft. This shows the tall elliptical shape of the oldest portions of tunnel.”
<u>Right</u>: caption: “Caisson 1 being constructed in Lackawanna Railroad property, 1906. Shown here is the lower level, which was partly sunk before the upper level was constructed above it.” The two-level junction was constructed of reinforced concrete at the surface and then sunk as a caisson into position. Doing so avoided the problems of widening a shield tunnel in the waterlogged soil. This caisson was built from March to June 1906. The lower level was completely built and sunk partway and then the top level was built over it.

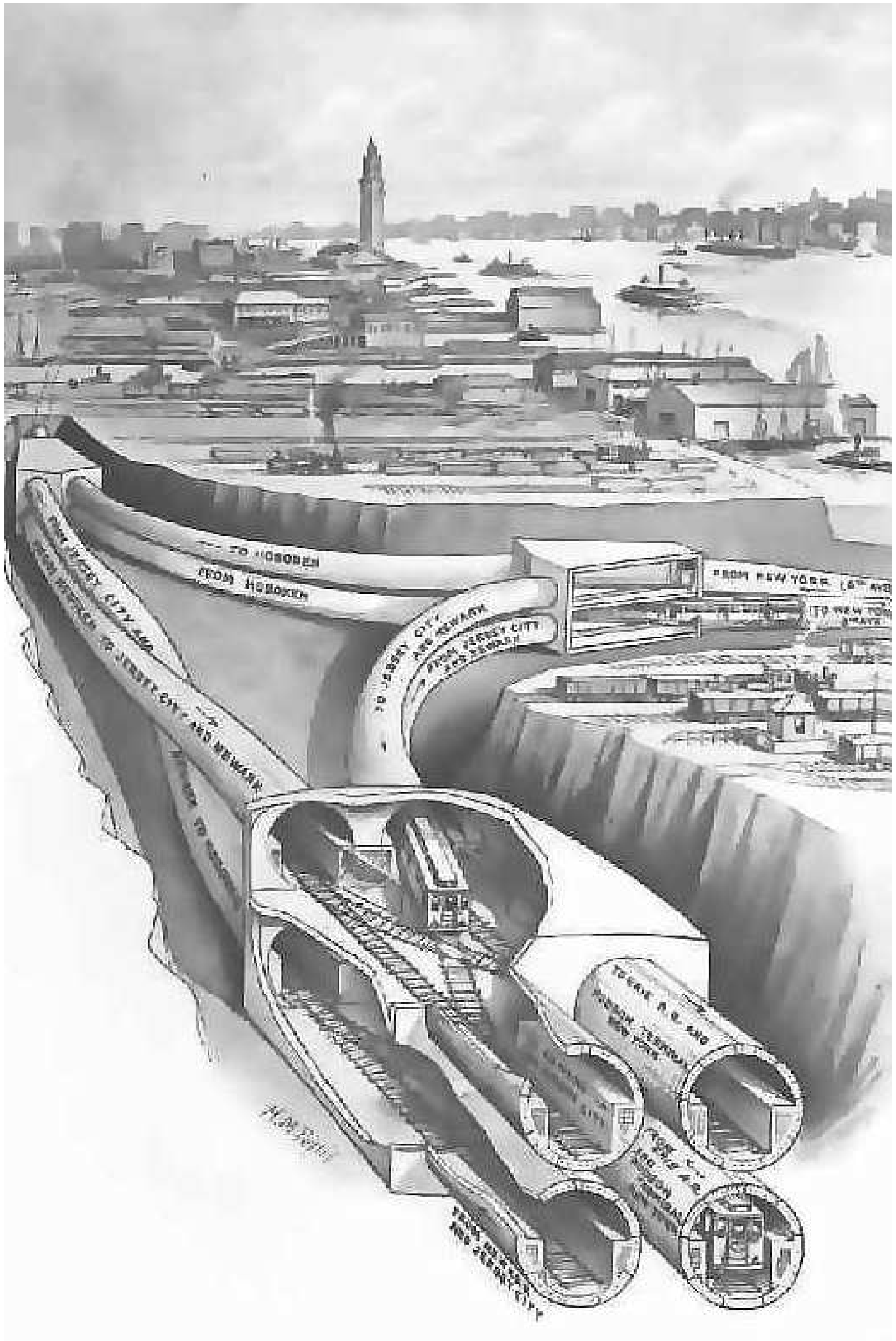


<u>Above</u>: caption: "One of the mammoth caissons about to depart for fields of useful engineering endeavor"



Caisson No. 1.

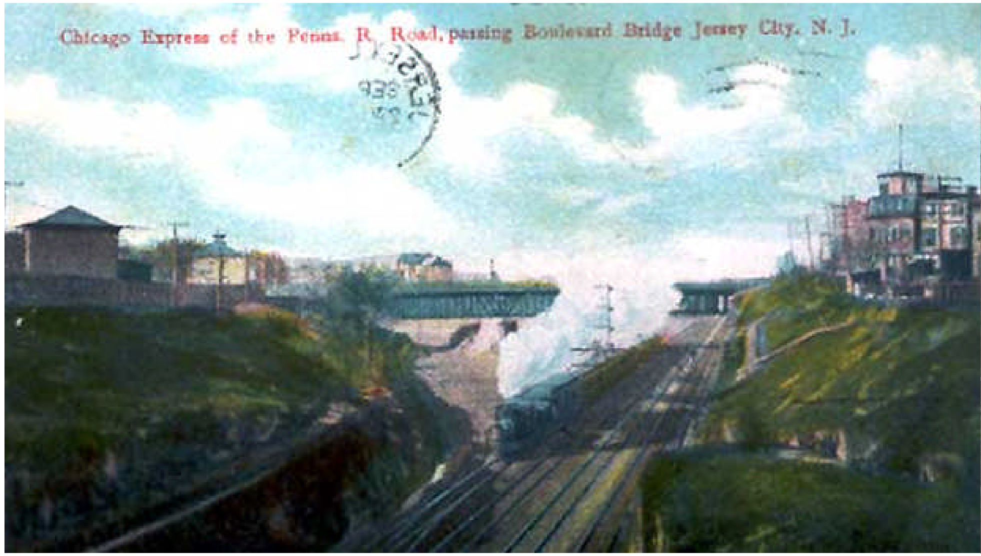
<u>Above</u>: caption: “Diagrams of Caisson 1. The 15th Street shaft is just beyond to the right. In the lower two diagrams the turnout to the top is for Hoboken and that to the bottom for Pavonia. The useless middle route ends immediately as shown and never had track*.*” Two shields moving west from the 15th Street shaft were then run into the caisson, the lower shield always a little ahead of the upper, carried through, and run out the far side to continue the tunnels on two levels curving to the north to *Caisson 2*. They were again carried through Caisson 2 and continued toward *Hoboken*, meeting shields coming down from the terminal in June and August 1907. Lengths of tunnel were then dug with shields south and west from *Caisson 1* and 2 until the opening of the first segment of the railway stopped work. When *Caisson 3* was completed work was continued from there.

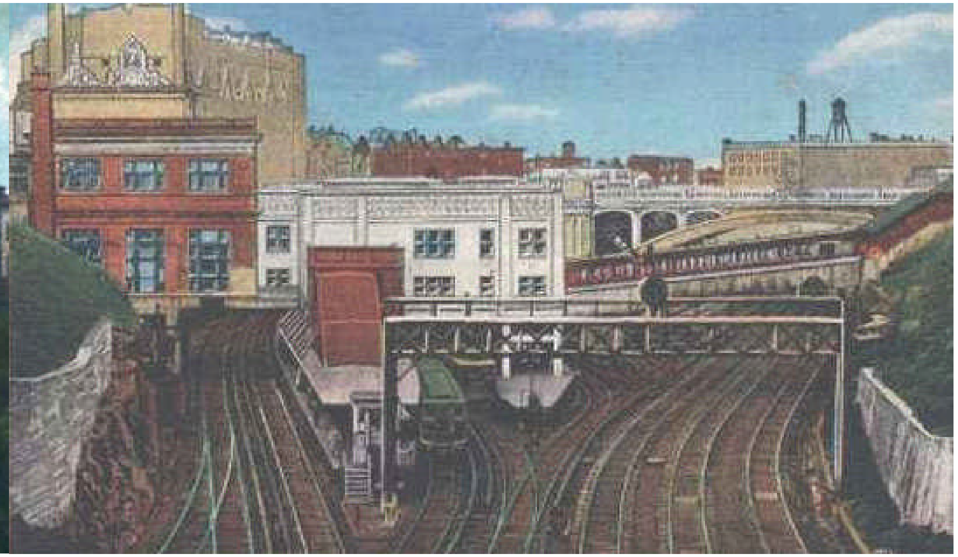


Below the *New Jersey* shore (approximately at the *Jersey City/Hoboken* boundary line), there was a complicated junction inside a planned double-deck caisson (which evolved into a single level junction) that was sunk 86-feet below high water and the tubes split. A short northbound extension went through a series of very sharp curves ending in Hoboken underneath the former *DL&W Railroad.* Two other tunnels left this junction and headed south, parallel to the river until just before *Grove Street Station* when they combined in a similar "Flying Junction" with the *Hudson Terminal*/*Journal Square* segments of the Tubes (along with two tunnels from lower *Manhattan*). The combined tubes headed west through *Jersey City* coming to the surface just before *Journal Square*.

Left: view of the complicated double *Flying Junction* on the New Jersey side of the river as it appeared in a contemporary issue of *Scribner's* magazine

The Joint Service Electric Railroad

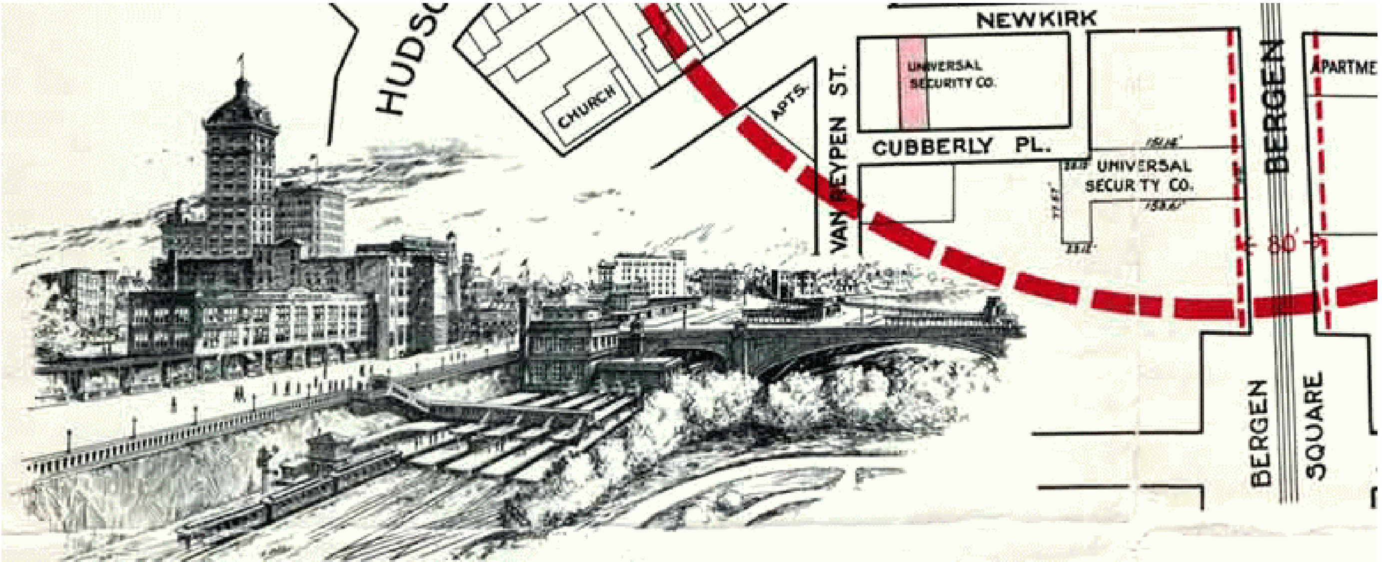




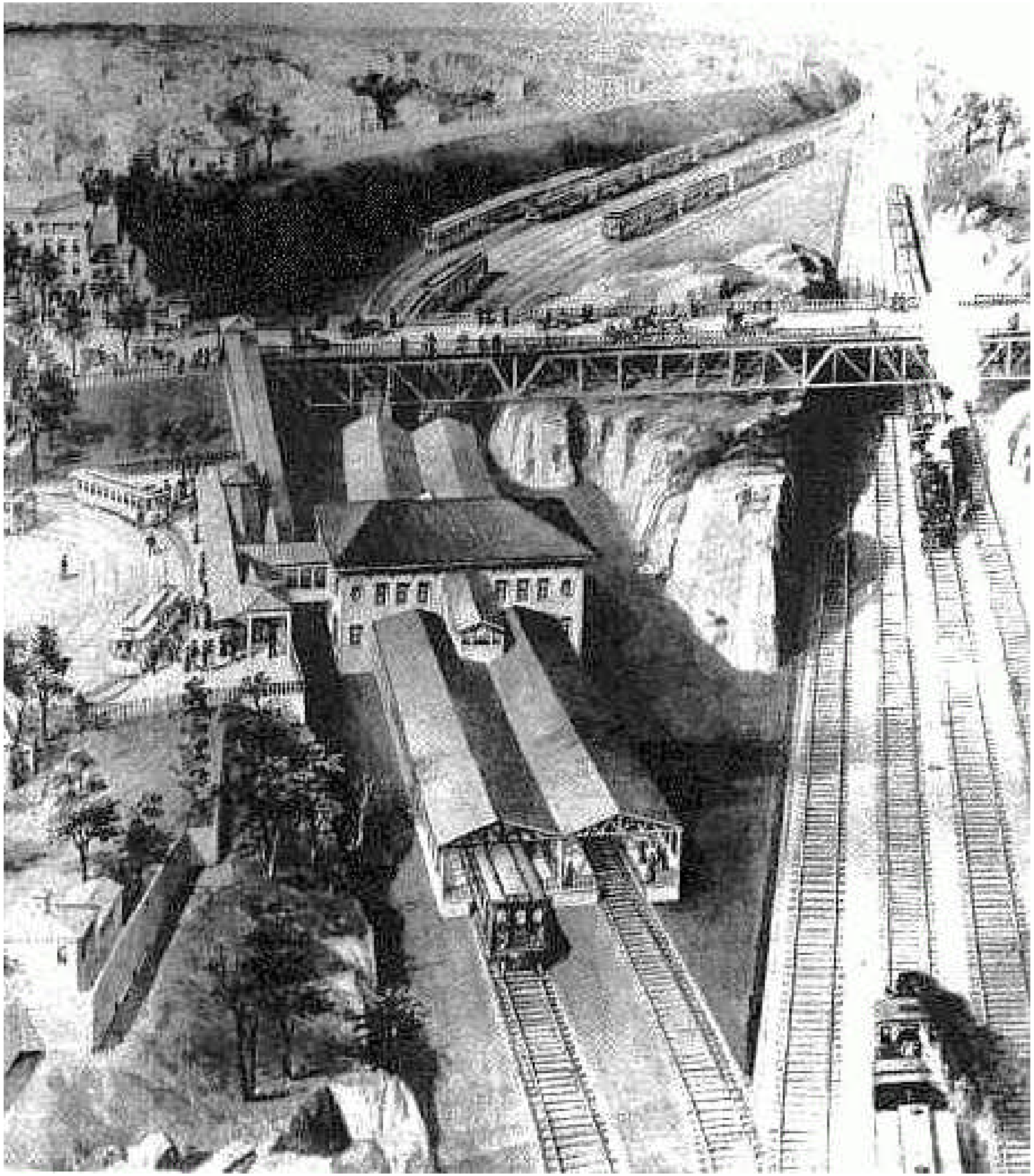
Cutting through the ridge of the *Palisades* in *Jersey City* at *Journal Square* (originally called *Summit Avenue*), the combined tunnel route came to the surface and continued west (via the *Meadowlands*), through *Manhattan Transfer* (in *Harrison*) to *Newark*. The section of the tubes west of Journal Square was a joint operation of the PaRR and the H&MRR, operated under the name "Joint Service Electric Railroad." As the Tubes came above ground (just before Journal Square) they were joined on the north by the mainline of the PaRR. These PaRR trains ran westward on a viaduct over *Railroad Avenue* from *Grove* and *Henderson Street/s* (the tracks reached Grove Street on an embankment from the PaRR terminal at the river's edge).

<u>Left</u>: caption: "Chicago Express of the Penn R. Road passing Boulevard Bridge Jersey City, N.J."

<u>Right</u>: caption: "Journal Square Hudson Tube Station, Jersey City, N.J."

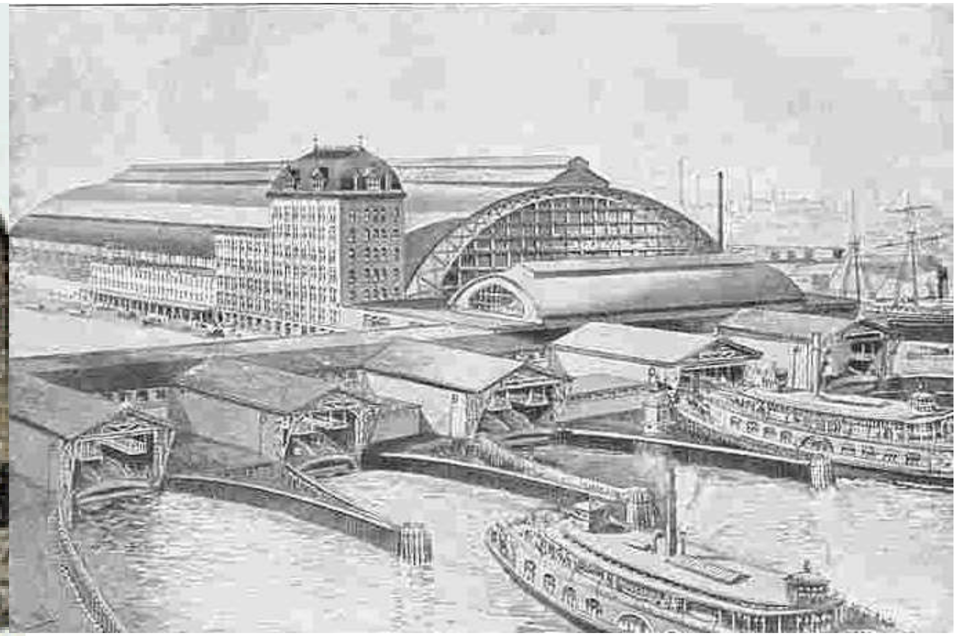


CONCOURSE FROM BOULEVARD TO SUMMIT AVENUE



<u>Left</u>: the original plan for the *Journal Square* H&MRR station befit the then bucolic area surrounding the station. The trolley loop as well as an entry hall leading to a separate passenger concourse were retained in the actual construction. However, both were on a grander scale than in the original plan, particularly the trolley loop which evolved into a major traction terminal and transfer point.

Exchange Place



Opened on July 19th 1909, the *Exchange Place* station was the main station of the PaRR serving *New York City*. Although the PaRR believed that the opening of New York City's *Penn Station* in 1910 would take over nearly all of the long distance passengers, the PaRR still expected a large volume of commuter and local passenger traffic into the *Jersey City Pennsylvania Station*. Three large and fast elevators connected the tube station with the street and with the PaRR Terminal. Thus, the H&MRR planned an expansive layout for its Exchange Place station; a layout which revealed itself to be unnecessary in short order since the importance of the Jersey City Penn Station diminished much more rapidly than had been expected (the economic life of *Jersey City* moved westwards, away from the river and Exchange Place to *Journal Square*). The station was in operation until the early 1960s when on November 17th 1961, PaRR trains made their last runs between Jersey City and *Newark* after 127 years of service.

<u>Left</u>: caption: "Circa 1900 image of the Montgomery Street side of the Pennsylvania Railroad terminal, Jersey City, N.J."

<u>Right</u>: caption: "Pennsylvania Railroad, Jersey City Station"

HUDSON & MANHATTAN RAILROAD CO.

From Stations of this Company in

NEW YORK, N. Y., HOBOKEN or JERSEY CITY

(Except Journal Square) N. J.

—TO—

PENNSYLVANIA RAILROAD CO. Station at

NEWARK, N. J.

Good for one continuous passage beginning within One Year in addition to date of issue stamped on back, except that for passage wholly within the State of New Jersey this ticket is good until used. This Company assumes no liability while passenger is on the Road of the Pennsylvania Railroad Company. Baggage will not be checked on this ticket. Subject to tariff regulations.

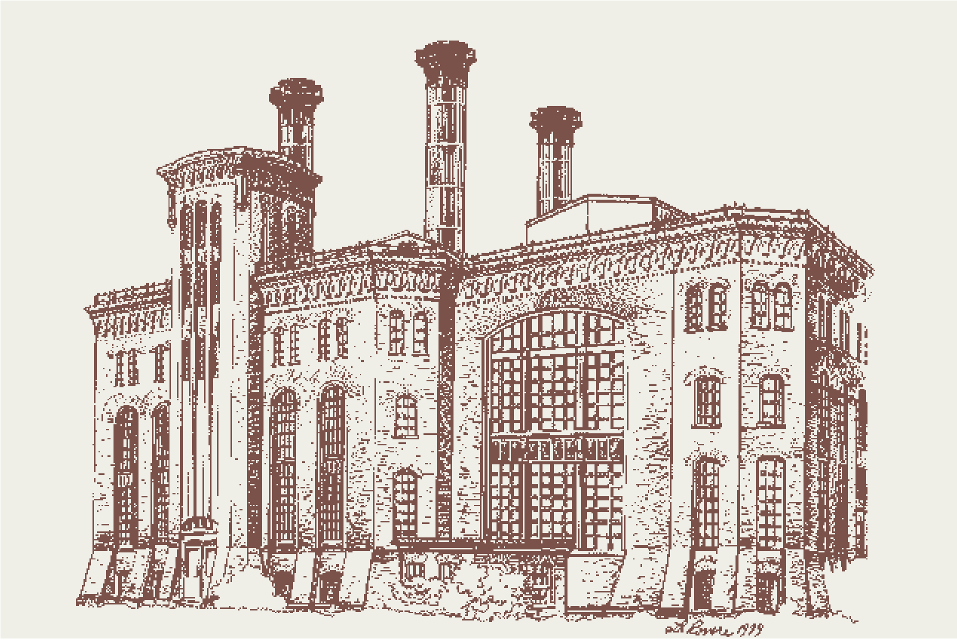
H.T. 2

K 192101

COMPTROLLER

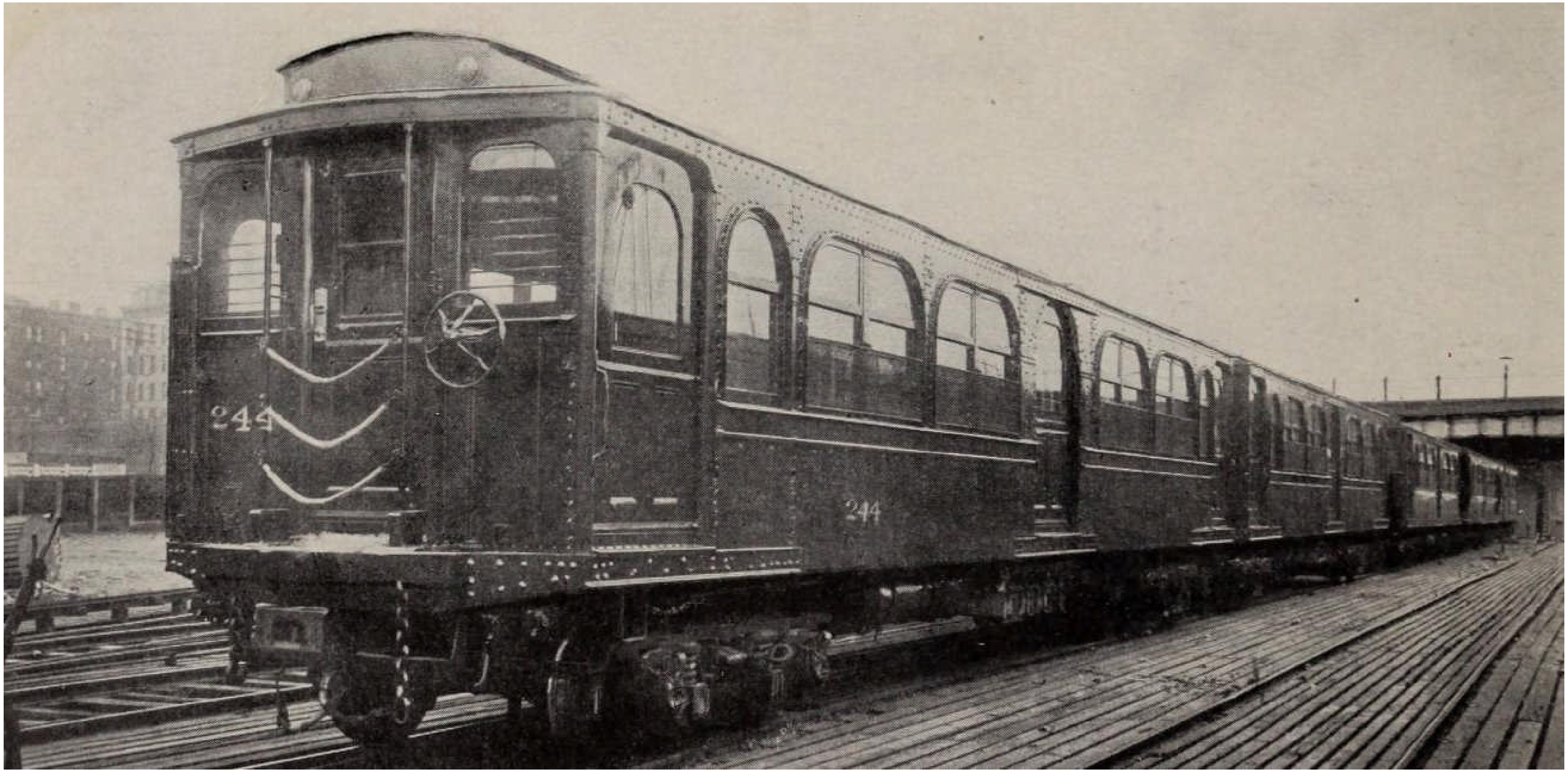
The *Exchange Place* station was blasted out of solid Palisades rock to a depth 85-feet below street level. The station was almost 1K-feet long, 150-feet wide and was located directly under the PaRR station. Its walls and roof were finished with concrete. The station was originally designed for four tracks, two of which were to be for through trains to *Manhattan* while the other two were for local trains terminating at the PaRR Station. Initial plans called for Exchange Place to be the H&MRR's branch-off point to the *Central Railroad of New Jersey* terminal on *Johnson Avenue.* At the time, it was assumed that the majority of passenger traffic would be entering the H&MRR station from the PaRR station, not from the street. Consequently, of the six elevator entrances at the station, two lead from the PaRR station to the street while four were to run between the PaRR's platforms and the H&MRR's Exchange Place platforms.

The Power to Serve



<u>Above L&R</u>: the H&MRR constructed its own powerhouse in lower *Jersey City* (between the *Exchange Place* and *Erie* station/s, near the intersection of *Washington* and *Second Street/s*). Architect *John Oakman* designed a neo-Norman structure that became an immediate landmark in the area. The Power House was closed in 1929 when it became more economical to purchase electricity from outside sources.

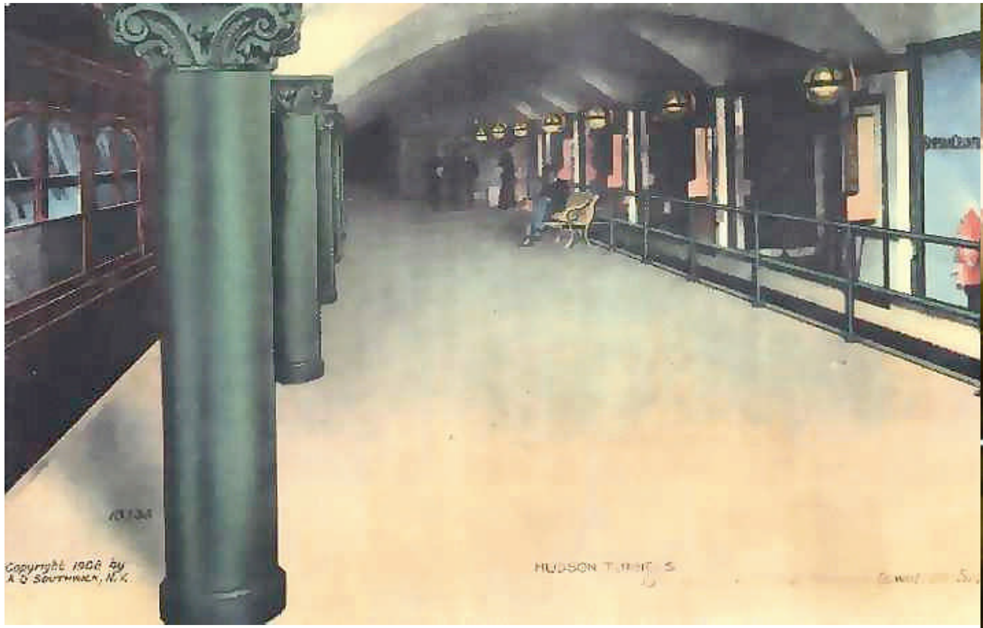
The McAdoo System



"…The McAdoo system of tunnels and subways consists of about twenty miles of underground and under-river construction in the Metropolitan district, and when the system is completed, the cost will reach nearly, if not quite, seventy millions of dollars. The work has afforded employment to an army of professional and laboring men, as many as eight thousand five hundred persons having been engaged at one time…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

<u>Above</u>: caption: "A train on the storage tracks makes ready to carry the traveler under the majestic Hudson"



"…There are two platforms in each terminal, the arriving and the departing. Passengers being given egress and ingress on opposite sides of the cars, thereby avoiding the station delays heretofore so perplexing. The stations are designed with a view to permanency, comfort and beauty. They afford ample facilities, not only for the business of the present, but for the increasing traffic of the future…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

<u>Above L&R</u>: HM&RR's *19th Street* station, NYC (closed in 1955)

HUDSON TUBES

Stations	Min
TO NEWARK	
Hudson Terminal	0
Exchange pl........	3
Grove st...............	6
Ch for Uptown tr	
Journal sq	9
Manhattan Trns..	16
Ch for P.R.R. tr	
Harrison(4h st)..	18
Park pl(New'k)	**20**
TO HOBOKEN	
Hudson Terminal	0
Exchange pl........	3
Erie R.R. sta......	6
Hoboken (La.RR)	9

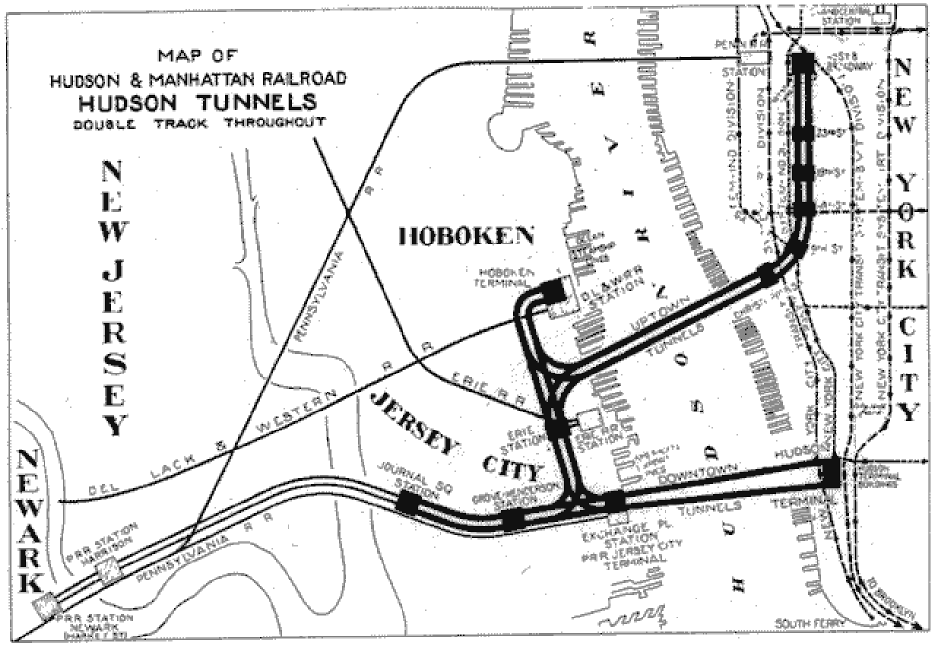
Stations	Min
TO HOBOKEN	
Ch for Broadway (B.M.T. subw)	
28th & 6th av....	1
23rd & 6th av....	2
19th & 6th av....	3
14th & 6th av....	4
9th & 6th av....	5
Christopher st......	6
Hoboken (La.RR)	15
TO NEWARK	
33rd st...............	0
Chg for Broadway (B.M.T. sub)	
28th & 6th av....	1

Stations	Min
19th & 6th av....	3
23rd & 6th av....	2
14th & 6th av....	4
9th & 6th av....	5
Christopher st......	6
Hoboken (La.RR)	15
Erie R.R. sta......	15
Grove st...............	17
Ch for Newark	
Journal sq	20
Manhattan Trns..	32
Harrison	33
Newark	35

HUDSON & MANHATTAN RAILROAD COMPANY

HUDSON RIVER TUNNELS

GENERAL OFFICES—30 CHURCH STREET, NEW YORK.



RUNNING TIME BETWEEN STATIONS

Note.—*A* Transfer Journal Square. *B* Transfer Erie Station.

(MINUTES)

FROM \ TO	Hudson Term'l, New York	Exchange Place, Jersey City	Erie Station, Jersey City	Hoboken	Grove Street, Jersey City	Journal Square, Jersey City	Harrison, N.J. (P. R.R. Station)	Newark, N.J. (P. R.R. Station)	33d St. Terminal, New York
Hudson Terminal, New York	....	3	6	9	[illegible]	[illegible]	18	20	*B*
Exchange Place, Jersey City	3	....	3	6	2	6	15	17	*B*
Erie Station, Jersey City	6	3	....	3	2	6	*A*	*A*	14
Hoboken	9	6	3	....	*B*	*B*	*B A*	*B A*	14
Grove Street, Jersey City	5	2	2	*B*	....	4	13	15	16
Journal Square, Jersey City	9	6	6	*B*	4	....	9	11	20
Harrison, N.J (Penna. R.R. Station)	18	15	*A*	*A B*	13	9	....	2	*A*
Newark, N.J. (Penna. R.R. Station)	20	17	*A*	*A B*	15	11	2	....	*A*
33d Street Terminal, New York	*B*	*B*	14	14	16	20	*A*	*A*	....

SCHEDULE OF TRAINS

Trains are operated at regular intervals day and night.

On week-days during morning and evening heavy traffic hours, the headway of trains is 3 minutes, except to and from Newark, where the headway is 6 minutes.

During other hours of the day until midnight the headway is 5 to 10 minutes.

For information regarding train service on Sundays and holidays, and between midnight and 7.00 a.m. on week-days apply to ticket agents.

Trains to and from 33d Street terminal (Broadway), New York, stop at Christopher, 9th, 14th, 19th and 23d Street Stations, New York.

Equipment—Trains of all-steel cars, electrically operated.

Public Telephones—At all stations

Parcel Check Rooms—At Hudson Terminal and 33d Street Terminal.

CONNECTIONS.

At Hudson Terminal New York—With Subways of New York City Transit System, IRT Division, BMT Division and Ind. Division.

At Pennsylvania R.R. Station Newark—With Pennsylvania R.R. and Lehigh Valley R.R. trains to and from Pennsylvania Station, New York

At Exchange Place (P. R.R. Jersey City Terminal)—With local Pennsylvania R.R. trains.

At Erie Station Jersey City—With Erie R.R. and N.Y S. & W. R.R.

At Hoboken—With D. L. & W. R.R.

At 33d Street and Broadway (entrances also at 30th Street), New York—With Subways of New York City Transit System, IRT Division, BMT Division and Ind. Division, and with Pennsylvania R.R. and Long Island R.R. Terminal (one block).

Regularly scheduled joint service trains between Hudson Terminal, N.Y., and Newark, N.J., connect with incoming and outgoing through trains of Pennsylvania R.R. and Lehigh Valley R.R. at Pennsylvania R.R. Station, Newark, N.J. For schedules, consult time-tables of those railroads

Ticket office of Pennsylvania R.R. is located on main concourse of Hudson Terminal, New York. Through and local railroad tickets and Pullman tickets may be obtained at this office.

"…There is always a gentle breeze here. The trains in their passing too and fro act as giant pistons whose every movement changes the atmosphere in the tunnel, forcing out the foul air, and creating a vacuum in the rear which draws in a supply of fresh air from the surface, thereby giving an absolutely perfect ventilation…"

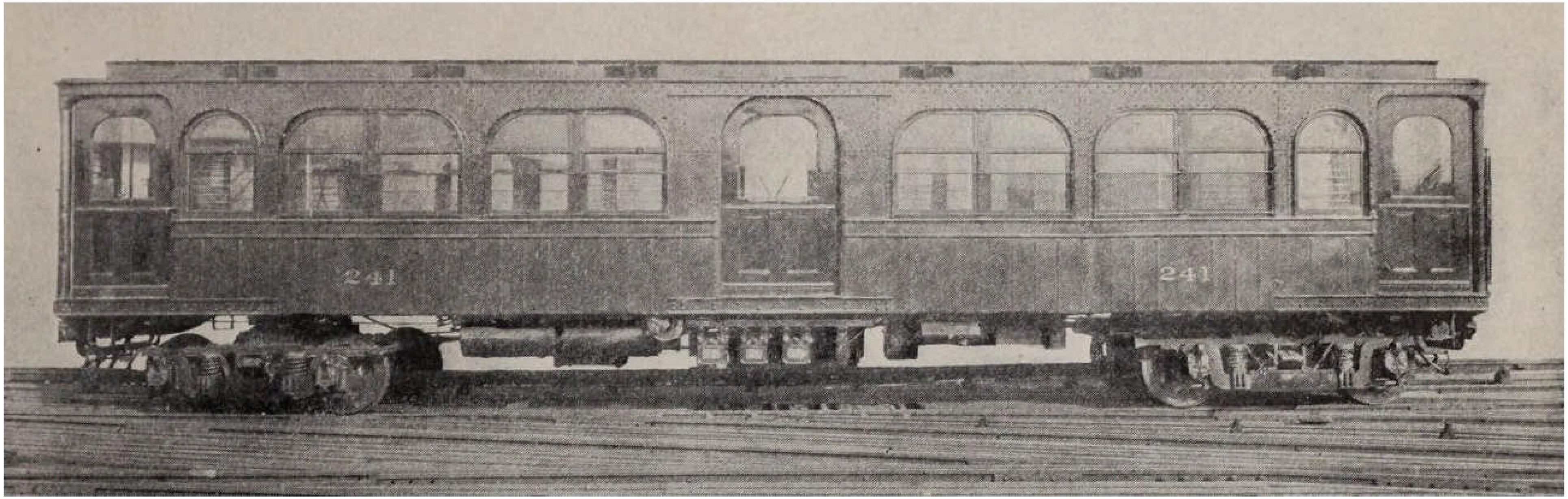
RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

<u>Left</u>: H&MRR system map and time schedule (ca. 1910)

"…Steel and concrete alone enter into the construction of these subterranean stations. Vaulted arches rise on all sides, from whose artistic and substantial sides gently glow the irridescence of the electric bulb, which casts over the scene a gentle halo of early twilight…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

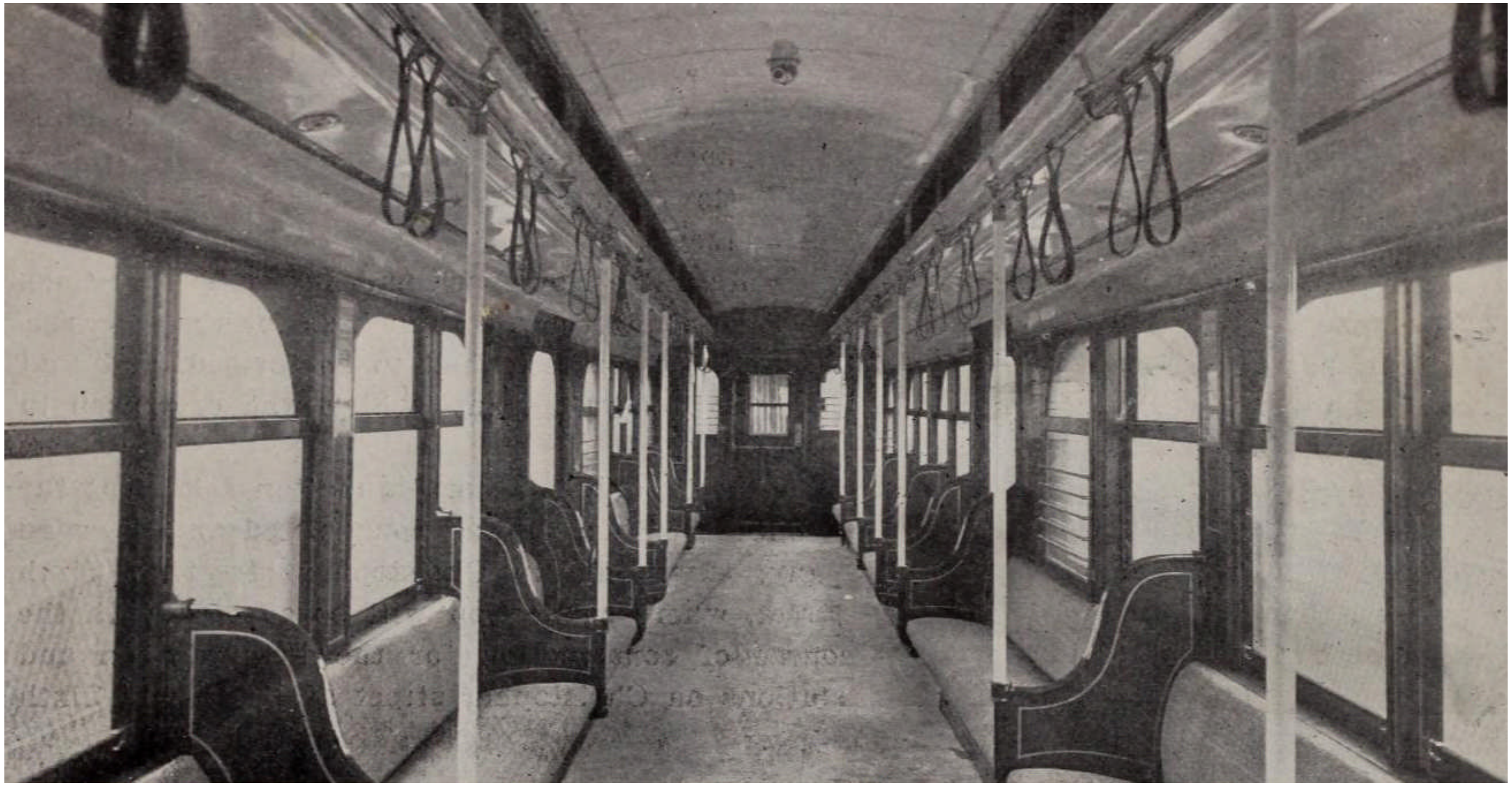
Left: caption: "A view of Hoboken station just before the official opening of the Tubes"



"…The cars are constructed exclusively of steel and carborundum, and are absolutely fireproof. The trains are vestibuled and the cars divided into sections; entrance and exit therefrom is obtained through sliding doors at both ends and in the center of each car. These are controlled and operated by compressed air. A train is made up of eight cars, forming a complete compressed air system, automatically signaling the motor man to 'go ahead,' when every car door in the train has been securely closed…the cars are electrically propelled, lighted and heated, and run under a headway of ten minutes, completing the trip between the Hoboken terminal and Nineteenth street, New York, in about ten minutes…"

RE: excerpt from *The Hudson & Manhattan Tunnels in Picture and Story*

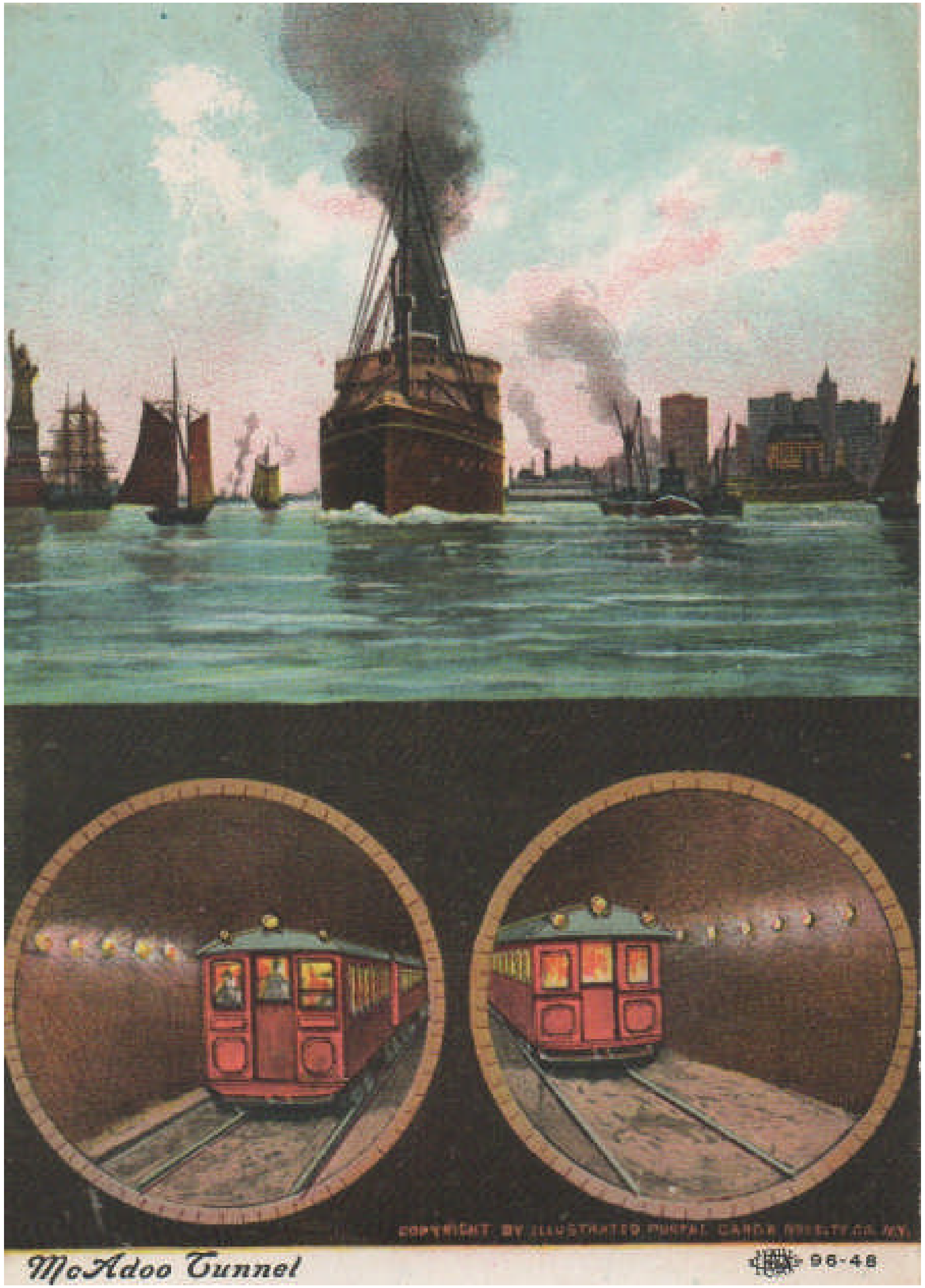
Above: caption: "This is how the steel cars look in daylight"



Part 4

Decline & Fall

Boom & Bust

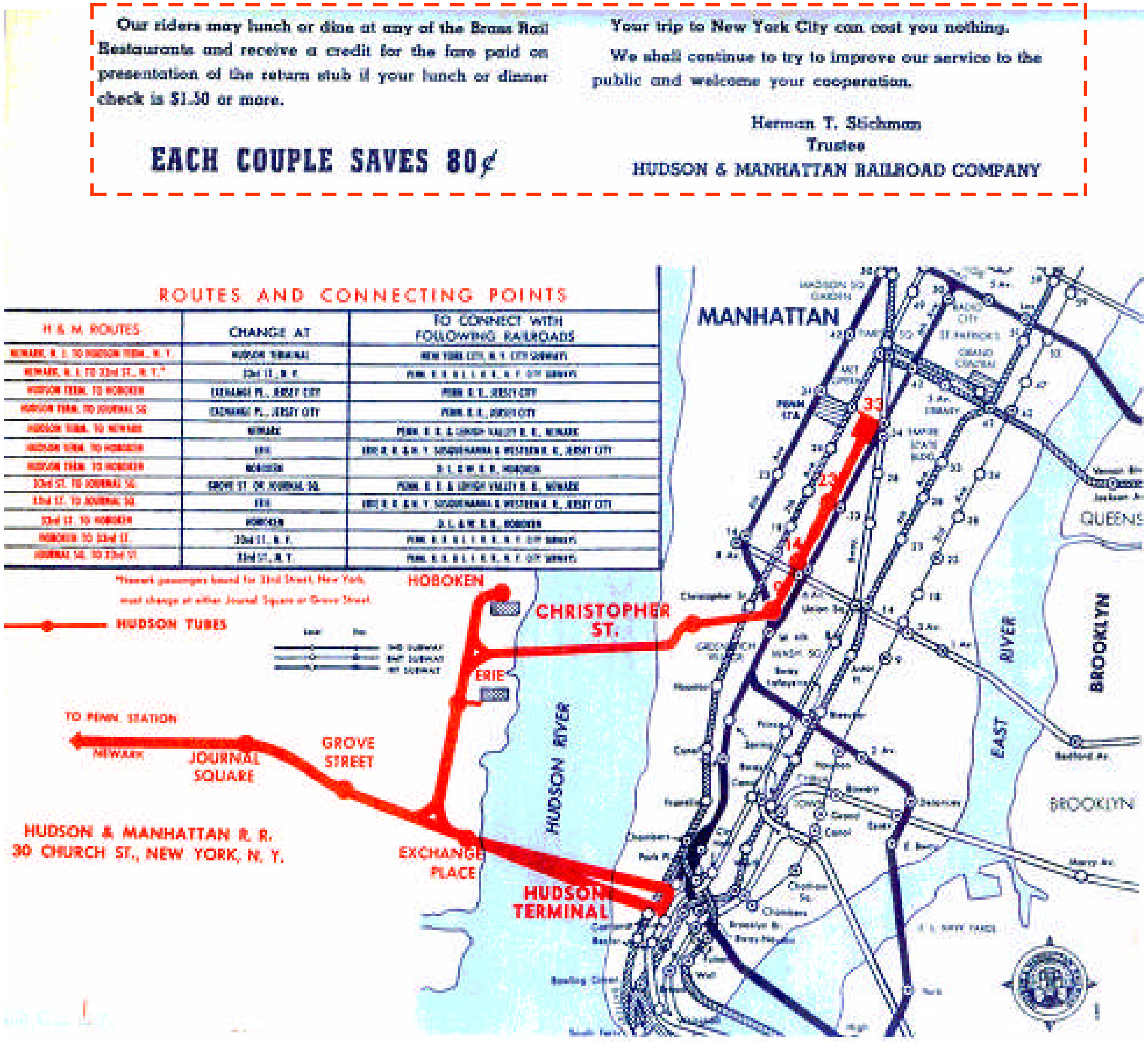


From the opening of the system through WWI, the "McAdoo Tubes" did well financially. However, by the early 1920s there was a leveling-off in passenger volume and profits for the H&MRR became stagnant and financial problems began affecting the upgrading of the H&MRR's rolling stock and facilities. In 1927, the *Holland Tunnel* opened connecting *Jersey City* and *Manhattan* for vehicular traffic and the depression began in October 1929. A long decline in both passengers and in profitability thus began. The supplemental construction of both the *George Washington Bridge* and *Lincoln Tunnel* made matters even worse for the cash-strapped commuter railroad. With WWII came a boom in passenger volume, but with the peace the H&MRR entered into a period of steady financial decline (like many other railroads in the post-WWII era). Labor disputes and a management crisis in 1947 added to the turmoil (the H&MRR even tried to lure passengers away from the NYC Subway system for intra-Manhattan travel to boost ridership).

In the early 1950s, a drive was implemented to generate revenue by increasing rental of commercial space for retail establishments. The H&MRR even considered either closing the entire uptown section and using the downtown tubes for trolley service or abandoning the railroad completely. At this time, there were also rumors circulating that the H&MRR was trying to sell itself to the *Port of New York Authority*.

<u>Above</u>: caption: "The real Estate Department has fostered new, modern stores at Hudson Terminal and at the 33rd Street Station"

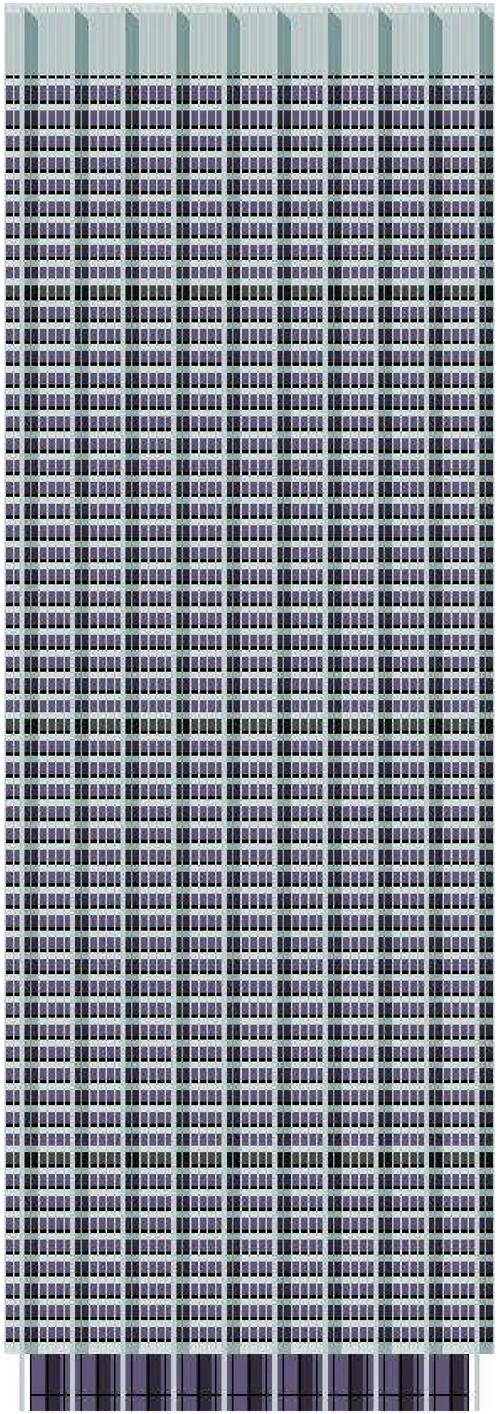
<u>Left</u>: caption: "Commuter's Cafe menu, Hudson Terminal"



<u>Left</u>: caption: "Our riders may lunch or dine at any of the Brass Rail Restaurants and receive a credit for the fare paid on presentation of the return stub if your lunch or dinner check is $1.50 or more. Your trip to New York City can cost you nothing. We shall continue to try to improve our service to the public and welcome your cooperation."

On August 1st 1954 the H&MRR shut the *19th Street* station as a cost-savings measure. On August 11th 1954, several H&MRR bond holders applied for receivership for the company under *Chapter 10* of the *Chandler Act,* but the H&MRR appealed. On November 19th 1954, the H&MRR filed for voluntary reorganization (under *Chapter 77*). The courts denied this but permitted bankruptcy proceedings under the Chandler Act (as desired by the bond holders). On December 8th 1954, the H&MRR consented to the Chapter 10 reorganization and on December 14th 1954, *Herman T. Stichman*, New York State Commissioner of Housing, was appointed Trustee of the H&MRR. Under Trustee Stichman, steps were taken to improve service and the railroad's financial position. On May 22nd 1957, *Arthur W. Page*, made a report to the *Metropolitan Transit Commission* on improving rail transit between *New York* and *New Jersey*. He recommended the creation of a bi-state public agency: "The Metropolitan District of New York & New Jersey," as well as the appropriation of $55 million for rehabilitating the New Jersey commuter railroads. The long running financial pressures on the H&MRR acted to preserve the Tubes in their original form. Thus, by 1957, the Hudson Tubes were, essentially, as they had been at their opening a half-century earlier.

New Era



"David Rockefeller's gamble on One Chase Plaza (1955) entailed extraordinary risk. If it were not supported by positive momentum throughout the whole Lower Manhattan real estate market, the first financial district office tower to be built in a generation could well prove a disaster for Chase and a serious blow to the family fortune. Accordingly, David mobilized the downtown business elite around a high-profile strategy for redeveloping the entire district in the image of international corporate modernity. To this end, in 1956 David Rockefeller founded the Downtown Lower Manhattan Association (DLMA)."

RE: excerpt from *Divided We Stand*

<u>Left</u>: *One Chase Plaza* (elevation)

"A proposal to build a World Trade Center in the financial district of downtown Manhattan generated widespread enthusiasm among New York business executives and government officials last week. Estimated to cost $250 million, the center would be the first stage of a $ 1-billion redevelopment program for lower Manhattan proposed over a year ago. The plan calls for clearing a 13-acre site on the East River. Only two existing buildings would remain. An elevated plaza, two stories above grade, would cover the entire site. Three buildings would rise out of the plaza nine-story World Trade Mart, 880 x 365-feet in plan, with two interior courtyards; a 50-to-70-story commerce office hotel building; and a Central Securities Exchange Building. The giant World Trade Mart would provide office and display space for international trade activities, offices for insurance brokers and travel offices. It would contain exhibit space for governmental trade missions, space for commodity exchanges and an international clearing house for merchants…"

RE: excerpt from *ENR* (February 1960)


7 World Trade Center
City Hall Park
World Trade Center
Battery Park City
Originally proposed WTC site
Battery Park

"…The commerce building would house U.S. and foreign business, banking and brokerage firms in international markets. A world trade club would provide meeting rooms for foreign and American citizens engaged in this field. Ten floors at the top of the building would furnish 500 to 700 hotel rooms to accommodate transient shippers and international merchants. Planners hope to have the New York Stock Exchange as a tenant in the Central Securities Exchange Building to be a world trading center. Stock Exchange officials have made no commitment yet. Shopping arcades occupy the main concourse at street level and the floor above. One underground level contains parking, loading and storage areas. A proposed heliport, adjoining the site on the East River, would provide rapid access to metropolitan airports..."

RE: excerpt from *ENR* (February 1960)

<u>Above</u>: artist’s rendering of proposed east-side WTC

"…The Lower Downtown Manhattan Association, a civic organization representing business firms and real estate owners in downtown New York, sponsors the redevelopment studies. The association's report recommends that the Port of New York Authority make detailed studies on planning, financing and putting the center into operation. This recommendation was sent to Governor Rockefeller of New York, Governor Meyner of New Jersey and Mayor Wagner of New York City. Association Chairman David Rockefeller said he expected most, if not all, development money to represent private investment. There is no target date for construction. But Mr. Rockefeller expressed hopes that the Trade Center could start taking leases when foreign visitors arrive for the New York World's Fair in 1964. Skidmore, Owings, and Merrill, New York City architects, are planning consultants for the Lower Downtown Manhattan Association."

RE: excerpt from *ENR* (February 1960)

"What's in it for me?"

NJ Governor *Richard B. Meyner*, Spring 1961

RE: comment made upon viewing the plan to locate a WTC on Manhattan's east-side

"For more than three centuries, foreign trade has been the lifeblood of the Port of New York. The port has been the magnet which has attracted many other businesses and industries which made this metropolis the world's largest and made it prosper as a center of finance, publishing, communications and the arts…Certainly no one would question the need to continue to promote and strengthen the facilities and institutions of the Port of New York. This is the sole purpose of the Trade Center…We all recall how Rockefeller Center turned a stagnant Sixth Avenue into the gleaming skyscraper city it is today. We all recall how the UN turned the old gas house district along the East River into a soaring symbol of man's hopes for peace. In the same way, the Trade Center will dramatically revitalize a drab and decaying area of Lower Manhattan and transform it into a magnificent international marketplace for people from all over the world."

***Austin Tobin*, PNYA Director**

RE: May 1st 1961 testimony to the NYC Council

The WTC Moment

“In the WTC ‘moment,’ it became possible to further dispense manufacturing from downtown, move what remained of New York’s port to New Jersey and bury Lower Manhattan’s rundown piers under virgin real estate. Also, immured were any lingering hopes for a cross-bay freight tunnel. The WTC ‘moment’ occurred between 1957 & 1958 and entailed several key events:

- ***Robert F. Wagner (Independent) was elected NYC mayor in 1957 thus, the Longshoreman’s Union lost their Tammany Hall support which was the port’s last line of defense;***
- ***Developers/contractors such as Tishman formed a strategic alliance with building trades unions guaranteeing work and no strikes, and;***
- ***Nelson Rockefeller – David’s brother, was elected NYS governor in 1958”***

RE: excerpt from *Divided We Stand*

<u>Left</u>: the Brothers Rockefeller (David, at left) celebrate Nelson's (at right) 1958 *New York State* Gubernatorial Victory

"After decades of shunning railroads as a bottomless pit, Austin Tobin and the PA finally bought in. The new WTC was born legislatively joined at the hip to the Hudson Tubes, New Jersey's bankrupt commuter life-line to thousands of Manhattan jobs. The WTC had been extracted from the east-side renewal scheme and plunked down a mile across town on top of Radio Row. As part of the package for New Jersey, the PA would build a transportation center and office complex at the tube's terminal in Jersey City. But implicit in the deal - though it could never be publicly acknowledged, was that New Jersey got what remained of the Port of New York."

RE: excerpt from *Divided We Stand*

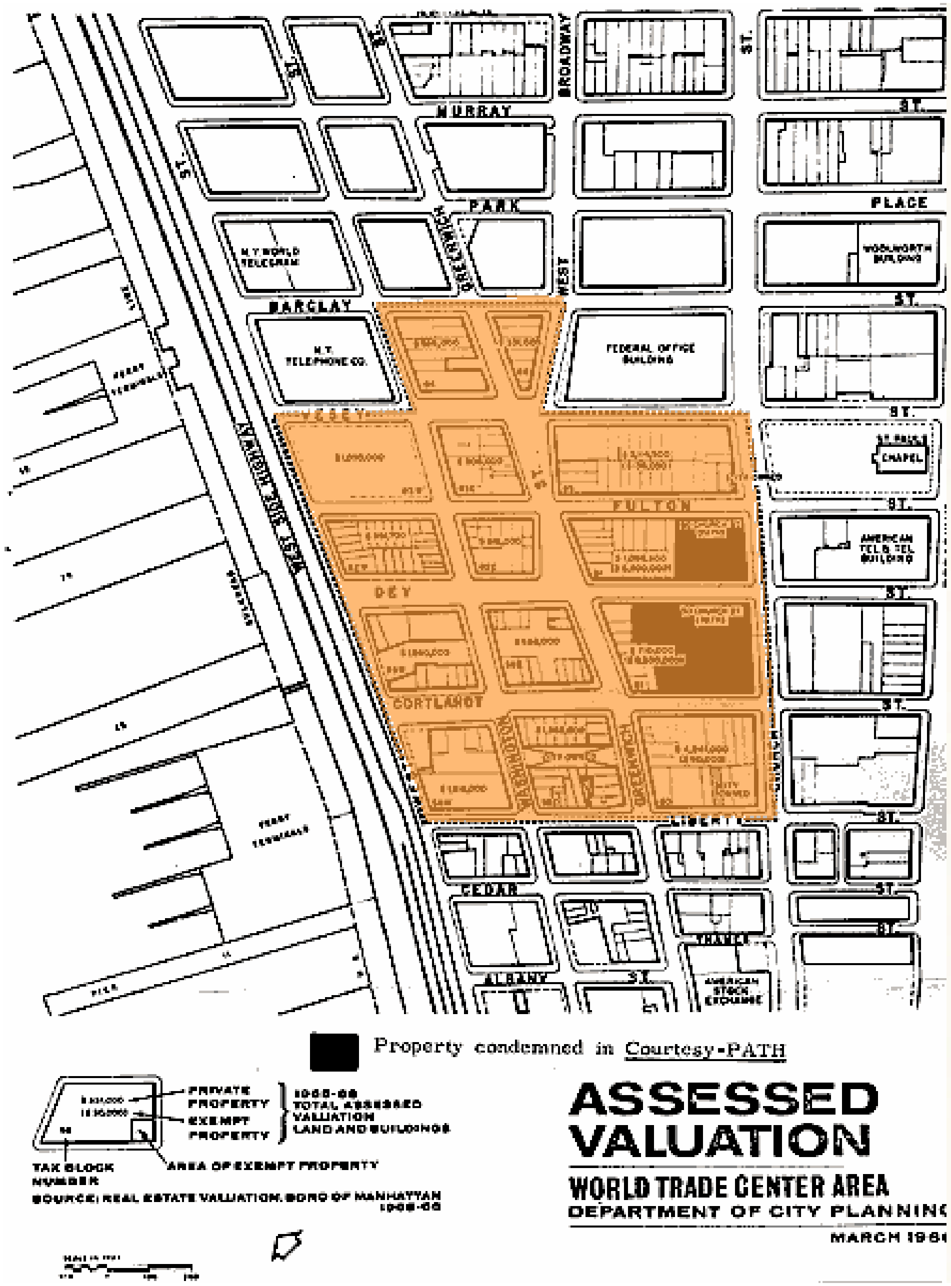
The Beauty of the Compromise

"The beauty of the compromise is that while substantially meeting New Jersey's objections, it gives New York all it really wanted in the first place"

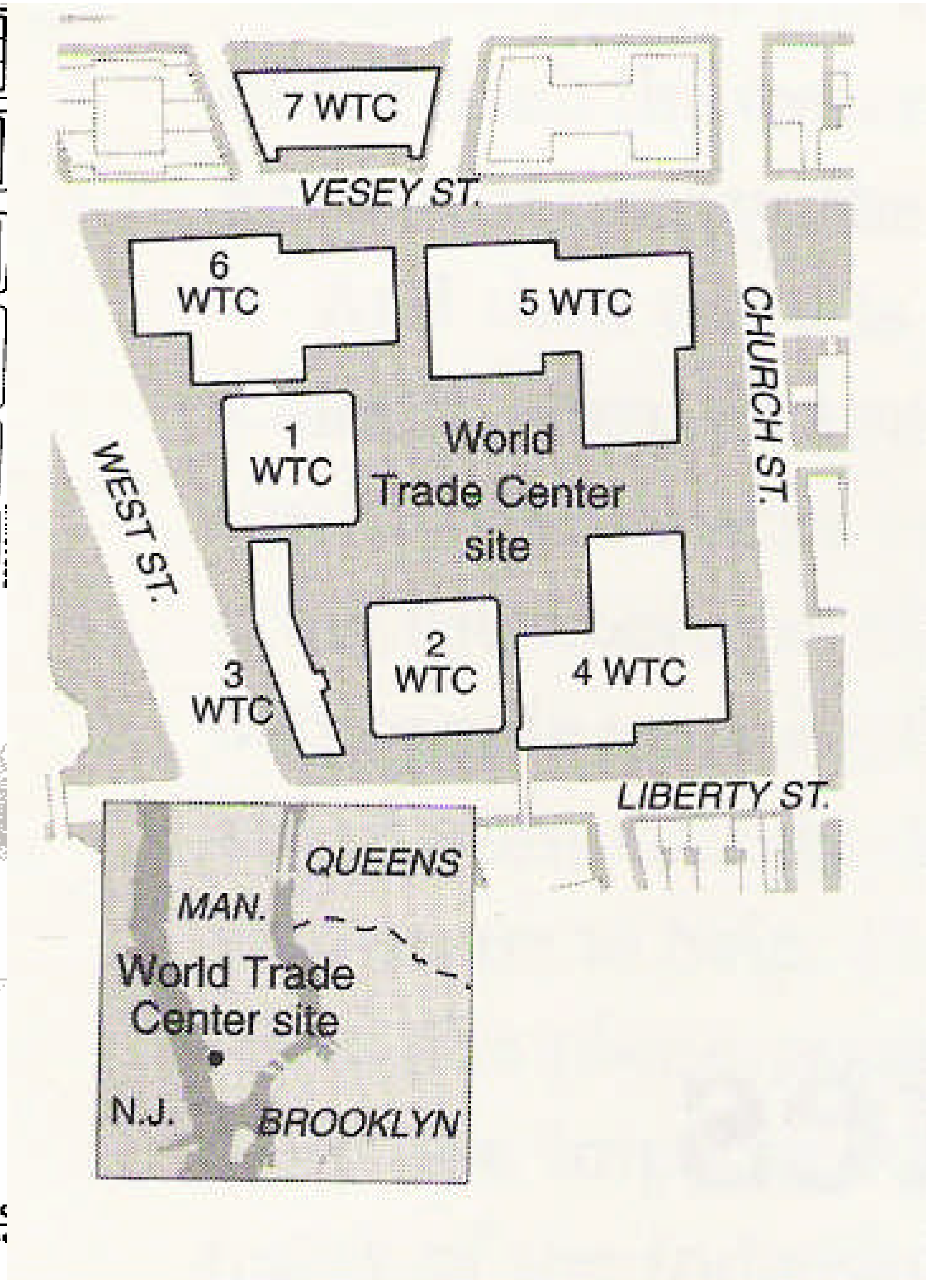
Newark Sunday News

RE: PNYA's proposal to move the proposed WTC from the east-side to the west-side of *Manhattan* – above the 15-acre site of the *H&MRR* which the PNYA had taken over. It provided better subway connections and a direct-link with *New Jersey*, which saved-face for NJ politicians. PATH: *Port Authority Trans Hudson,* was born.

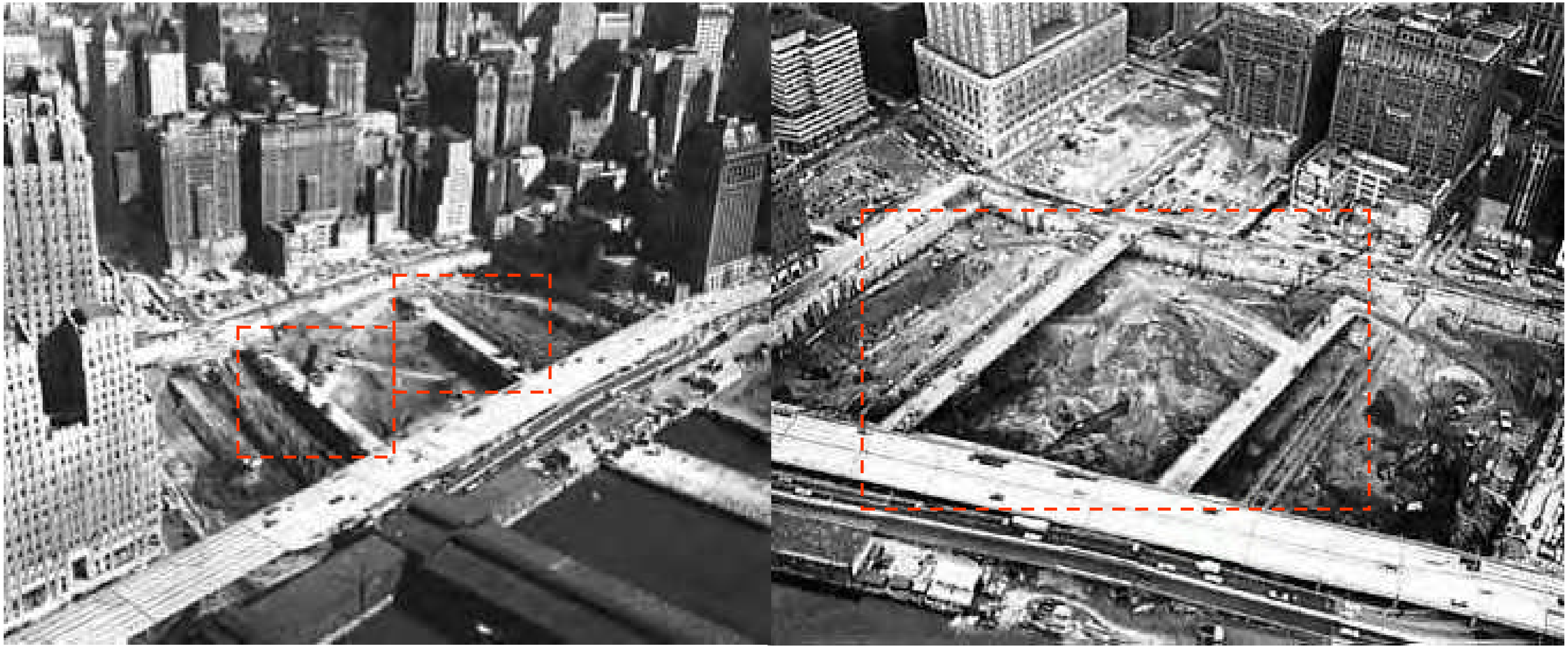
"At least now we can see the damn thing"
***Richard Meyner*, Governor of *New Jersey* (1962)**
RE: moving of the WTC from the east-side of *Manhattan Island* to the west-side (across the *Hudson River* from *New Jersey*)
<u>Left</u>: ca. 1940s map of the "Radio Row" area (outlined) of lower *Manhattan*



Before WTC



After WTC



"Two rail tunnels – the tubes for the PATH train to New Jersey – ran right through the foundation site. Trains carrying nearly 80,000 passengers ran through the 500-foot iron tubes that traversed the site. The excavation would unearth and expose them, and a way had to be found to jack them up as the foundation was constructed around them."

RE: excerpt from *102 Minutes*

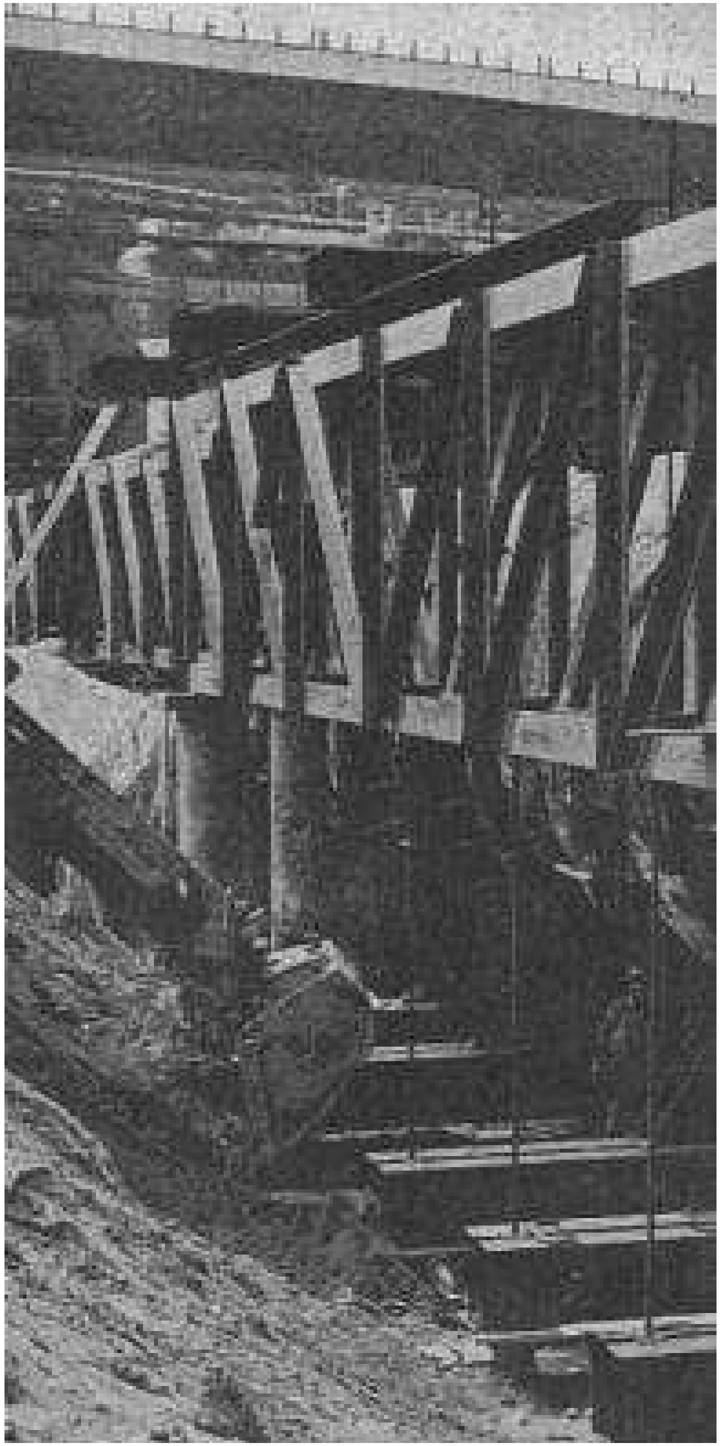
<u>Above L&R</u>: WTC site excavation exposing the H&MRR tubes


"All of the digging must be done over, under and around a pair of subway tunnels that carry nearly 600 commuter trains through the excavation daily. Without interruption of train traffic, the live and dead loads of about 1,000-feet of each tube must be transferred from the soil to a suspension system that will hold the tubes about thirty feet in the air for the next two years."

RE: excerpt from *ENR* (ca. 1968)

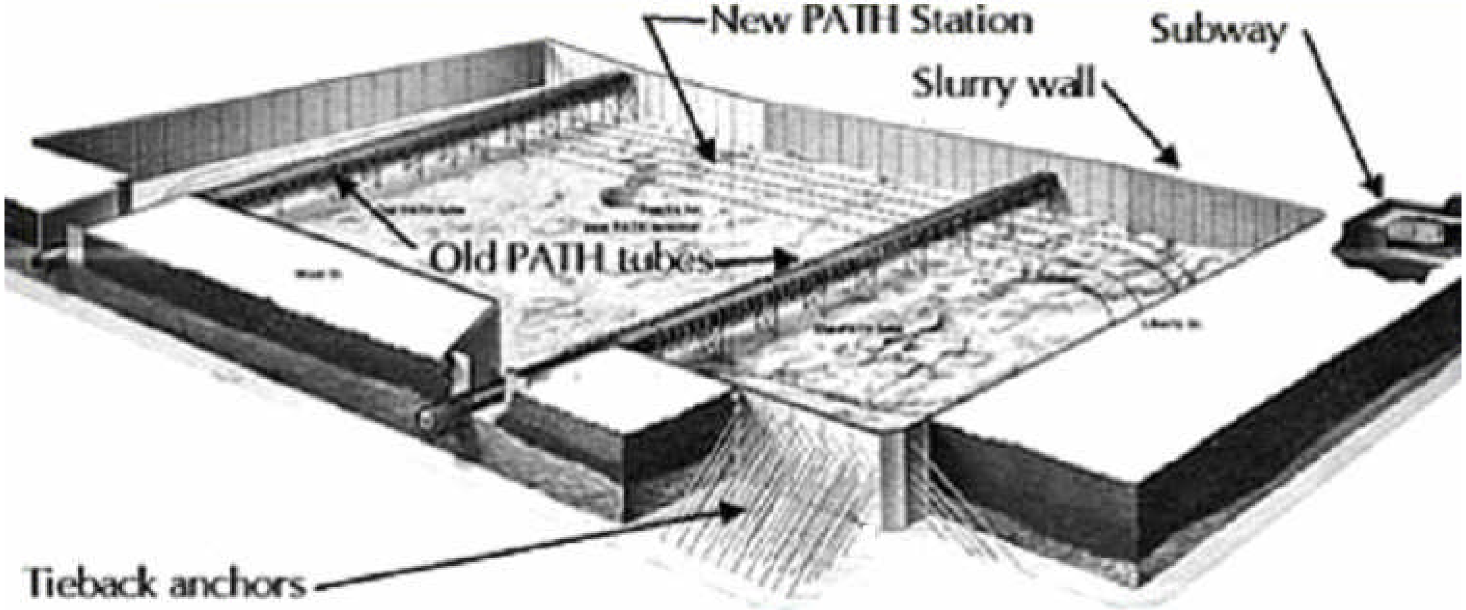
"To support the tubes as the earth was removed from under them, the contractor installed a line of 24-inch diameter caissons 40 to 50-feet center-to-center on either side of each tube. These were socketed into rock two-feet below final sub-grade, cleaned, and filled with a steel core and concrete before any excavation was done. During this operation, the PNYA had manned listening posts inside the tubes with telephone connections to the rigs above. Telephone communications were also maintained whenever work was performed within ten-feet of the tubes. The contractor was allowed to excavate to two-feet below the spring line, cutting off the caissons as he excavated to keep them out of his way. At this point the contractor cut the caissons and capped them with steel plates. American Bridge Division of U.S. Steel Co. spanned the caissons with trusses eight-feet deep and spanned the tube with WF beams. The contractor then cut a five-foot-wide transverse trench under the tube and slid a saddle through it. The saddle was attached to high-strength rods extending from the cross-members above, and the rods were tensioned to pick up the load of the tube…"

RE: excerpt from *ENR*



"…To prevent settlement, the contractor was allowed to dig only one trench at a time in each bent, since ten-feet was determined as the maximum length of tube that could be left unsupported. To speed the work, however, the contractors used wide, flat steel straps that would be slid under the tubes at the edge of each hole to temporarily support the tube while another trench was cut for another cradle. With the tubes safely supported, the contractor covered each with 3x12 fire re-tardant plank decking supported on 12x12 timbers. This will provide the tubes with protection against falling objects. The tubes then will be removed and replaced by new tracks in a new PATH terminal under the new buildings."

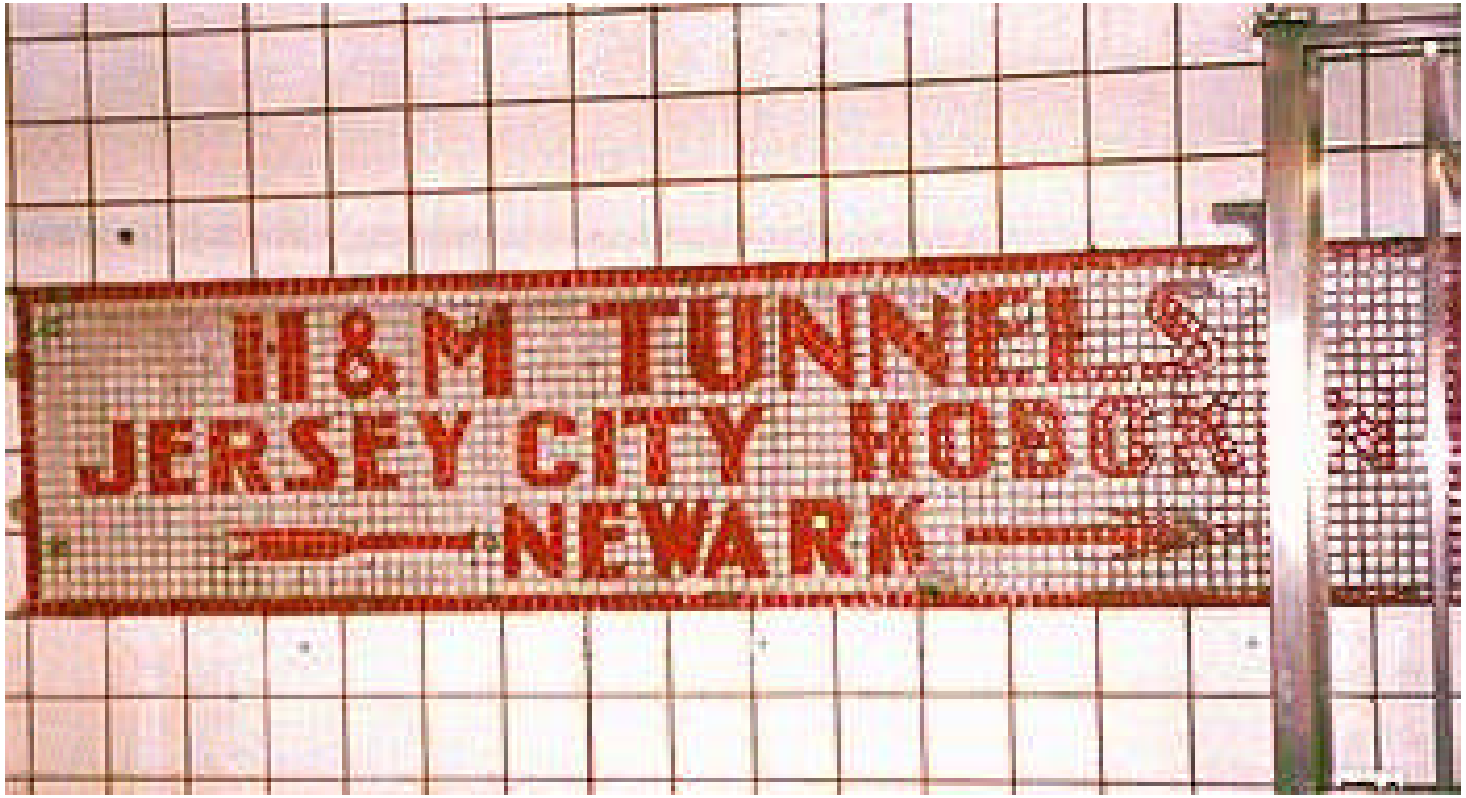
RE: excerpt from *ENR*

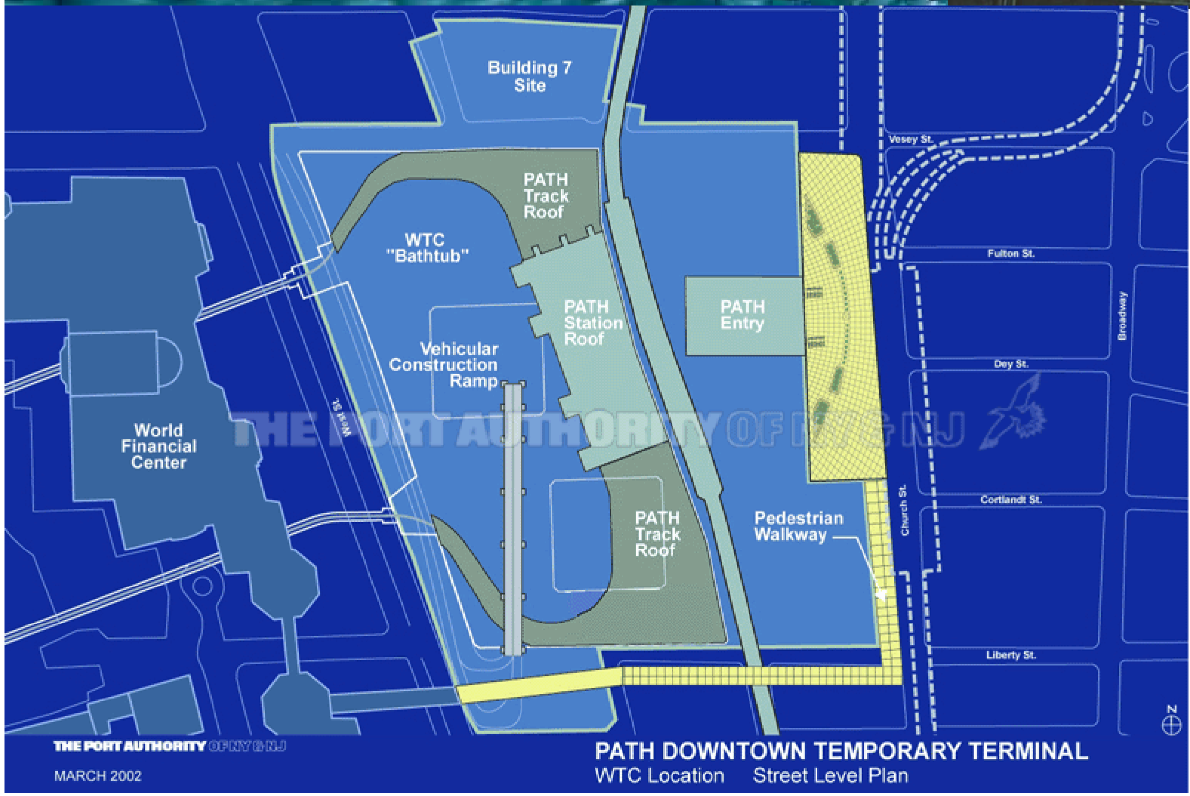


"The tubes were unearthed nearly three-quarters of a century after they had been built, and after all that time in the cool cocoon of the earth, the summer heat was a shock to their cast-iron skin. The sudden heat caused the iron to expand, so it was decided to cut a two-inch slot in each of the tubes to relieve the pressure. With the tubes continuing to run, the tunnels were nestled on cradles deeply rooted in bedrock. Soon after the two-inch slots were cut in the PATH tubes, a passenger who saw sunlight pouring through the slot got off at the nearest station hysterical that the tunnel was breaking apart, not knowing of the existence of the open trench they had just passed through. The PA decided to wrap sheet metal around the slot openings."

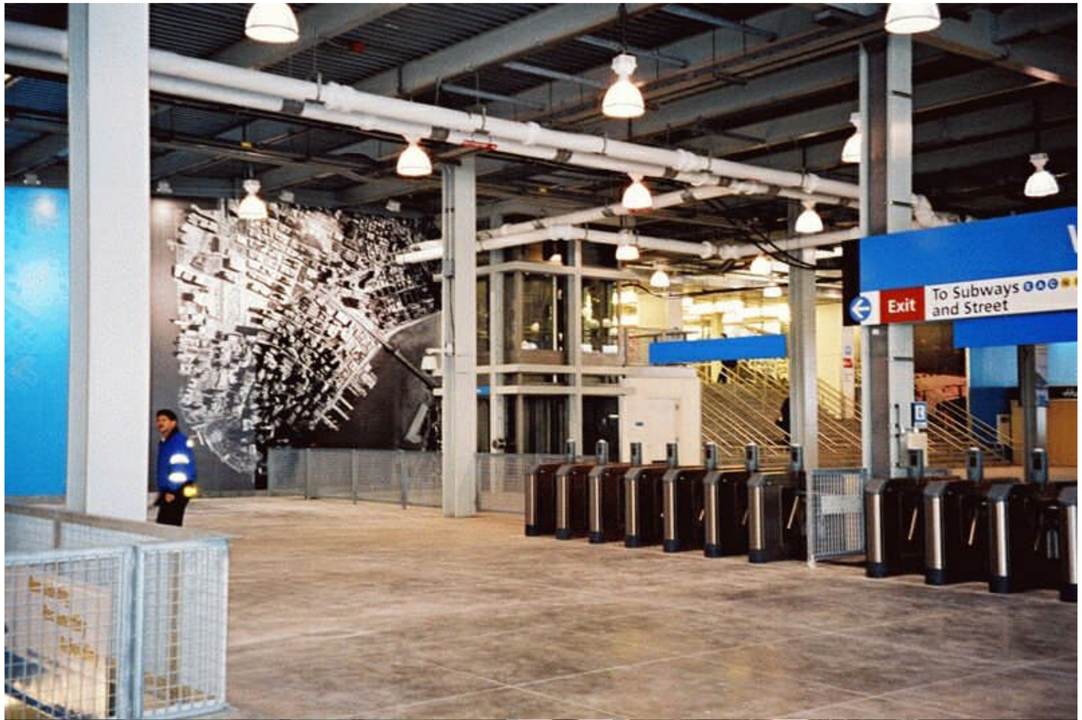
RE: excerpt from *102 Minutes*

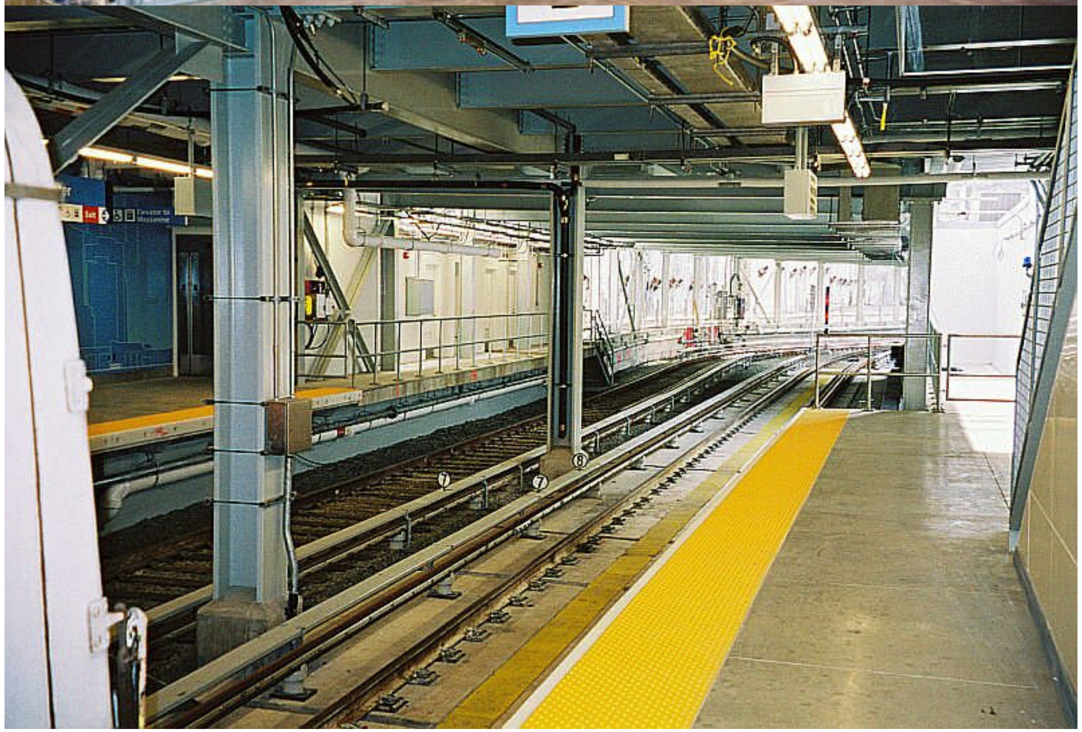
Although it was with great reluctance that the PNYA became the owner/operator of the H&MRR, it carried out a radical rehabilitation of the network and brought the system up to modern standards. Stations, stairways and corridors marked with the familiar red and white "H&M" signs (at right in photo) found, on the morning of September 1st 1962, every removable indication of the H&MRR's existence replaced with PATH signage (at left in photo). Only those items permanently embedded (i.e. tile signage) escaped the campaign.

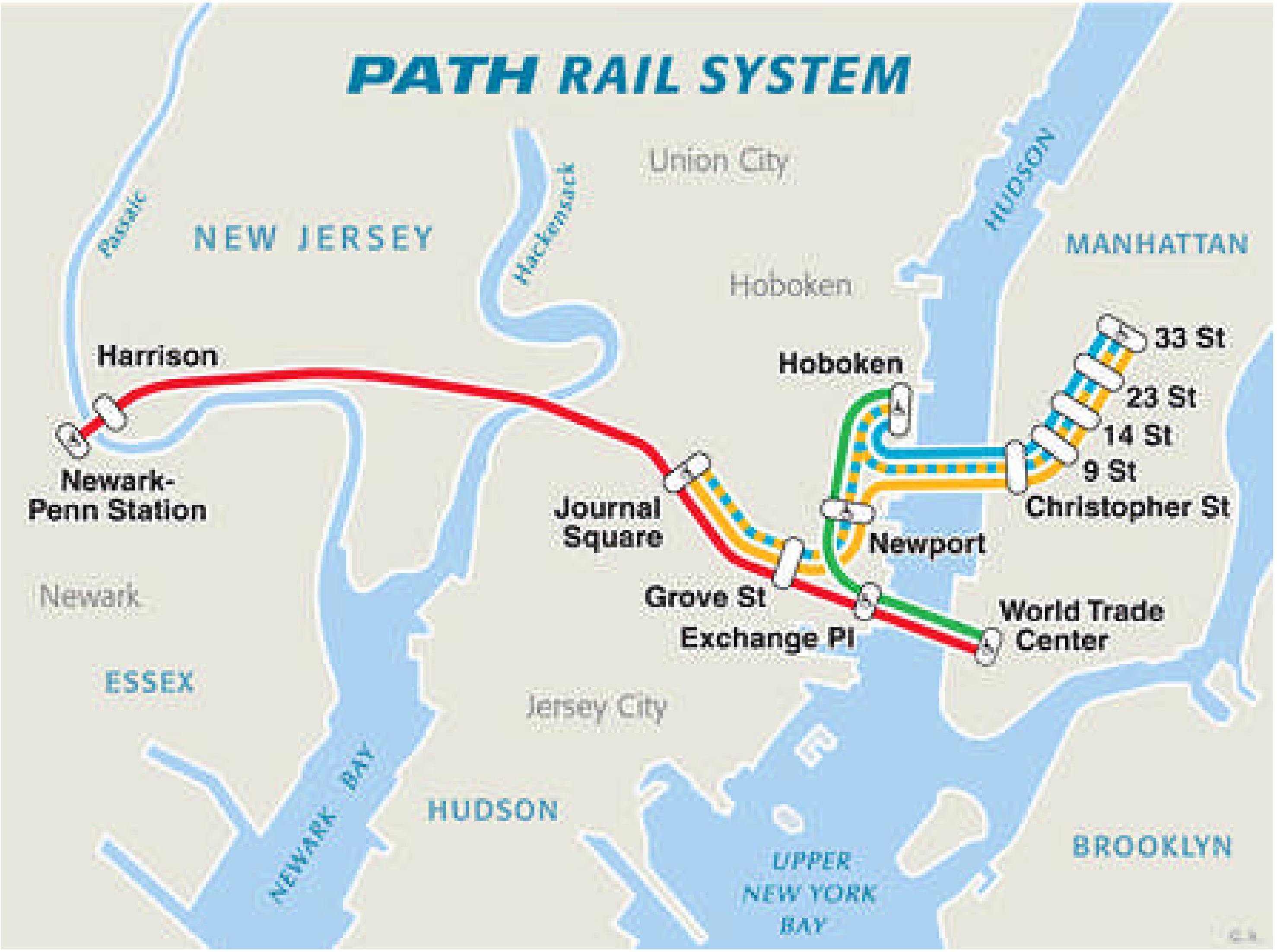

H&M TUNNELS
JERSEY CITY
NEWARK



<u>Above & Left</u>: in the wake of the 9/11 attack on the WTC, on November 23rd 2003 the temporary WTC PATH station opened with its entrance on *Church Street*. Like the destroyed WTC PATH station, the temporary station retained four levels: street, concourse, mezzanine and platform.


Exit
To Subways
and Street





PATH RAIL SYSTEM
Union City
Passaic
NEW JERSEY
Hackensack
HUDSON
MANHATTAN
Hoboken
33 St
Hoboken
23 St
Harrison
14 St
9 St
Newark-
Penn Station
Journal
Square
Christopher St
Newport
Grove St
Newark
World Trade
Center
Exchange Pl
ESSEX
Jersey City
NEWARK BAY
HUDSON
BROOKLYN
UPPER
NEW YORK
BAY

BETHLEHEM
NETCONG
PENNSYLVANIA
DOVER
SUFFERN
NEW YORK
MORRISTOWN
RIDGEWOOD
PATERSON
FAIR LAWN
MONTCLAIR
PASSAIC
RUTHERFORD
HACKENSACK
TRENTON
PRINCETON
RARITAN
SOMERVILLE
WATCHUNG MTNS
15 Miles from World Trade Center
NEWARK PENNSYLVANIA STATION
E. ORANGE
NEWARK
KEARNY
PLAINFIELD
ELIZABETH
NEW BRUNSWICK
NEWARK INTERNATIONAL AIRPORT
JOURNAL SQUARE TRANSPORTATION CENTER
UNION CITY
JERSEY CITY
NEW JERSEY
HOBOKEN
BAYONNE
PERTH AMBOY
Hudson River
LINCOLN CENTER
CENTRAL PARK
PORT AUTHORITY BUS TERMINAL
PENNSYLVANIA STATION
MADISON SQUARE GARDEN
EMPIRE STATE BLDG
PAN AM BLDG.
GRAND CENTRAL STATION
UNITED NATIONS
STATEN ISLAND
Upper New York Bay
LIBERTY STATE PARK
STATUE OF LIBERTY
VERRAZANO NARROWS BRIDGE
PASSENGER FERRY
WORLD TRADE CENTER
BATTERY PARK
MANHATTAN
East River
BROOKLYN
RED BANK
LONG BRANCH
35 Miles from World Trade Center
TO PHILADELPHIA
© 1984 Port Authority Trans-Hudson Corp.


WTC
PATH
WAKE UP WITH 1
Platform B

Part 5

An Absolute Necessity

The Logical Result

"…The idea of tunneling under the Hudson and East Rivers for an entrance into New York City did not evolve suddenly. It was the logical result of long-studied plans in which Mr. Alexander Johnston Cassatt, the late President of the Company, participated from the beginning, and an entrance into New York City was decided upon only when the Executive Officers and Directors of the Company realized that it had become an absolute necessity…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Left</u>: *Alexander J. Cassatt* (1839-1906), President – *Pennsylvania Railroad Company* (1899-1906)

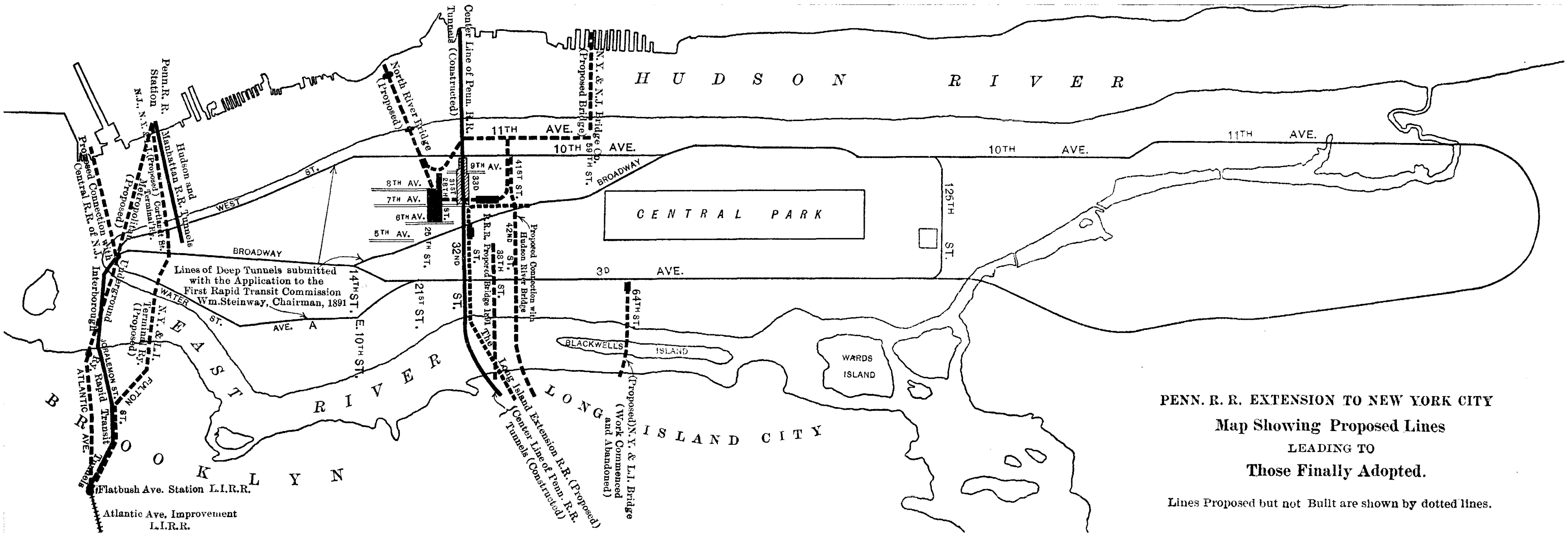
"…After the Company in 1871 leased the United Railroads of New Jersey, which terminate in Jersey City, the Officers of the Railroad looked longingly toward New York City. They wanted a station there, but they were confronted both by the great expense of such an undertaking, as well as the lack of a feasible plan, for at that time the engineering obstacles seemed to be insurmountable. The panic of 1873 made it impossible to promote any large extension or to become actively engaged in a proposition from which no immediate return could be shown; but from this time, and particularly in 1874, when the Hudson Tunnel scheme, now completed and in operation under the control of the Hudson Companies, was first started, the problem was considered…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

"…In 1884, a proposition was entertained to build the 'North River Bridge' across the Hudson River, with a span almost twice that of the Brooklyn Bridge. The panic of that year, however, put a damper on all new undertakings. In 1892 the subject was again revived, and after careful surveys had been made, a number of different propositions were submitted, but the silver panic of 1893 prevented the adoption of any particular plan…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

The Tunnel Scheme



"…In 1900 the control of the Long Island Railroad was acquired by the Pennsylvania Railroad Company, and it then became desirable that the Pennsylvania should have a physical connection with the Long Island Railroad. As the other railroad lines using ferries to carry passengers into New York City did not approve of the construction of the Hudson River Bridge, and as it was impossible to obtain a charter for a bridge to be used exclusively by a single company, a tunnel scheme was adopted by the Pennsylvania Railroad. The improvement in methods of tunnel construction, the use of electric power in tunnels, and the favorable condition of business, were the principal considerations which led to the adoption of the plan of construction which has since been carried out…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Above</u>: caption: "Map Showing Proposed Lines Leading to Those Finally Adopted"

Build it and They Will Come

"…In 1901 the Pennsylvania Railroad was employing ferries to land its passengers in New York City just as it did in 1871, when it first leased the United Railroads of New Jersey. Railroads on the western bank of the Hudson River opposite New York City carried, in 1886, nearly 59,000,000 people. In 1890 they carried over 72,000,000, in 1896 more than 94,000,000 and in 1906 about 140,000,0000. In 1890 the population gathered within a circle of 19 miles radius, with City Hall, Manhattan, as the center, was 3,326,998; in 1900 it was 4,612,153, and five years later it was 5,404,638, an increase in ten years of 38 per cent. In 1913 it is estimated that the population of this territory will approximate six million people, and in 1920 eight million…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

	Population.	Area, Square Miles.	Density per Square Mile.
Manhattan Borough	2,174,335	21.93	99,148
Brooklyn Borough	1,404,569	77.62	18,097
Queens Borough	209,686	129.50	1,618
Boston	607,340	42.66	14,237
Chicago	2,050,000	190.5	10,761
St. Louis	750,000	61.5	12,195
Philadelphia	1,500,000	129.5	11,582
Greater Pittsburgh	450,000	37.25	12,080
Baltimore	560,000	31.5	17,777
London, England	4,542,725	118.00	38,498

Above: chart showing major city/s population, area (in square miles) and population density (per square mile) – ca. 1907

"…These startling figures, and what they meant in transportation needs, in addition to the serious problem of providing corresponding freight facilities, were considered when the Pennsylvania Railroad was contemplating entering New York City. It was evident that one of the greatest transportation problems in history was rapidly evolving, and it was only by quick action that the Railroad could prepare to cope with it…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

Above: caption: "Lower Manhattan ca. 1914"

"…It must be remembered that the problem of the Pennsylvania Railroad in conveying persons and property into New York City is not merely a local necessity, but is largely due to the fact that its road is a great avenue of travel to and from the west and the south and that city, which is the metropolis of the country for business and pleasure. This responsibility is a gradual growth since its lease of the United New Jersey Railroad and Canal Company in 1871, when the number of passengers carried was slightly over seven million, and the tons of freight slightly over two million, whereas, during the past year, there were carried on the United Railroads of New Jersey Division twenty-three million passengers and thirty-one million tons of freight. In this period ferry boats and ferry facilities have been enlarged, but not at the same rate as traffic…From authentic figures published in 1896, the Pennsylvania Railroad carried nearly twenty-five per cent of the passenger traffic over the North River, and out of the one hundred and forty million passengers now carried, it is safe to say that the Pennsylvania Railroad must move yearly in its ferry boats about thirty-three million people in and out of New York City, in addition to vehicles and commodities…"

RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*

"…Across the river from the terminal at Jersey City stood the great metropolis with but one moderate sized railroad station in its center, and its citizens, fully conscious of the isolation of the city, were anxious to remedy it. The Pennsylvania Railroad Company, in seeking improved methods of transportation to and from New York City, recognized the fact that, trusting solely to ferry facilities, it would fall short of what it believed the future would require for the greater dispatch, comfort to and from the metropolis each year, but what, inside of twenty years, will mean fifty million…"

RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*

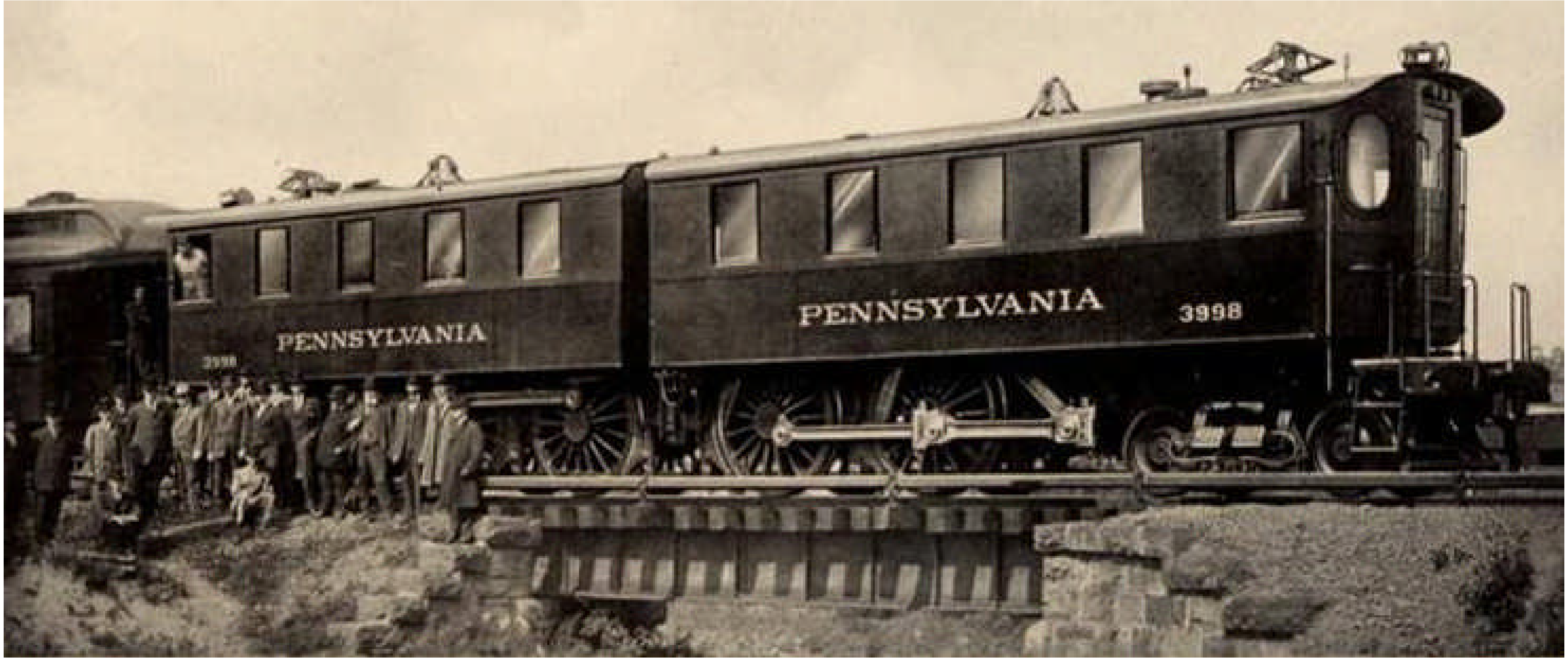
<u>Above</u>: at left, the original *Grand Central Depot* (ca. 1870s) and the expanded Grand Central Station (ca. 1903), at right. *Grand Central Terminal* would open in 1913.


Grand Central Terminal, New York.

The Plan

"…It was the Company's plan to run its passenger trains into a centrally located station in the city of New York, instead of one on the western bank of the Hudson River; to give rapid transit from the residential sections of Long Island, and to offer to Newark and other cities in New Jersey, direct and quick access to New York City, and to the resorts on Long Island beaches. It was considered essential to provide an all-rail connection between the South and West on the one hand, and New England and the East on the other. The Company desired to give the Boroughs of Brooklyn and Queens, with their population of over 1,500,000, direct railroad connections to and from New England, Southern and Western States, and to supply freight facilities with similar connections in these Boroughs, with freight stations suitably located to develop their commercial interests. It was planned to provide additional freight facilities, and, by the use of the Long Island Railroad, to shorten the water transportation trip for the New England traffic across New York Harbor from twelve to three and four-tenths miles..."

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

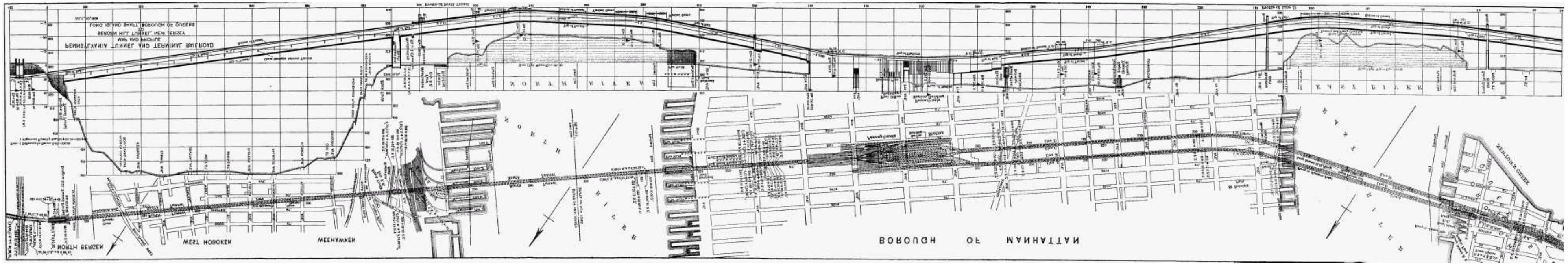


"…Various methods of accomplishing this result had at different times been considered, and at one time centered on a bridge for passenger traffic…The alternative was the construction of a tunnel line; but the difficulties incident to the operation by steam of a tunnel at the depth and with the gradients required by the topographical conditions, seemed to make a tunnel almost, if not quite, impracticable. Meanwhile, however, the successful operation of steam railroad trains in tunnels in other parts of the world by electric power indicated a satisfactory solution of the problem for suburban traffic…"

RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*

Above: caption: "Type of Locomotive to be used in Pennsylvania Tunnels"

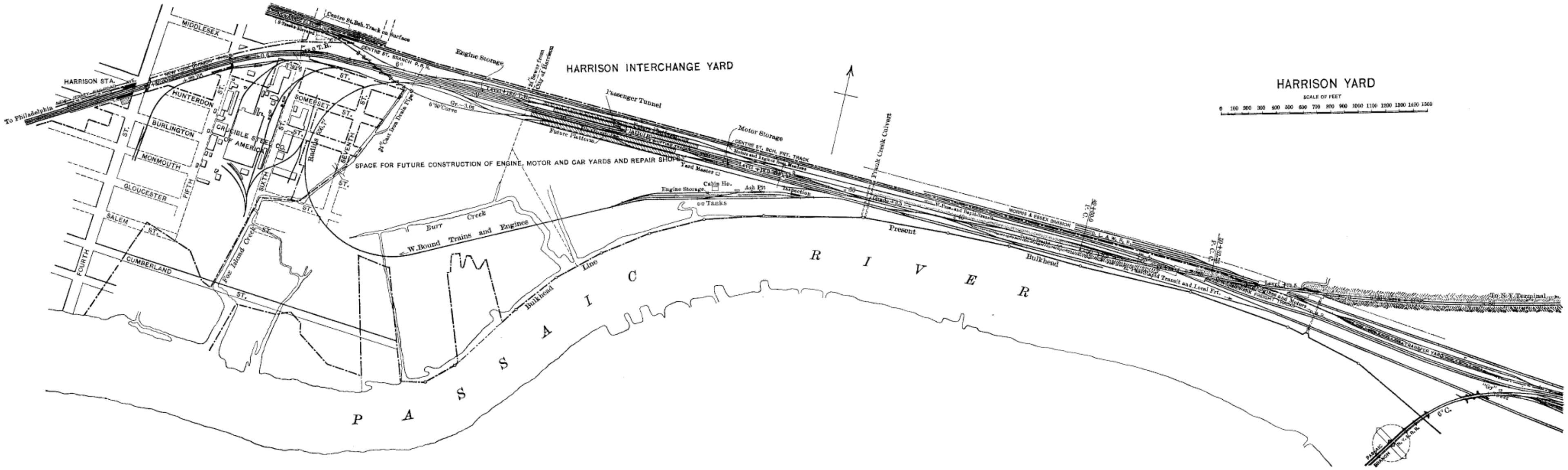
New York Tunnel Extension



"…The New York Tunnel Extension of the Pennsylvania Railroad running east and west from the New York Station begins at Harrison, New Jersey, a short distance east of Newark. Here is located a transfer yard for the huge electric locomotives used in the tunnels. At this point through passenger trains from Southern and Western points will change from steam to electric power, and passengers whose destination is in the downtown district of New York, may alight here and walk across the transfer platform to an electric train which will run into the Church and Cortlandt Street Station of the Hudson & Manhattan Railroad. This downtown rapid transit electric train starts from a new station on Military Park, in Newark, thence by a new bridge over the Passaic River at Centre Street, to Harrison, where passengers may transfer to trains for the Pennsylvania Station uptown, or continue to Jersey City and lower New York…"

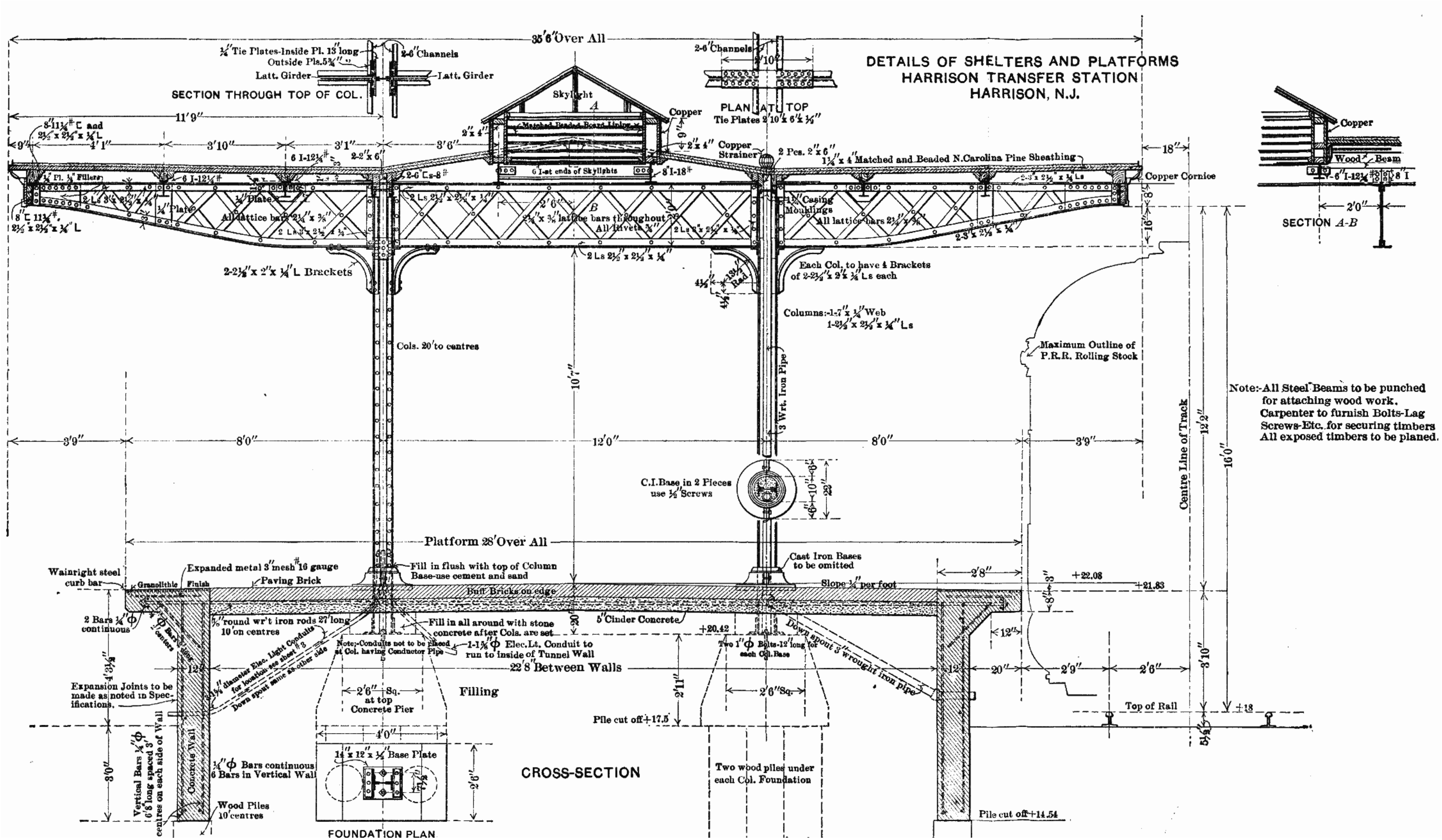
RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

Above: caption: "Pennsylvania Tunnel and Terminal Railroad Map and Profile / Bergen Hill Tunnel, NJ to Long Island Shaft, Borough of Queens"

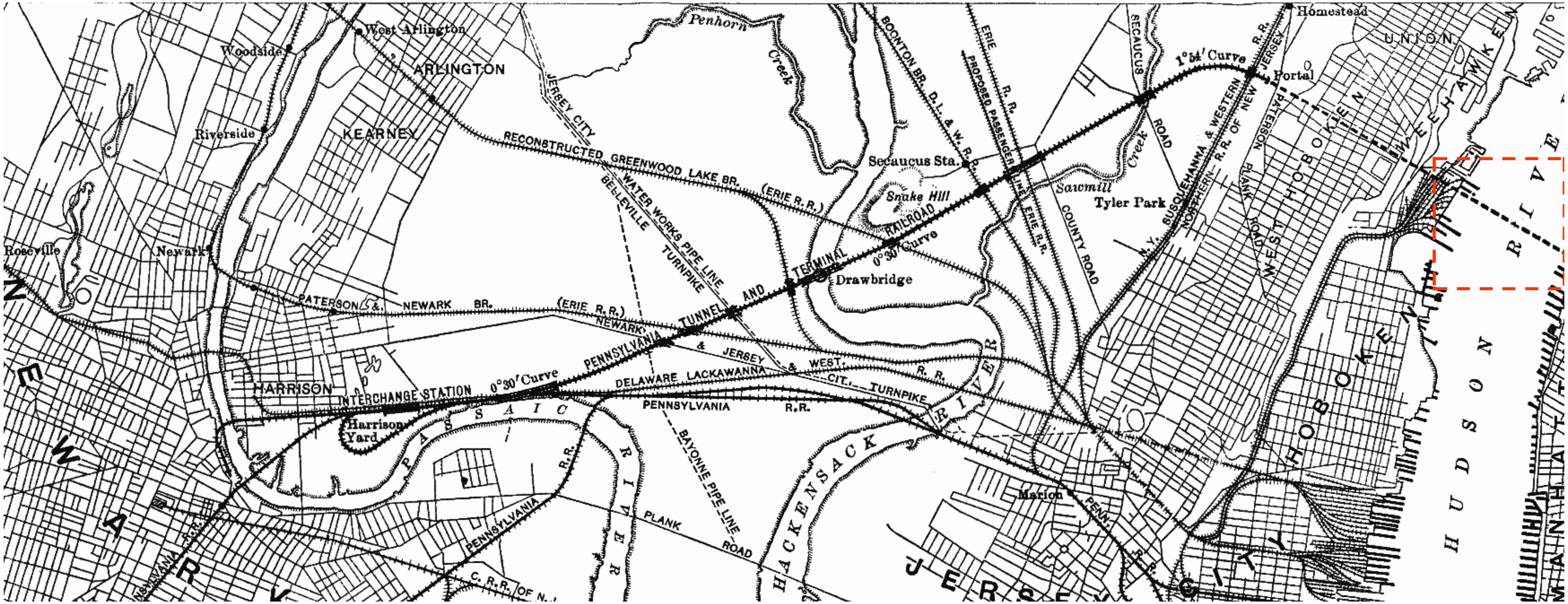


<u>Above</u>: caption: “Plan of Harrison Yard.” West of the *Hackensack* portal, the *Meadows Division* project included five miles of double-track line on a high fill across the *Hackensack Meadows* to a junction with the PaRR’s *New York Division* main line at *Harrison*. Work included:

- **A drawbridge at a crossing of the *Hackensack River***
- **Yard and terminal facilities at Harrison (where the change between steam and electric motive power would take place)**
- **A new station named *Manhattan Transfer* (where passengers could transfer between trains on the PaRR lines to *Manhattan* and/or *Jersey City* and the H&MRR)”**



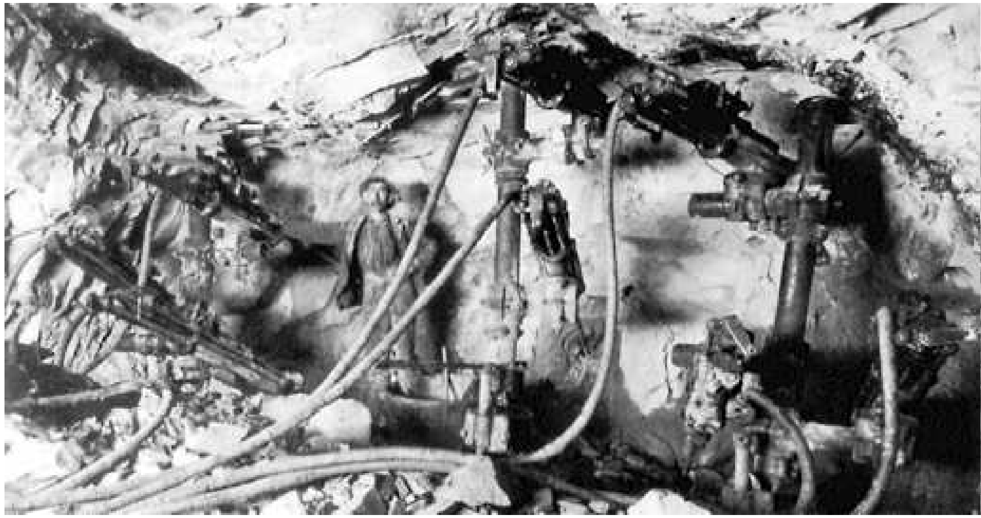
Above: caption: “Details of Shelters and Platforms Harrison Transfer Station Harrison, N.J.”



Above: caption: "The New York Tunnel Extension of the Pennsylvania Railroad diverges from the New York Division in the Town of Harrison, N.J., and, ascending on a 0.5% grade, crosses over the tracks of the New York Division and the main line of the Delaware, Lackawanna and Western Railroad. Thence it continues, with light undulating grades, across the Hackensack Meadows to a point just east of the Northern Railroad of New Jersey and the New York, Susquehanna and Western Railroad, where it descends to the tunnels under Bergen Hill and the North River." Work proceeded on the tunnel sections on either side of the river simultaneously with tunneling operations under the Hudson. On the *New Jersey* side, twin tunnels 5,940-feet long were bored through the traprock of *Bergen Hill,* between the *Weehawken* shaft and the *Hackensack* portal.

"…The principal physical features of the work are elevated tracks constructed in the open from a connection with the New York Division, east of Newark, across the Meadows to the portals of the tunnels at Bergen Hill, and a double track tunnel under Bergen Hill, West Hoboken, Weehawken, becoming two single track iron tube tunnels as they pass under the Hudson River into New York City to a point near Tenth Avenue. When the tracks emerge from the tunnels they begin to increase, and at the terminal station, lying between Thirty-first and Thirty-third Streets and Seventh and Eighth Avenues, will number twenty-one…"

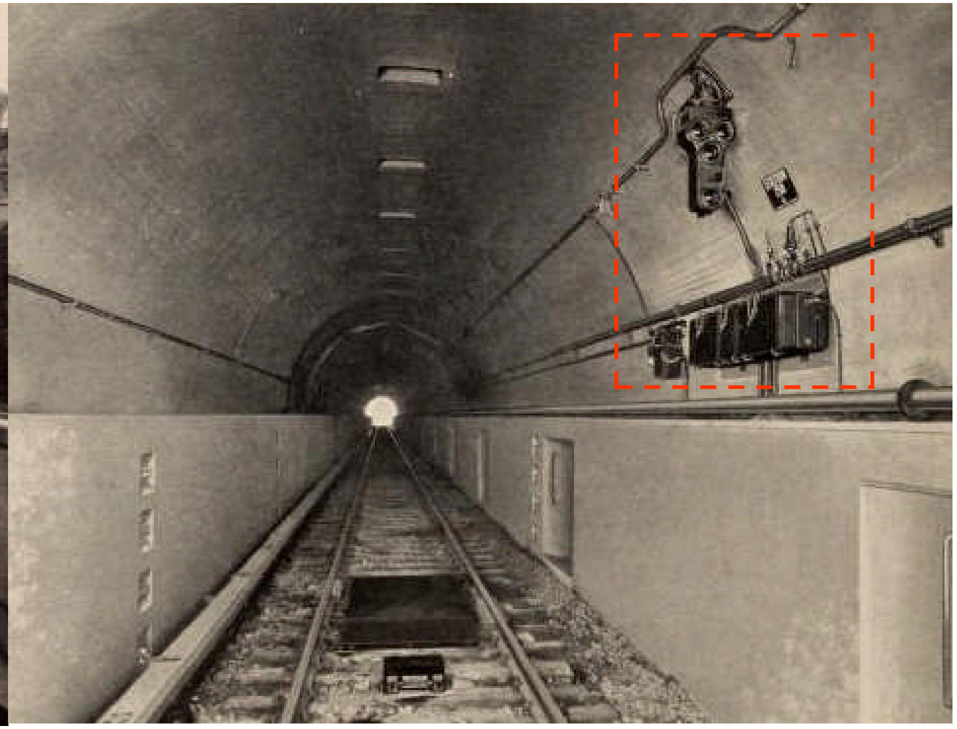
RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City.* On the *New York* side, twin tunnels between the *Manhattan* shaft and a portal at *Tenth Avenue* were drilled and blasted through rock, except for several hundred feet completed by "cut and cover" tunneling where soft material was found.



The tunneling crews worked from both ends of each tunnel, drilling into the hard rock with Rand "slugger" compressed-air drills. Then, dynamite was placed to break up the rock. Typically, tunnel headings were first drilled and blasted horizontally to form the upper section of the tunnel and then drilled and blasted vertically behind this heading on two "bench" levels to excavate the full tunnel section. Steam shovels loaded the excavated rock into 3-foot gauge muck trains, which were pulled out to tunnel portals by 12-ton "Vulcan" steam locomotives. The hard traprock was stored and later crushed for use as concrete aggregate and track ballast. Drilling through *Bergen Hill* proved tedious and costly. Progress was only from 2 to 7-feet per day and the tunnels were not finished until the end of 1908 (they were begun in early 1905).

<u>Left</u>: caption: "A view of rock tunneling in the south Bergen Hill tunnel shows the compressed-air drills used to drill the holes required for blasting and the columns used to support them"

<u>Right</u>: caption: "Steam engines were used to haul Moot gauge muck trains out of the Bergen Hill tunnels. This view was taken at the Hackensack portal on January 19, 1906."

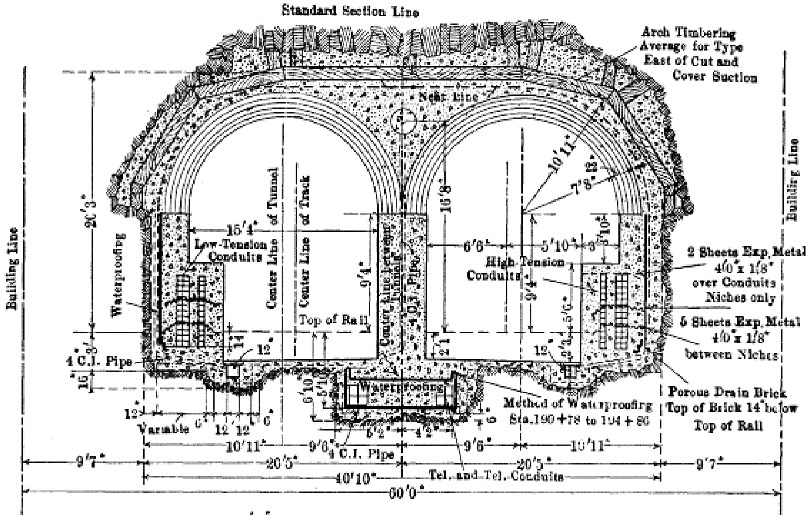


"…The through trains to New York leave Harrison on rails crossing over the old Pennsylvania tracks on a steel and concrete bridge. A double-track elevated line on embankments and bridges extends across the Hackensack Meadows to Bergen Hill, that high eminence which is a continuation of the rocky cliffs extending along the Hudson River. In the western slope of this hill are found the entrances to the tunnels which lead under the North River, into the Station in New York…"

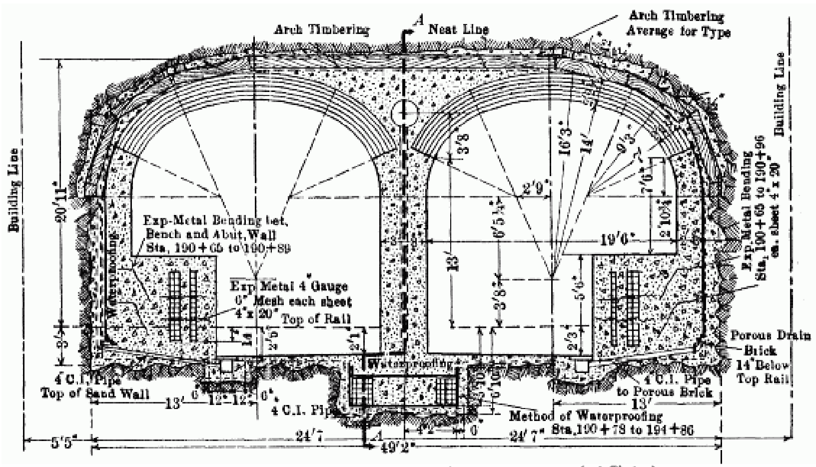
RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

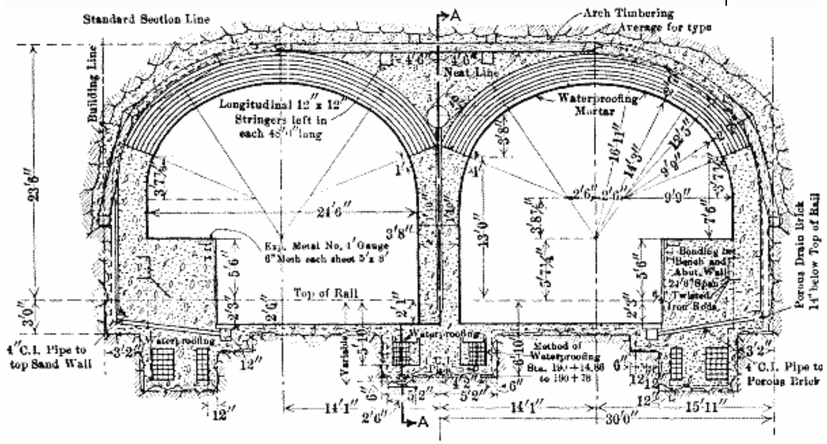
Left: caption: "Hackensack Portals of Bergen Hill Tunnel in New Jersey"

Right: caption: "Bergen Hill Tunnel Interior showing Signal Apparatus"



15'4" Span Twin Tunnels. Rock Roof.





"…In the original plan a four-track tunnel was contemplated from the east side of Tenth Avenue to the east side of Eleventh Avenue, but, owing to the extension of the Terminal Yard, previously noted, this plan was changed, and a two-track structure was built having a central wall between the tracks. This was constructed in tunnel, with the exception of 172 ft. about midway between Tenth and Eleventh Avenues, where the rock dipped below the roof of the tunnel, and there the construction was made in open cut. These tunnels were lined with concrete with brick arches, Figs. 6, 7, and 8 being typical cross-sections. This work was executed by the O'Rourke Engineering Construction Company, under a contract dated November 1, 1904…"

Charles M. Jacobs, **Chief Engineer**

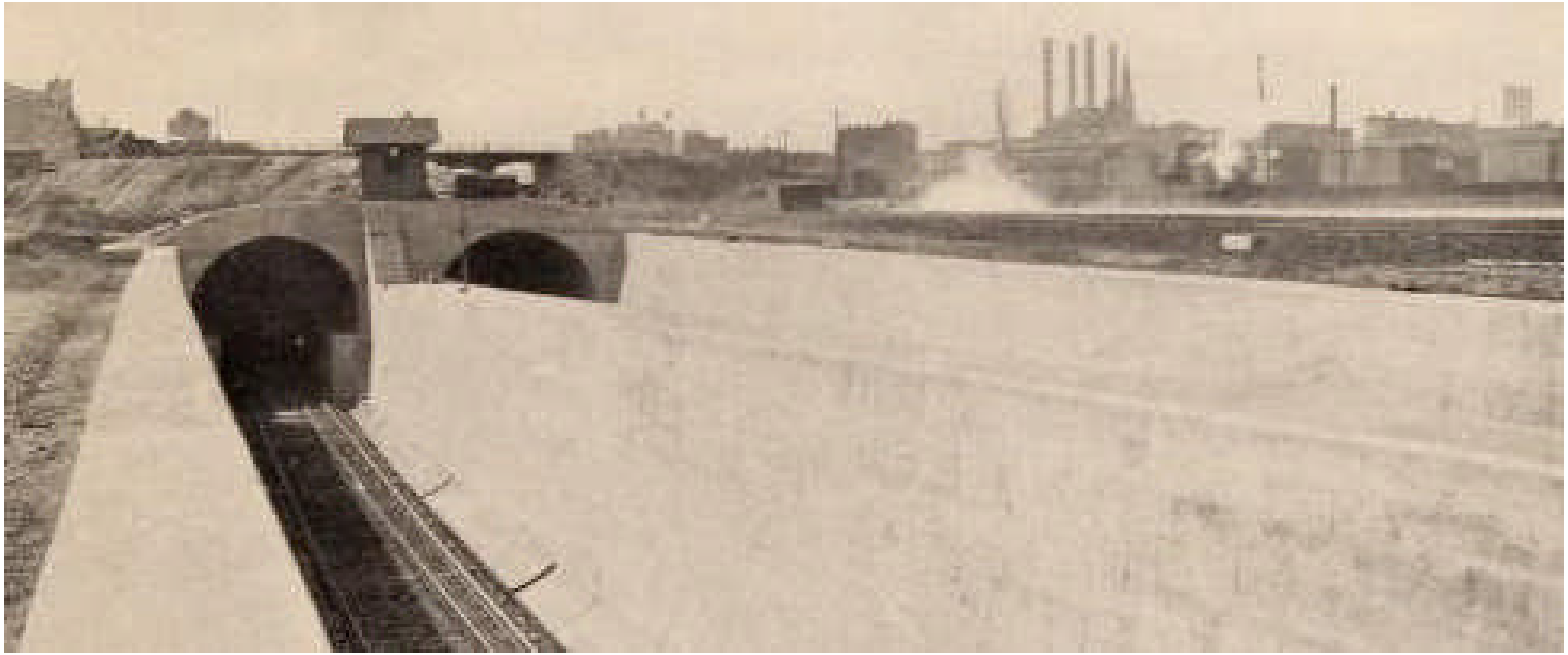
<u>Top</u>: caption: "15'4" Span Twin Tunnels. Rock Roof."

<u>Middle</u>: caption: "19'6" Span Twin Tunnels."

<u>Bottom</u>: caption: "21'6" Span Twin Tunnels."

"…The river tunnels leading to the Station are, all told, 6.8 miles long, and the land tunnels have the same length. From the Bergen Hill portal in New Jersey to the Long Island entrance of the tunnels it is 5.3 miles. It is 8.6 miles from Harrison, New Jersey, to the Station in New York, while from the latter point to Jamaica the distance is 11.85 miles. The maximum capacity in trains per hour of all of the Pennsylvania tunnels is 144, and the proposed initial daily service will consist of about 600 Long Island Railroad trains and 400 Pennsylvania trains…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

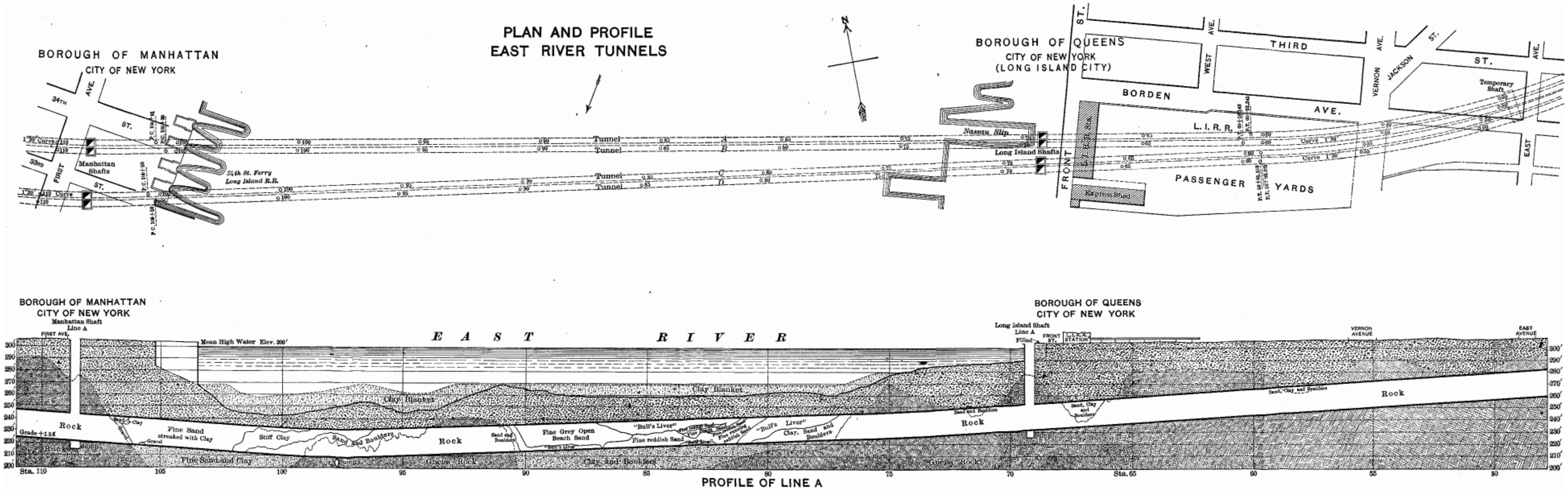


"…As a result of the nine years of thought and arduous labor, which made possible the Pennsylvania tunnels and Station, the traveler can now be carried straight into the heart of New York City on tracks encased in tubes of the most substantial construction – tubes which from New Jersey run without a curve to the Manhattan side of the Hudson River. Tubes equally free from curves run from the Station to the East River, under which they shoot almost in a straight line to Long Island…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

Above: caption: "Two of the Long Island Portals"

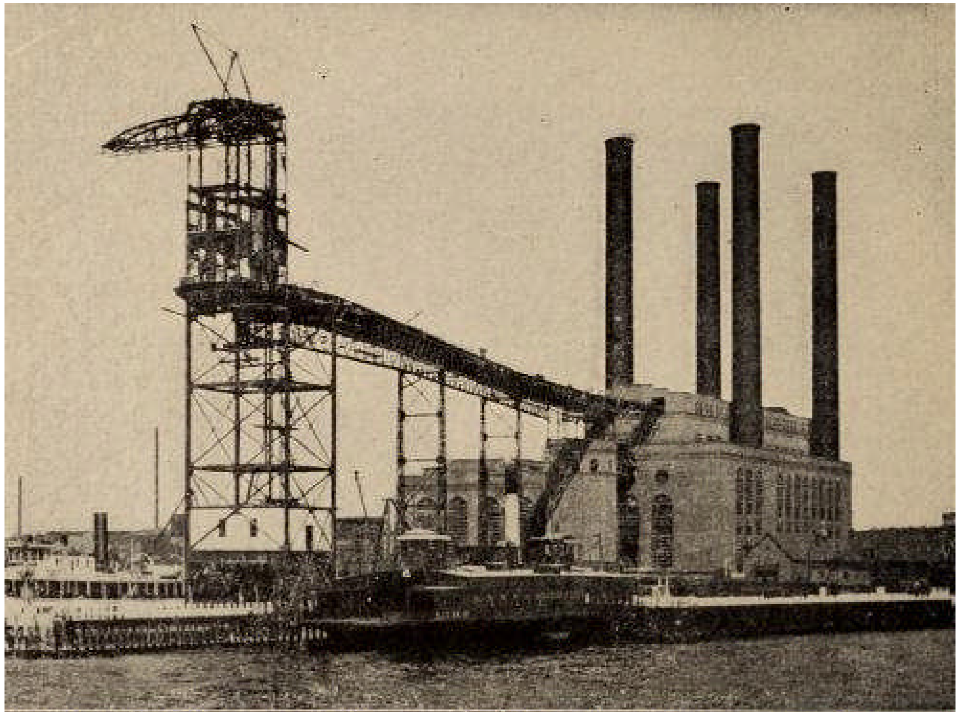
The tunneling problems encountered by *Alfred Noble*, the Chief Engineer for the *East River Section* of the project, were different from those confronted by *Charles Jacobs* in the *Hudson River* tunnels, but no less difficult. The railroad planned a four-track line east of the new *Manhattan* station to accommodate the movement of PaRR trains to and from *Sunnyside Yard* in *Queens*, the heavy suburban traffic of the LIRR and future traffic over the *Hell Gate Bridge*. Just to the east of the station, the tracks converged into two three-track tunnels, one under *32nd Street* and the other under *33rd Street*, each narrowing to two double-track tunnels a little farther east. Near *Second Avenue,* the tunnels separated into four individual tubes to cross under the East River to *Long Island City*.



"…From the latter point four single track iron tube tunnels extend under the East River and into Long Island, and the lines reach the open surface at the entrance to the Sunnyside train yard, where connection will be made with the Long Island Railroad, and later with the New York Connecting Railroad, to handle traffic to and from New England, as well as Long Island…"

RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*

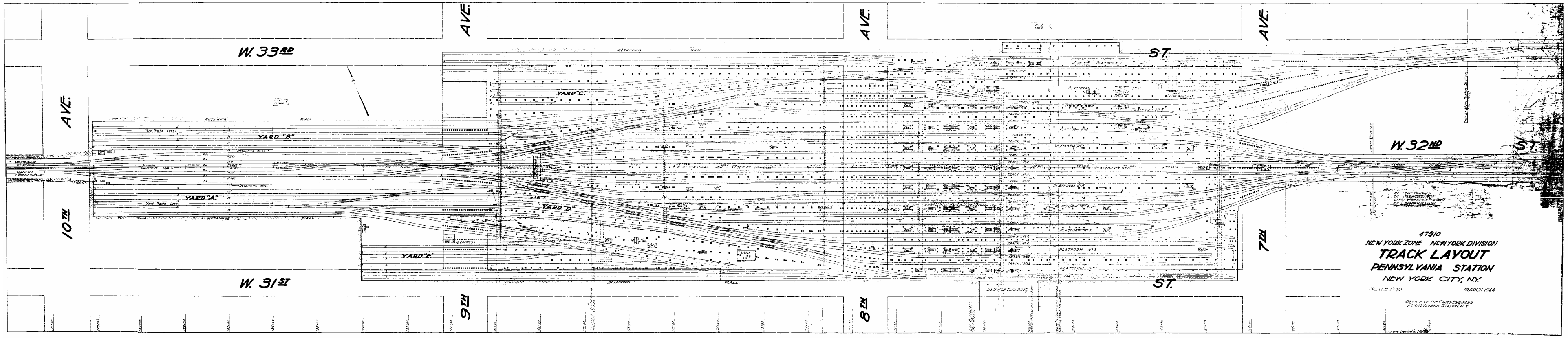
Above: caption: "Plan and Profile East River Tunnels"



All four tunnels descended on a 1.5% grade to a low point under the *East River* and then rose towards the *Long Island City* side on a 0.7% grade. They passed under a LIRR depot and yard before coming to the surface between *East* and *Thompson* Avenue/*s*. The tracks continued at surface level to connect with the new service and storage yard at *Sunnyside*, the LIRR and the future *New York Connecting RR* route over the *Hell Gate Bridge*.

<u>Top</u>: caption: "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."

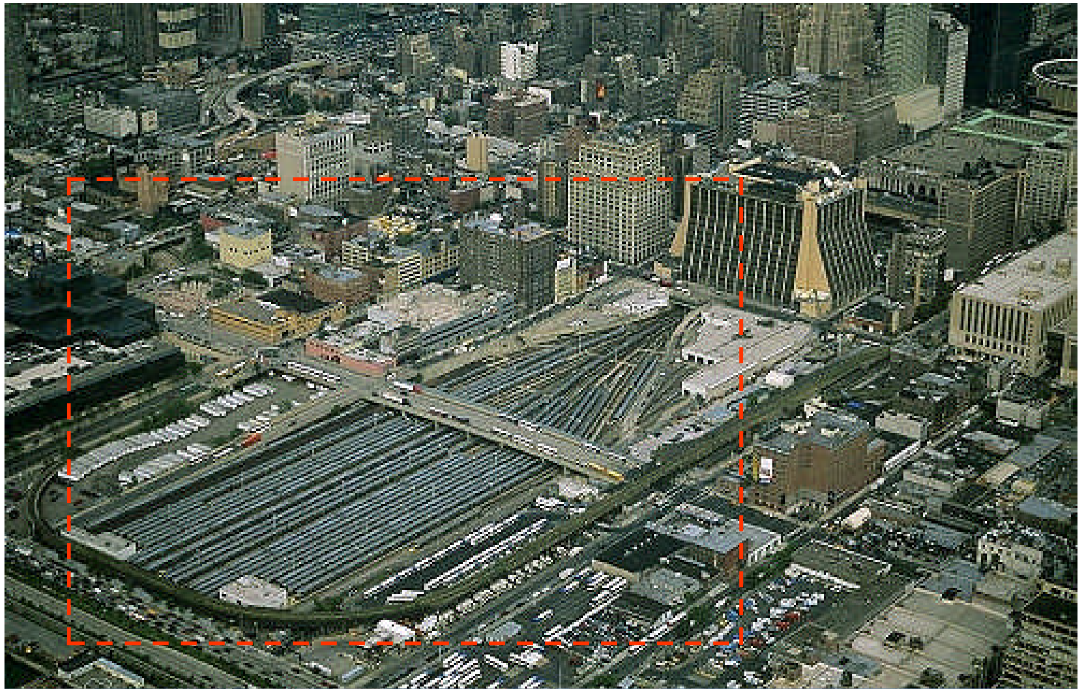
<u>Bottom</u>: caption: "Long Island City, emergence of tunnels and connection with Long Island RR System."

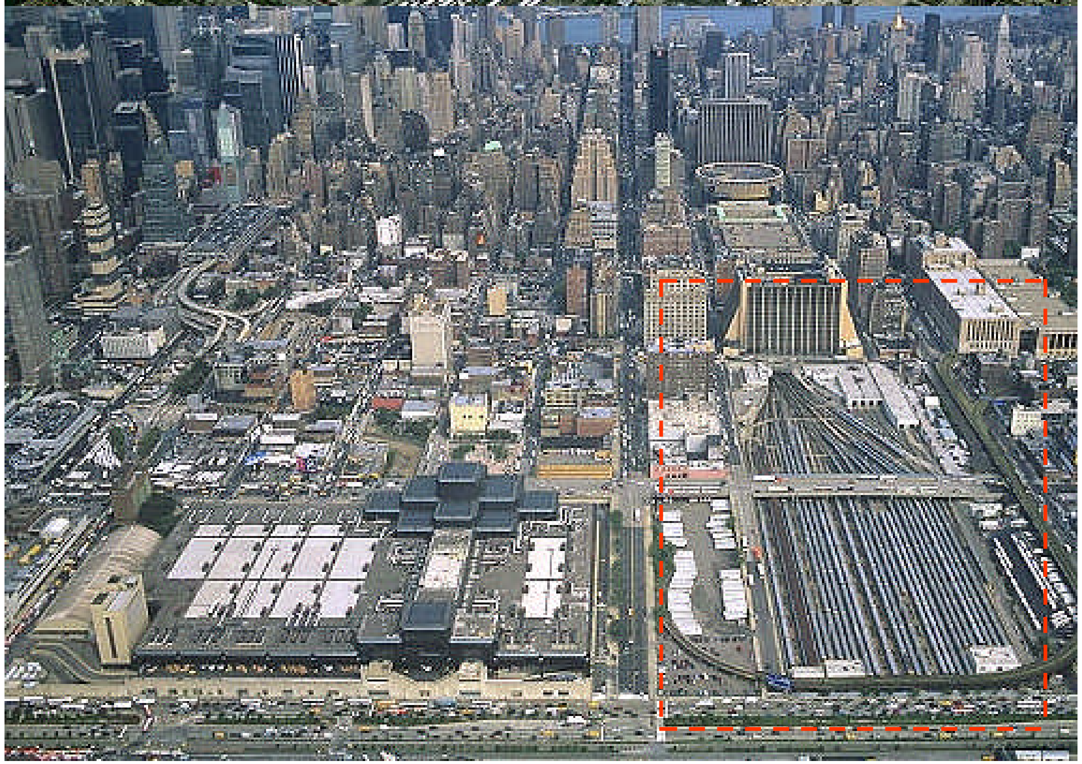


"…When the two tracks emerge from the tubes under the Hudson and reach the entrance to the Station yard at Tenth Avenue they begin to spread out. From this point, and extending into the Station, the number grows from two to twenty-one. The number of tracks leading out of the Station yard to the east gradually decreases from twenty-one to a total of four for the main line. These pass under the city and East River to the Sunnyside Yard on Long Island, the terminus of the tunnel extension, and the point of connection with the Long Island Railroad…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Above</u>: caption: "Platform/Track Map of Penn Station"

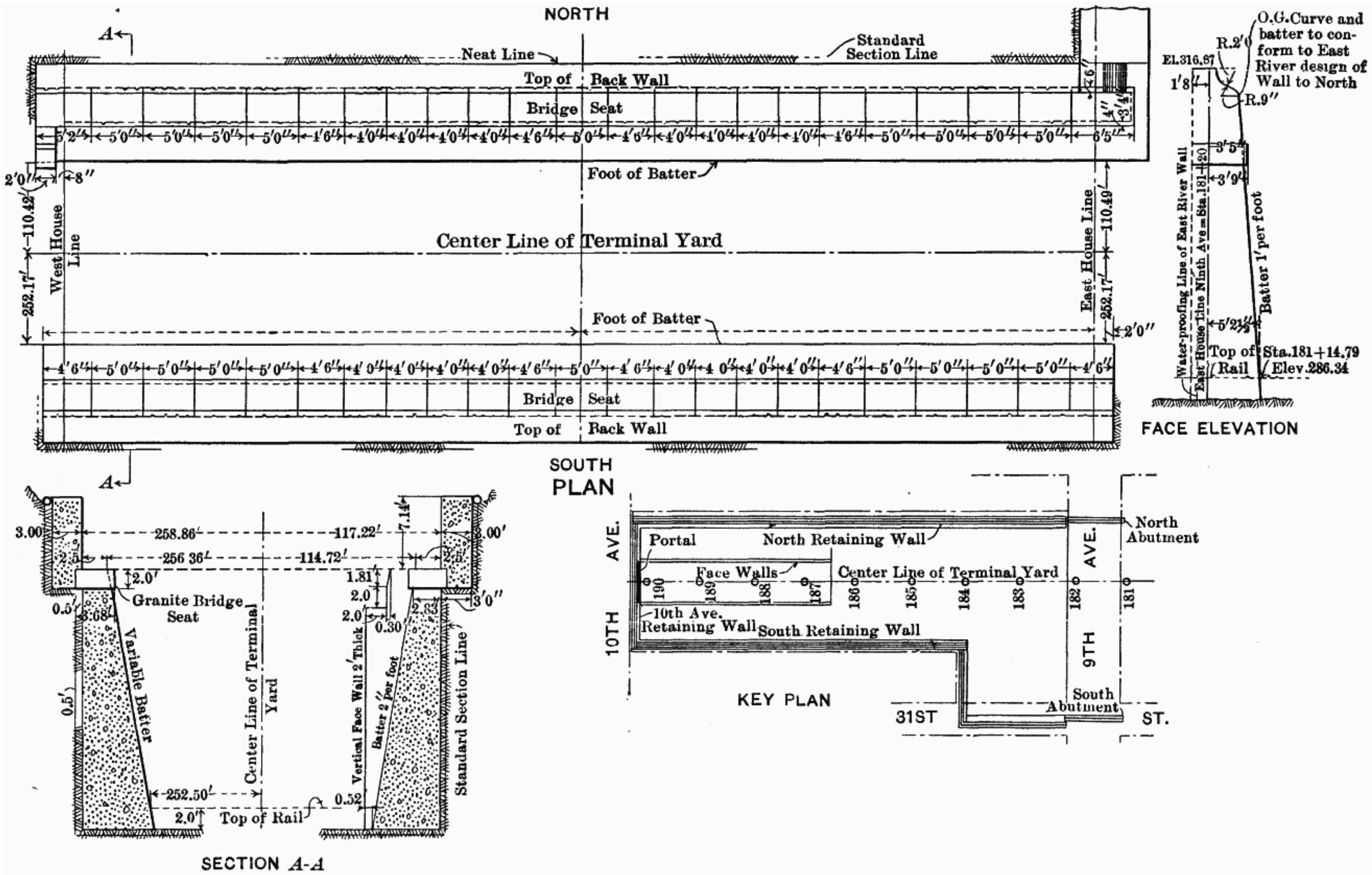




"…From the Station the Manhattan crosstown twin tunnels, containing four tracks in all, traverse a section of New York City second in importance only to the financial district, and on that includes the larger hotels, retail shops and theaters, and many residences. These tunnels end at the river shaft, situated in the block between Thirty-third and Thirty-fourth Streets east of First Avenue…"

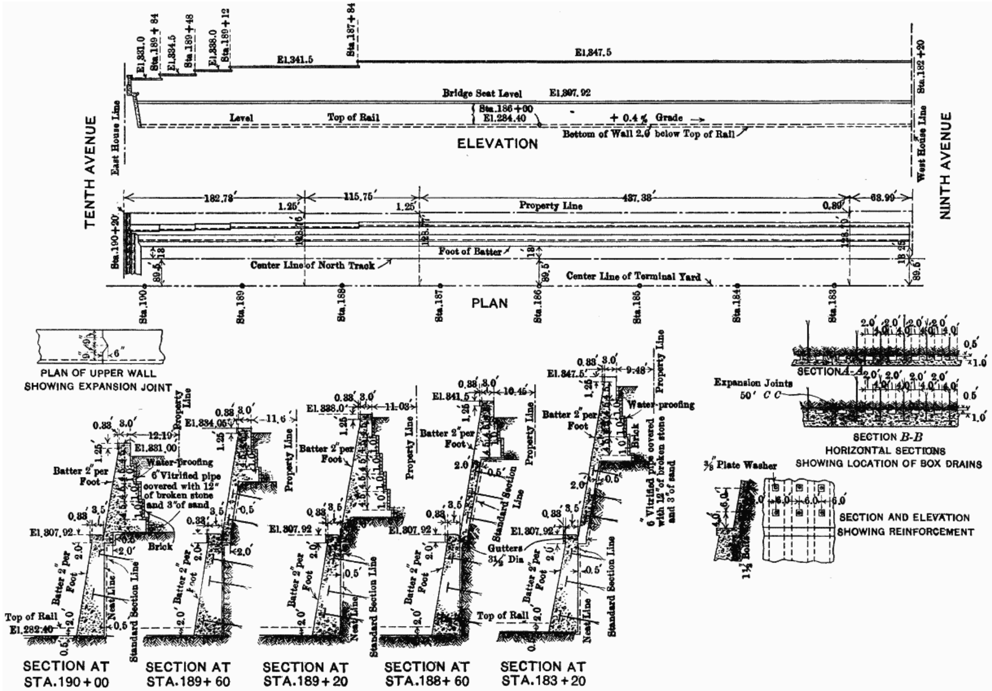
RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Left T&B</u>: aerial view/s of Penn Station's west-side yard



The terminal station work between *Ninth* and *Tenth Avenue/s* involved the excavation of about 5.4 acres; between the west house line of Ninth Avenue and the east house line of Tenth Avenue, to an average depth of about 50-feet. This included the construction of a masonry twin portal at Tenth Avenue (leading to the river tunnel/s) and the construction around the site of the concrete retaining and face walls.

<u>Above</u>: caption: "Ninth Ave. Abutments and Key Plan"

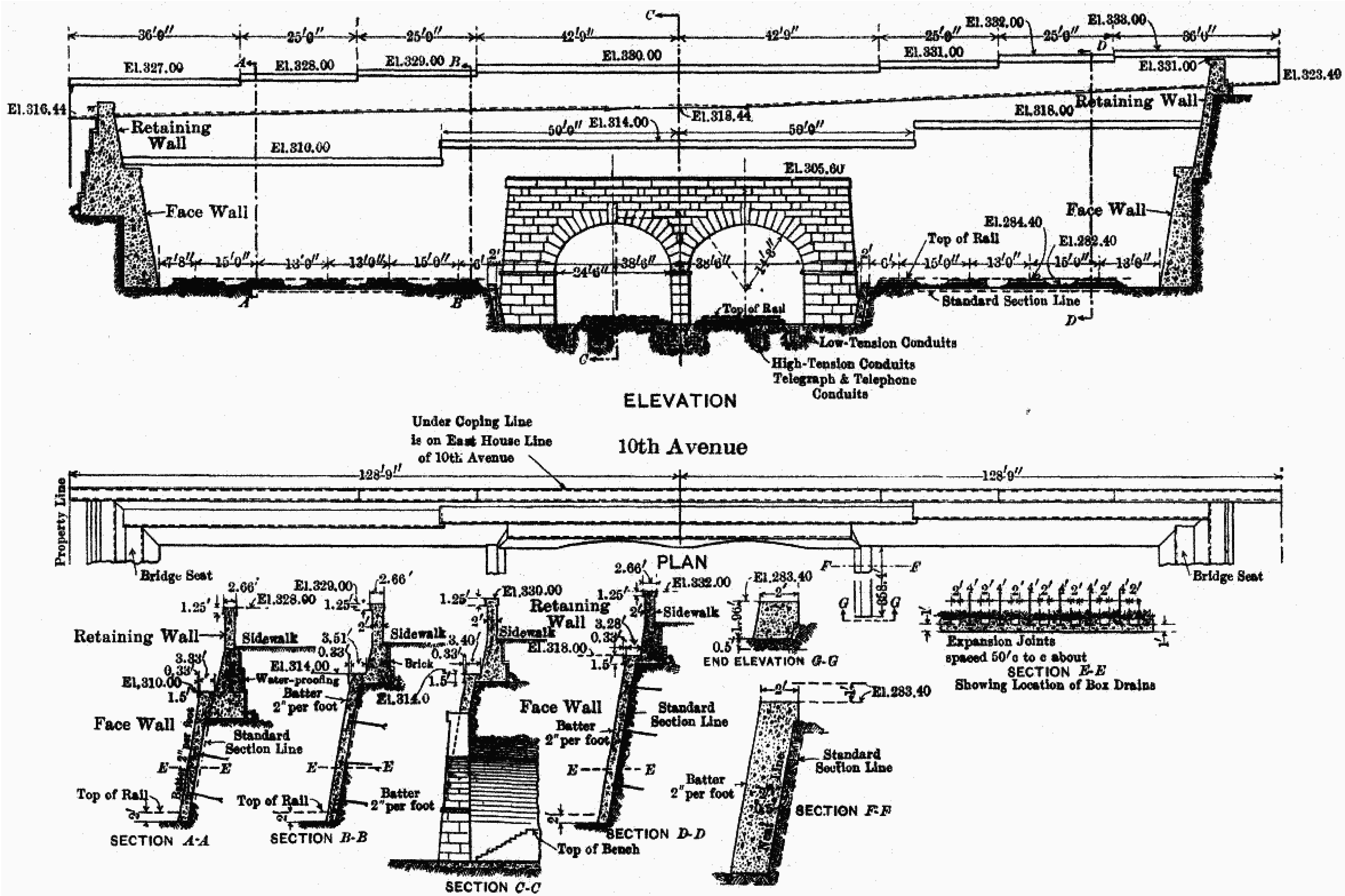


It was essential to maximize space at the bottom of the station excavation and, since the yard was to be left open to the elements, it was necessary to provide facing for the rock on the sides (to prevent disintegration due to exposure) as well as to provide a finished appearance to the work. Above the rock surface, a retaining wall (of gravity section) was designed, the top being slightly higher than the yards of the adjoining properties. The face wall was designed to be as thin as possible in order to allow the maximum space for tracks.

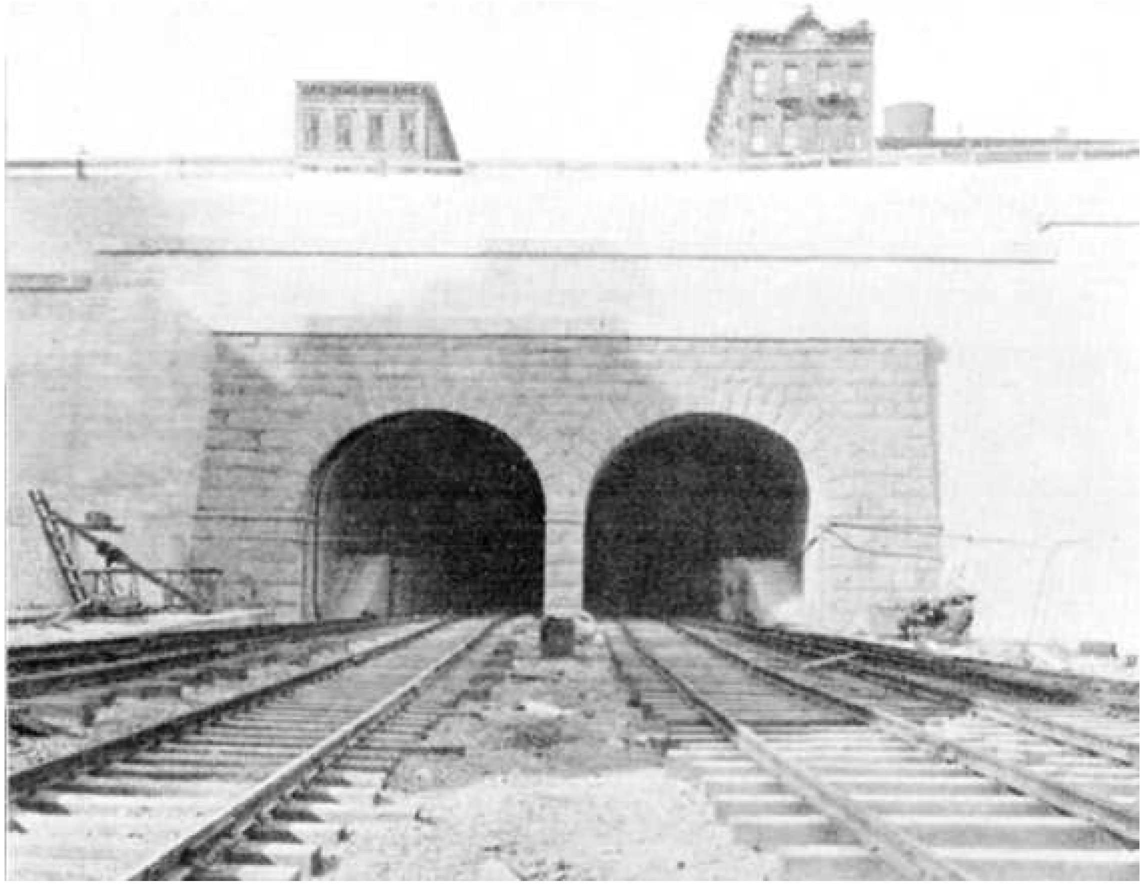
<u>Top</u>: caption: "Retaining and Face Walls North Side"

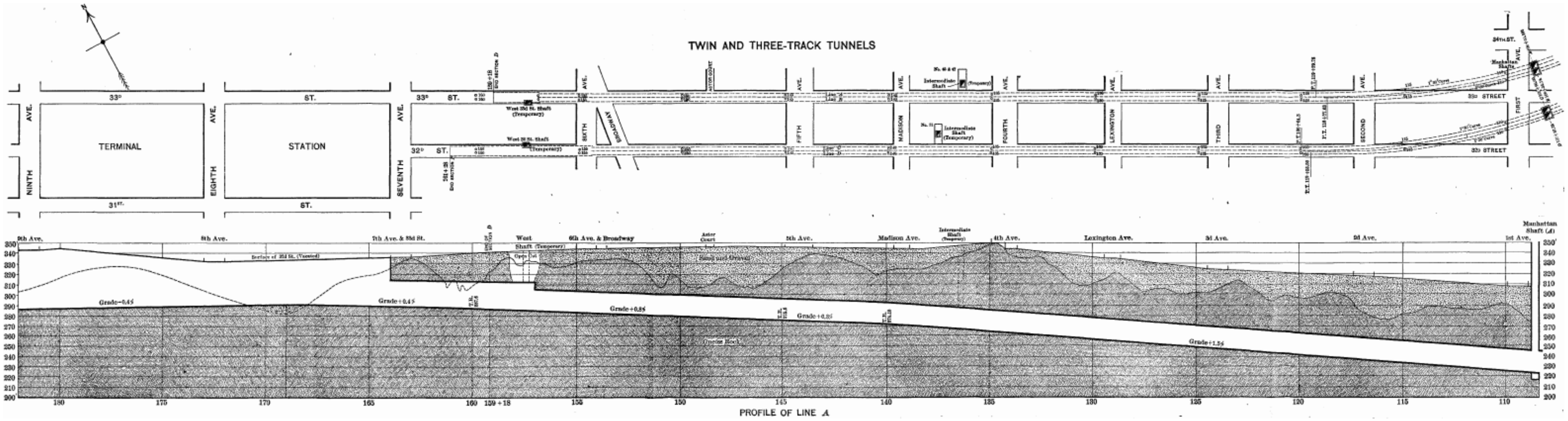
<u>Bottom</u>: caption: "View from Tenth Avenue Looking East, showing progress of Concrete Walls"

<u>Above</u>: caption: “View looking West from Ninth Avenue Elevated Railway, showing condition of Work.” Note retaining/face wall at left is nearly complete while the wall at right is still exposed.



<u>Above</u>: caption: "Portal, Retaining and Face Walls, Tenth Avenue." Drains were left behind the portal around the back of each arch, leading down to the bottom and through the concrete base at each side of the portal and in the central core-wall.

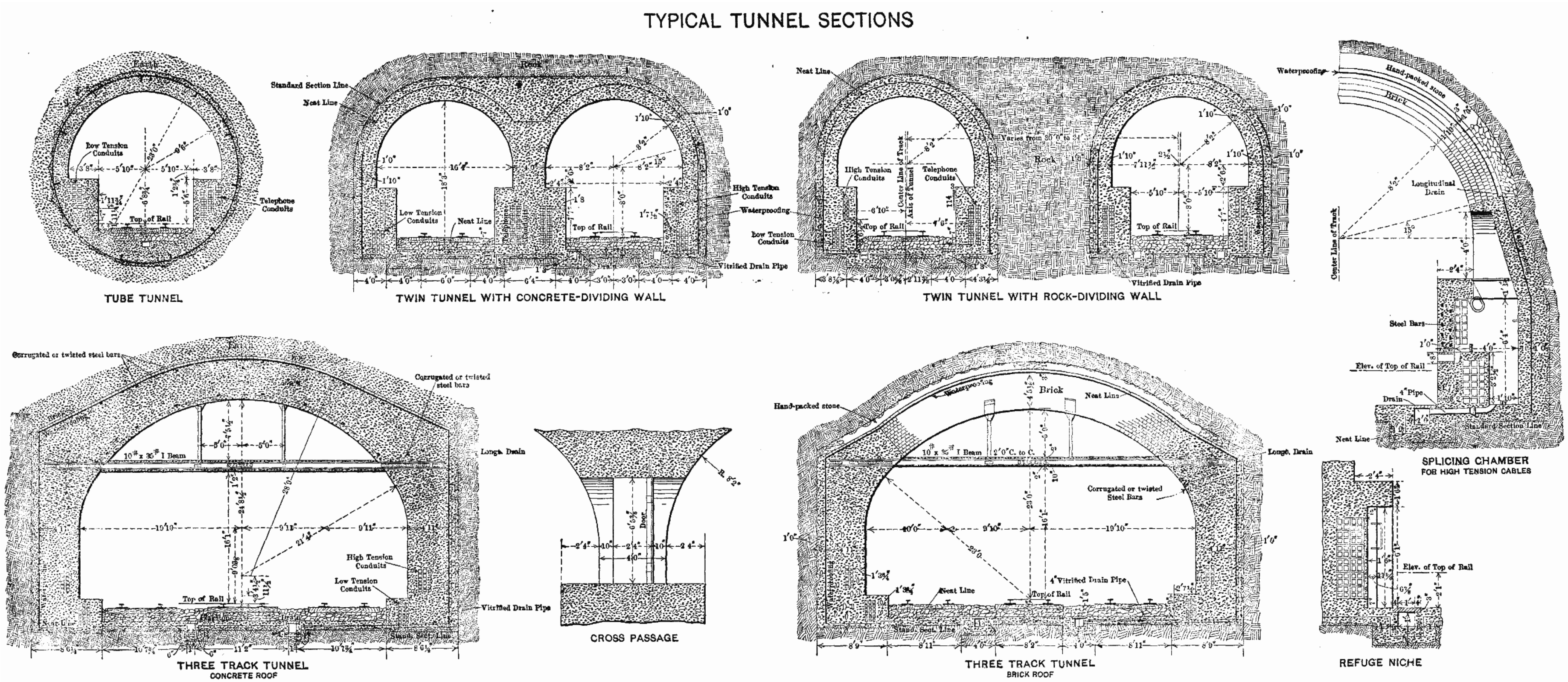




"…Easterly from Seventh Avenue the terminal tracks finally resolve into four tracks in two twin tunnels extending under Thirty-second Street to the East River shafts in Man-hattan…"

RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*

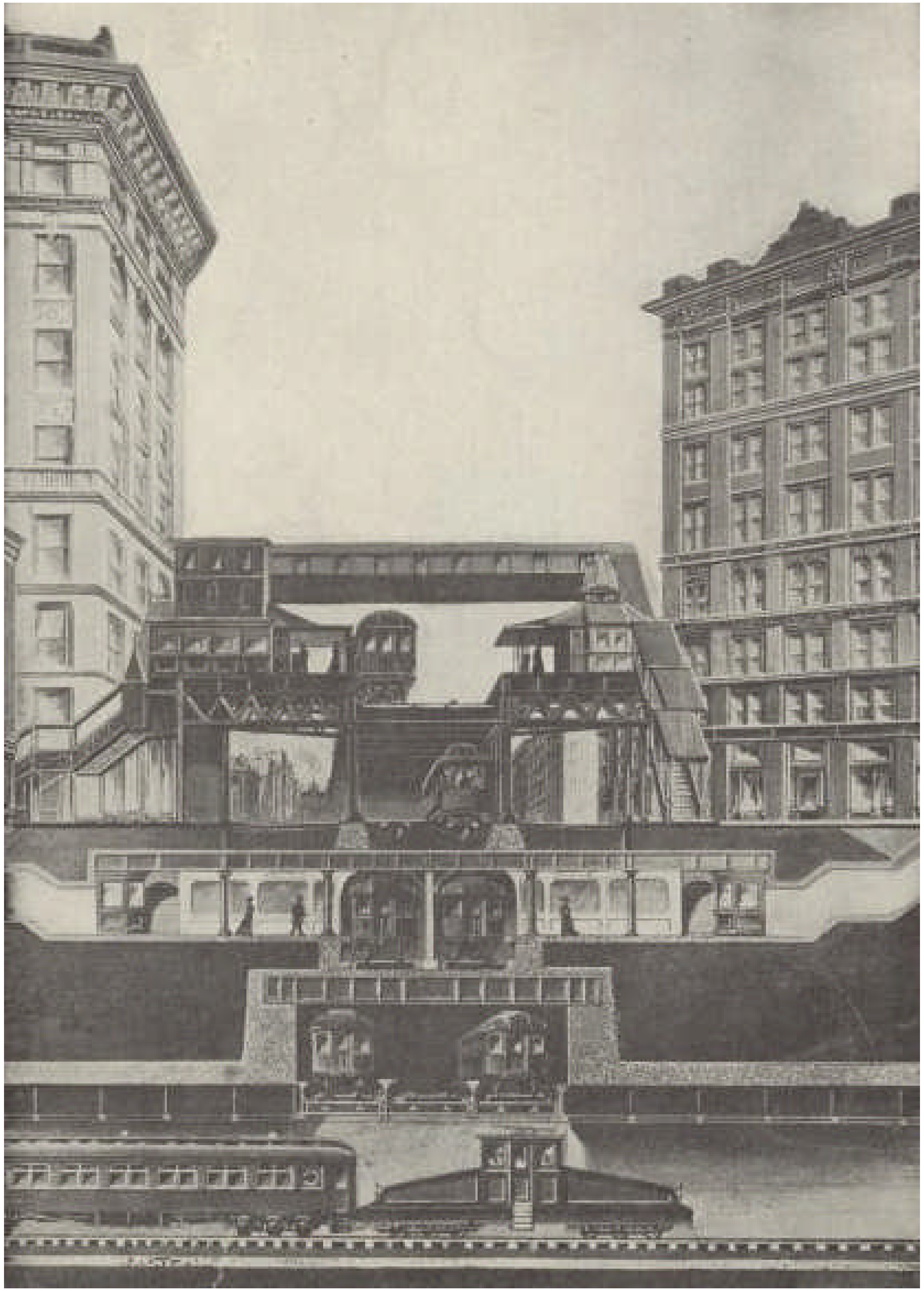
<u>Above</u>: caption: "Map and Profile, Cross-Town Tunnels"



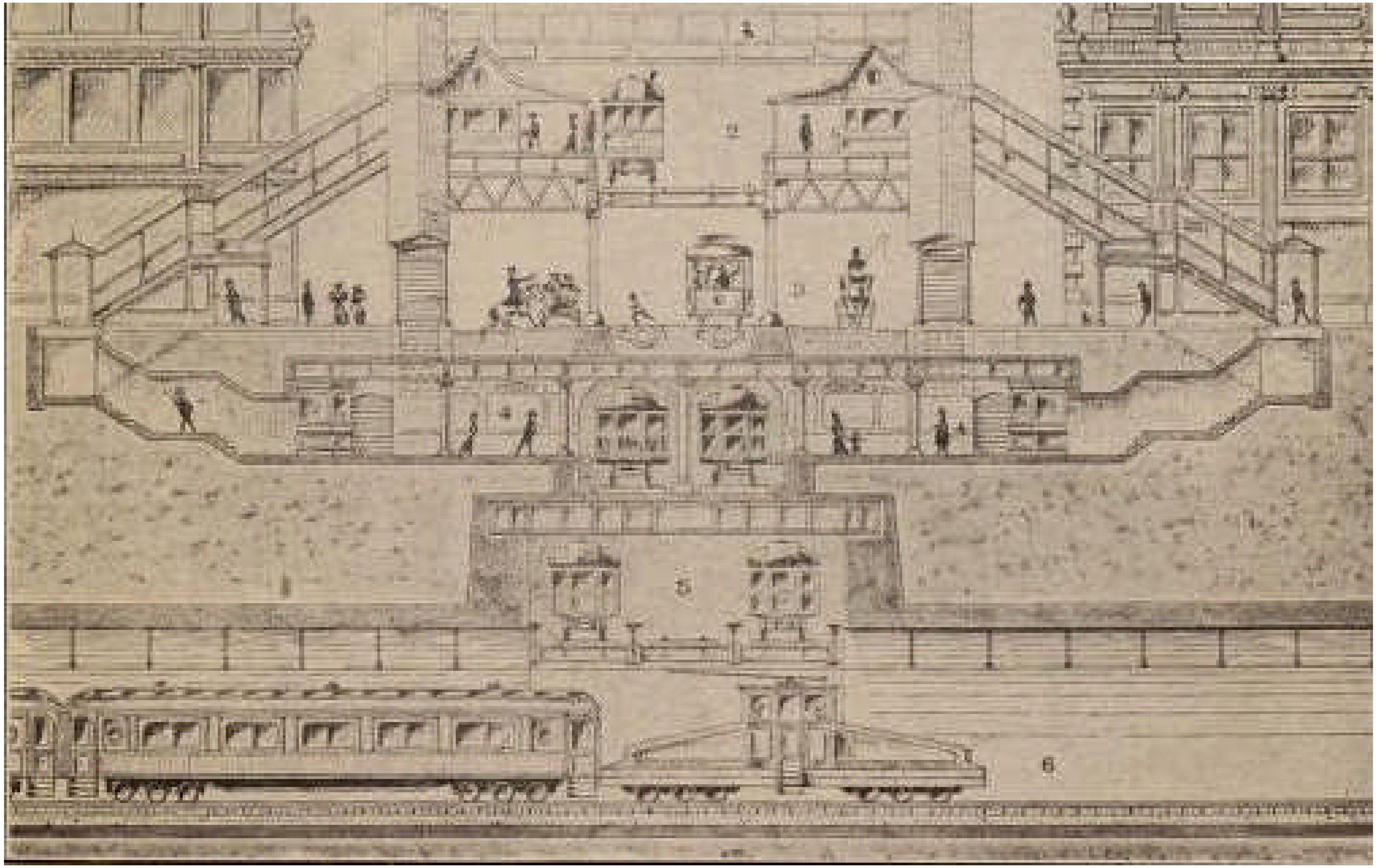
"…Under-water work has a fearsome sound – to those who have never seen it going on. Talk to men who have been engaged in it for years and you get another idea. There are plenty who can speak with authority, for the world was searched for men of the ripest experience to build the Pennsylvania tunnels. On the crosstown shafts, sixty Austrians, who received their training in the Simplon tunnel, were employed. There were engineers and foremen here who had tunneled in Egypt, South Africa, England and America, and who now are doubtless looking for other subterranean regions to conquer…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Above</u>: caption: "Typical Tunnel Sections" (Manhattan)



<u>Left</u>: caption: "Sectional View at 6th Avenue and 32nd Street. This picture shows the full development of New York's various transportation schemes now under way as they will appear at this particular point in the city. Starting at the bottom 55 feet below the street surface will be the new Pennsylvania Tunnel. Immediately above the roof of this there is to be the three track Rapid Transit subway. Over this, the tracks of the Hudson Company's system. Then appears the surface railroad, the Elevated at 32nd Street station, and above the Elevated the foot-bridge – in all five superimposed railroad systems."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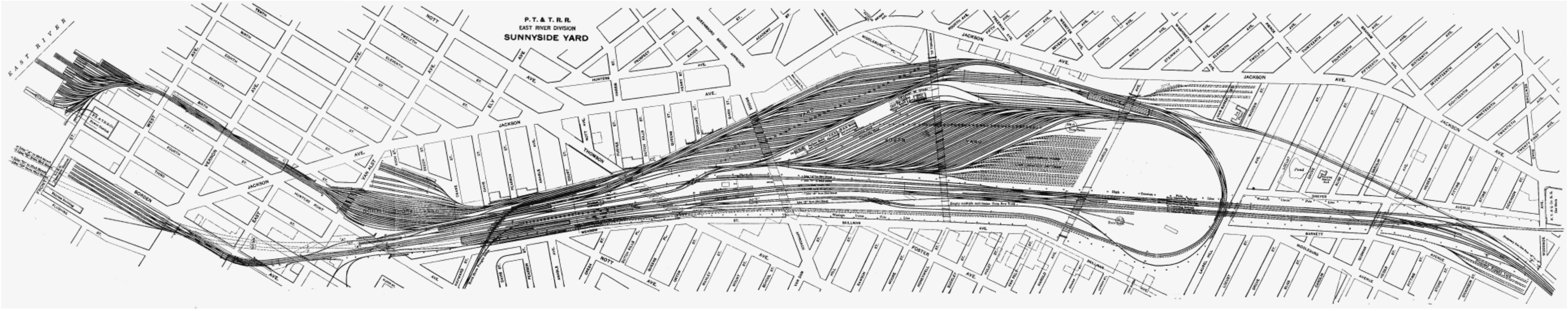


"…Sunnyside Yard, on Long Island, is to the New York Improvement what the West Philadelphia passenger yard is to the Philadelphia terminal, or the Jersey City Yard to the Jersey City Station. The new yard has many unique features, however, such as the provision for running all trains around a loop – doing away with the use of turntables – pulling them into the coach-cleaning yard at one end and departing from the other end, thus turning the entire train and avoiding the necessity for switching baggage cars and sleeping cars to opposite ends of the trains and the turning of combination cars separately. The arrangement of tracks on different levels makes provision for cross-over movements without grade crossings and eliminates interference with high-speed traffic…"

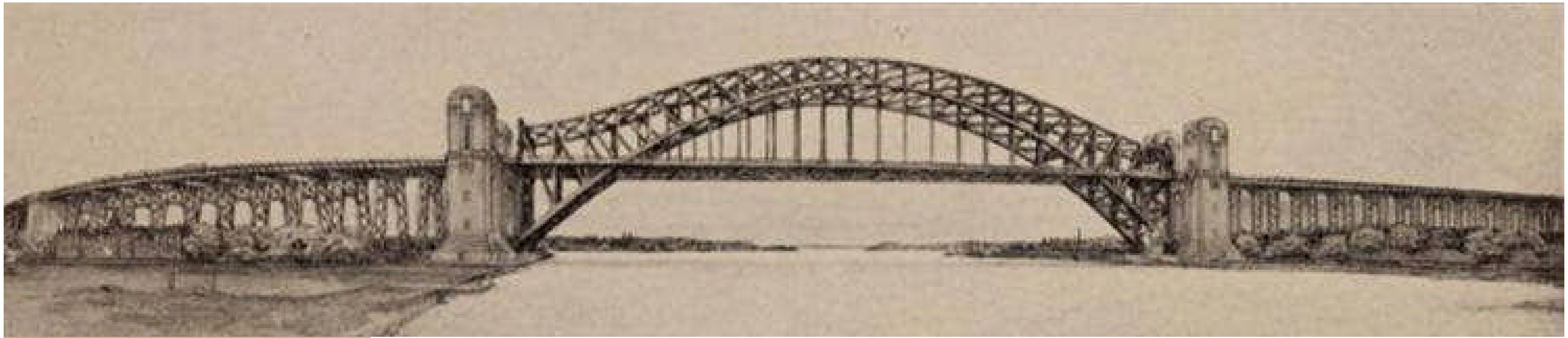
RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

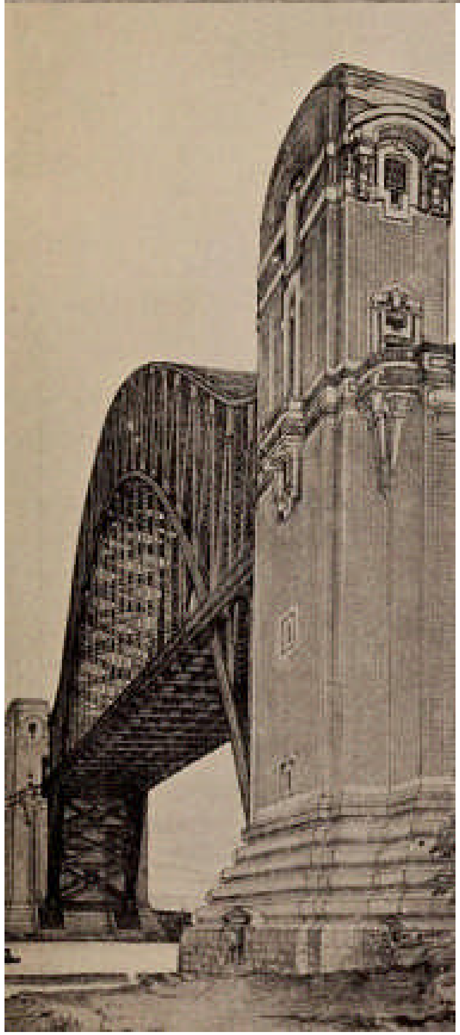
Above: caption: "East River Division Sunnyside Yard"

"…Sunnyside Yard is 5,500 feet long with a minimum width of 1,550 feet, embracing some 173 acres of land. It contains 53 miles of tracks which have a capacity of 1,387 cars. There is additional space for extending the trackage of the yard to provide more car standing-room in the future. From Sunnyside Yard there are tracks leading to the New York Connecting Railroad, which, when constructed, will form a junction with the New York, New Haven & Hartford Railroad at Port Morris, New York. The Connecting Railroad will cross East River by the 'Hell Gate' Bridge over Ward's and Randall's Islands…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Left</u>: caption: "Enough railway passenger coaches to move a fair-sized city are parked at Sunnyside Yards, Queens"





<u>Above</u>: caption: "Hell Gate Bridge, Connecting Railway from Queens over Hell Gate, Ward's Island, Little Hell Gate, 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."

<u>Left</u>: caption: "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."

"…In connection with its improvements in and around New York City, the Pennsylvania Railroad Company has constructed at Greenville, N.J., an extensive freight transfer yard…In addition to the many millions the Pennsylvania Railroad has spent for the four tunnels under the East River, and the vast Station and terminal in Manhattan by which all Long Island will benefit, the Long Island Railroad is increasing its own facilities in all directions to take care of the present large traffic and the larger traffic which will come with the use of the tunnels into the Pennsylvania Station in New York. This will place all parts of Long Island and its many seaside resorts within easy reach of New York City…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

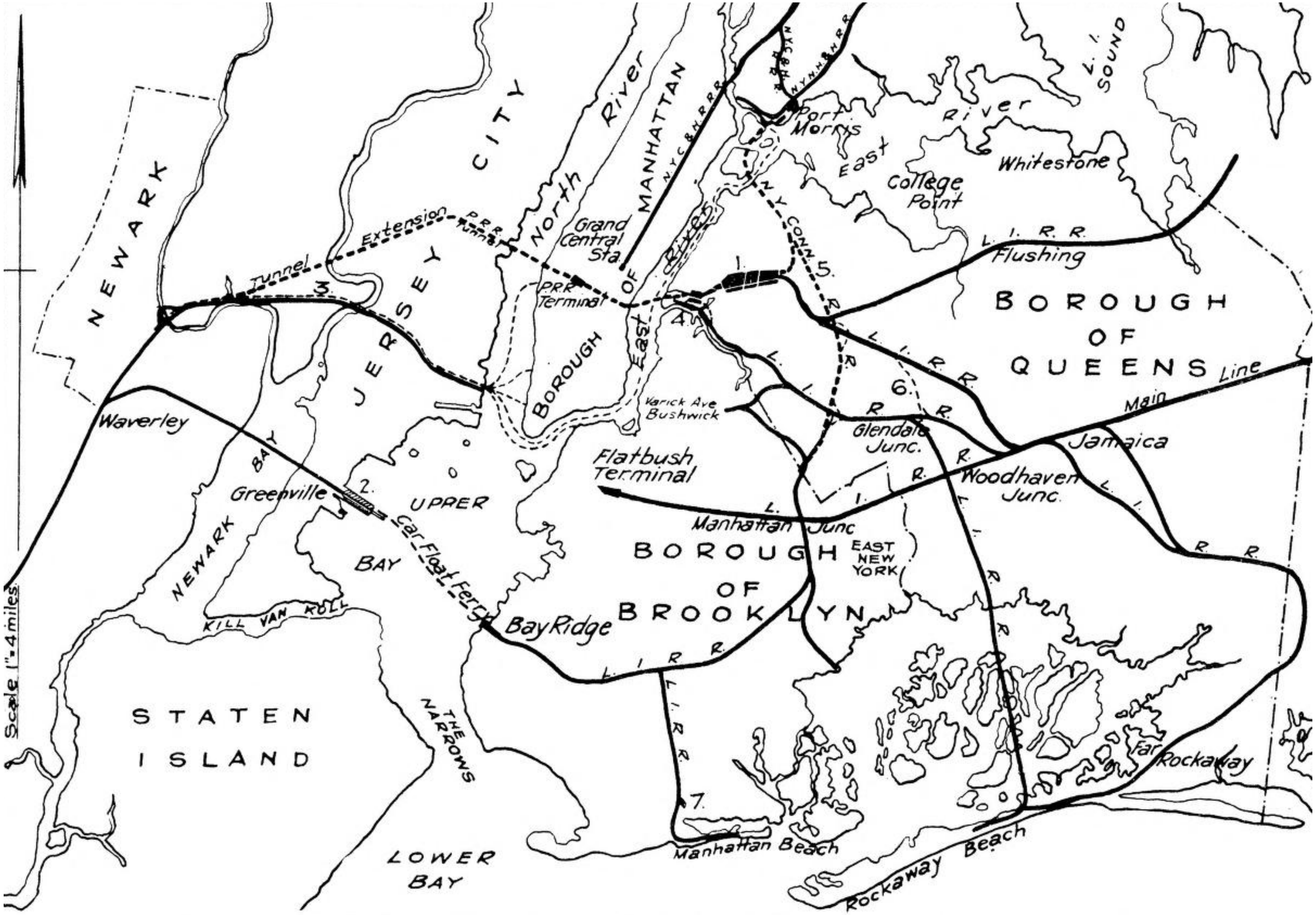
<u>Above</u>: caption: "Long Island commuters at rush hour, December 19, 1938"

In Summary

"…Summing up, the Pennsylvania Railroad Company's new York Tunnel Extension is a line of railroad from Newark, N.J., to Port Morris, N.Y., through the Borough of Manhattan and Queens, having for its principal purposes:

- ***The construction of a large passenger terminal centrally located in the City of New York;***
- ***Making the Long Island Railroad and integral part of the system;***
- ***Affording the Boroughs of Brooklyn, Queens and the balance of Long Island abundant opportunity for development, and;***
- ***Binding the New England States with those of the west and south by means of the New York Connecting Railroad."***

RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*



PENNSYLVANIA R.R. CO'S NEW YORK TUNNEL EXTENSION AND CONNECTIONS.

1. Sunnyside Yard.
2. Greenville Freight Terminal.
3. P.R.R. Electrified Line, Newark to Jersey City.
4. Newtown Creek Development - Bulkheads, piers, tracks.
5. New York Connecting Railroad.
6. Glendale cut-off between Main Line and Rockaway and Montauk Divisions.
7. Terminal, Sheepshead Bay,

New York Tunnel Extension and Station, including Interchange Yards at Harrison, N. J., and Sunnyside, L. I., P. T. & T. R. R. Co.	$100 000 000
Long Island Railroad electrification, Bay Ridge and Atlantic Avenue improvements, Glendale Cut-Off, freight yards, and new equipment	35 000 000
New York Connecting Railroad, to be built jointly by the Pennsylvania R. R. Co. and the New York, New Haven and Hartford R. R. Co., about	14 000 000
Pennsylvania Railroad improvements in the State of New Jersey, electrification of line from Jersey City to Park Place, Newark, Greenville freight line and terminal on New York Bay	10 000 000
Total	$159 000 000

<u>Above</u>: caption: "Estimate of cost of the Pennsylvania RR Company's improvements in the New York District when fully completed is based on the best information now available" (1910)

Left: caption: "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."

Challenge Met

"…With the traffic in and out of New York City growing more rapidly than it had during any period in the last twenty years, the question confronting the Management of the Railroad was whether the volume of this traffic was such to warrant any other method of transportation than ferries for crossing North and East Rivers. The action taken by the Pennsylvania Rail-road shows how it met this situation, and the result is the New York Station and Tunnel Extension…"

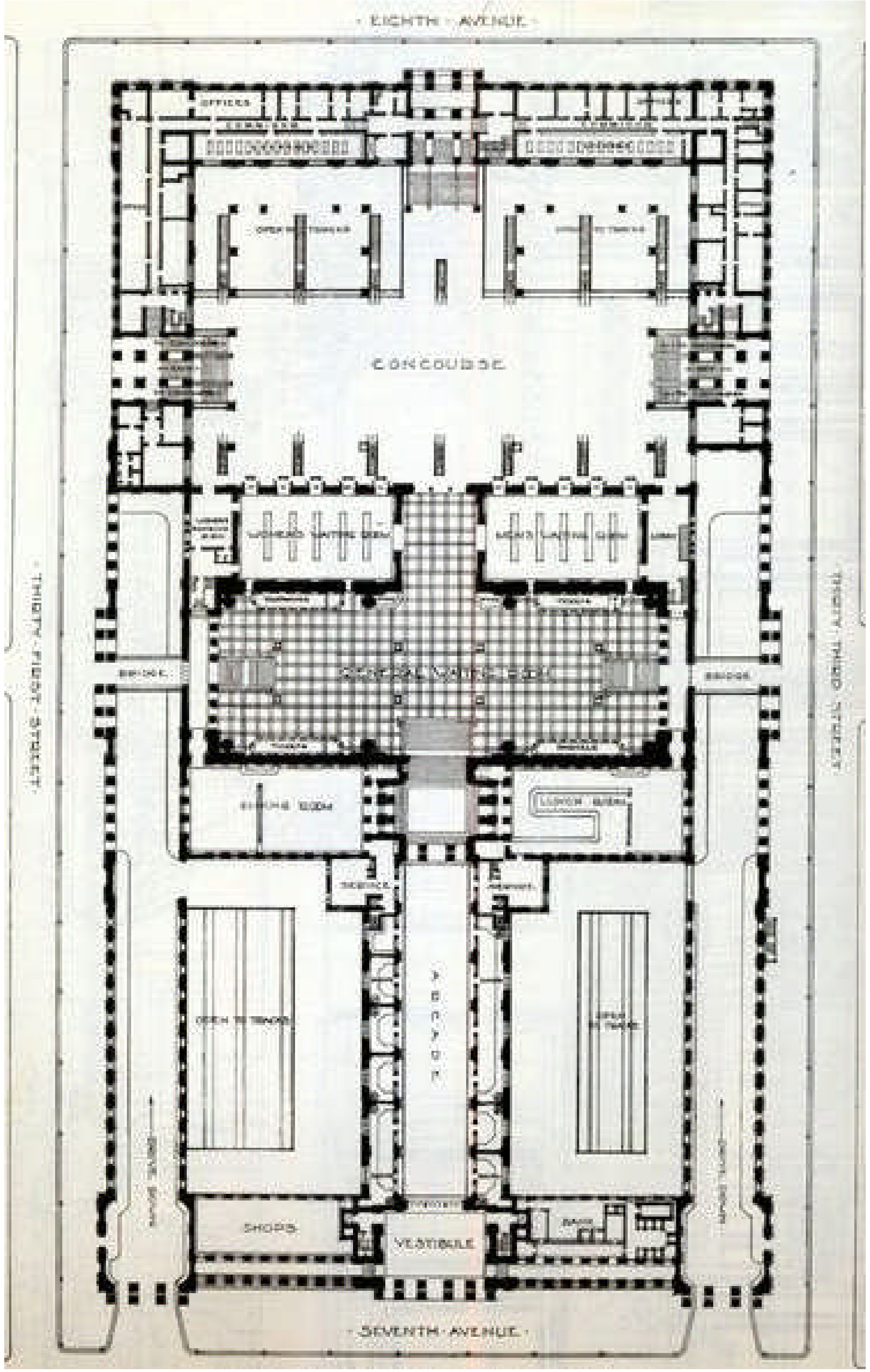
RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Above</u>: caption: "Pennsylvania Station - Seventh Avenue Facade"

The Art of Transportation

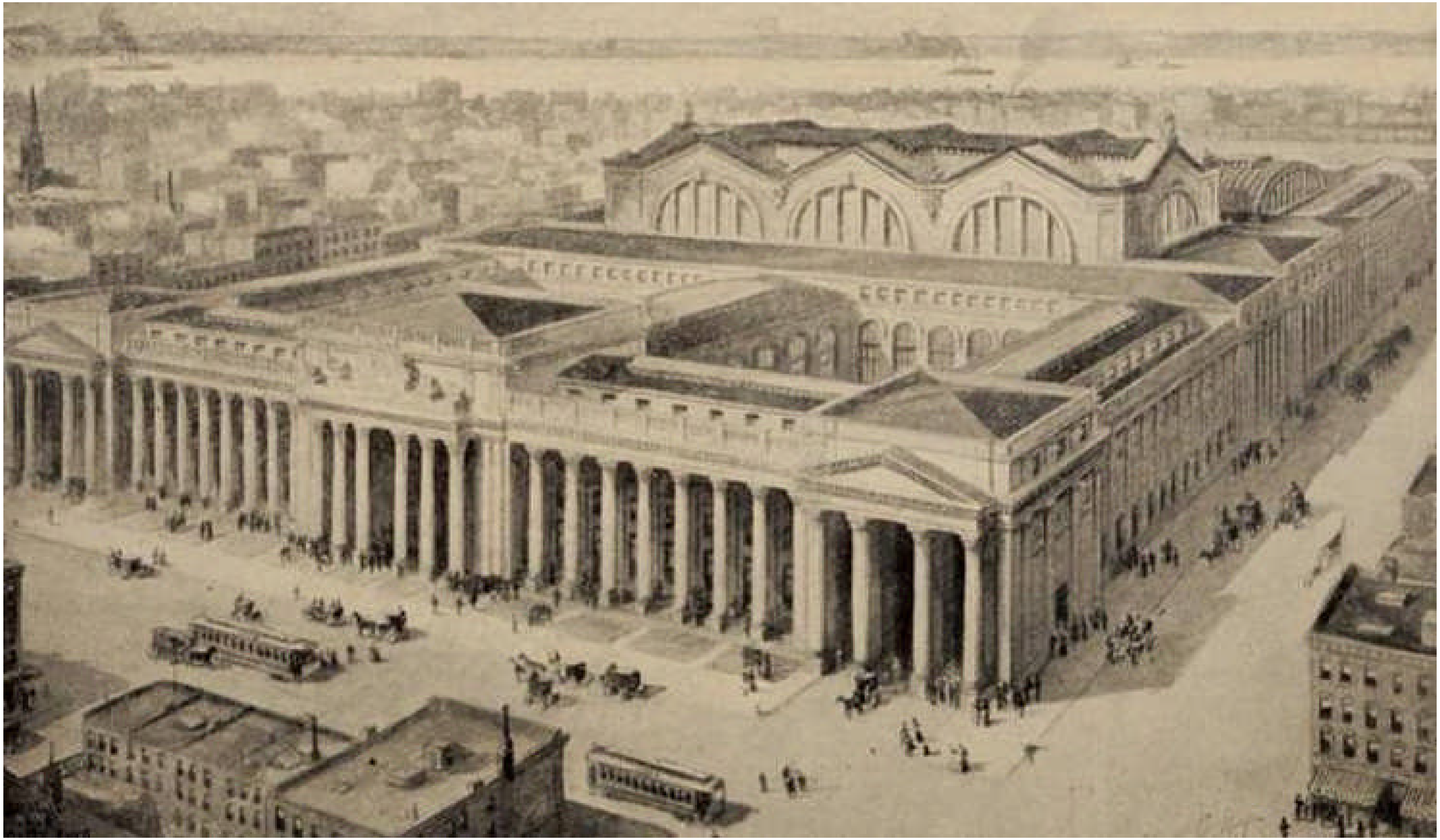
"…The Pennsylvania Station in New York City, at Seventh Avenue and Thirty-second Street, now completed, covers more territory than any other building ever constructed at one time in the history of the world…This Station is not only the largest structure of its kind in the world, but it epitomizes and embodies the highest development of the art of transportation. Every practicable convenience, the most ingenious of mechanical and electrical inventions, every safeguard against danger – all, in fact, that has so far been learned in railway transportation and station perfection, has been availed of for the benefit of every passenger, no matter whether he is to take a short ride to Long Island or a two thousand mile trip to the West…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*



"…In addition to the entrances to the concourse from the waiting room, and from Eighth Avenue, there are direct app-roaches from the two side streets. Midway in the block between Seventh and Eighth Avenues and opposite the entrance to the Station in Thirty-third Street, is a wide private street, which affords direct communication with Thirty-fourth Street, an important crosstown thoroughfare. Lead-ing up from the exit concourse of the Station to this private street is a moving stairway…"

<u>Left</u>: Concourse Level plan



Above: caption: "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, 34 by 210 ft., 21 tracks; Mc-Kim, Mead & White, architects."

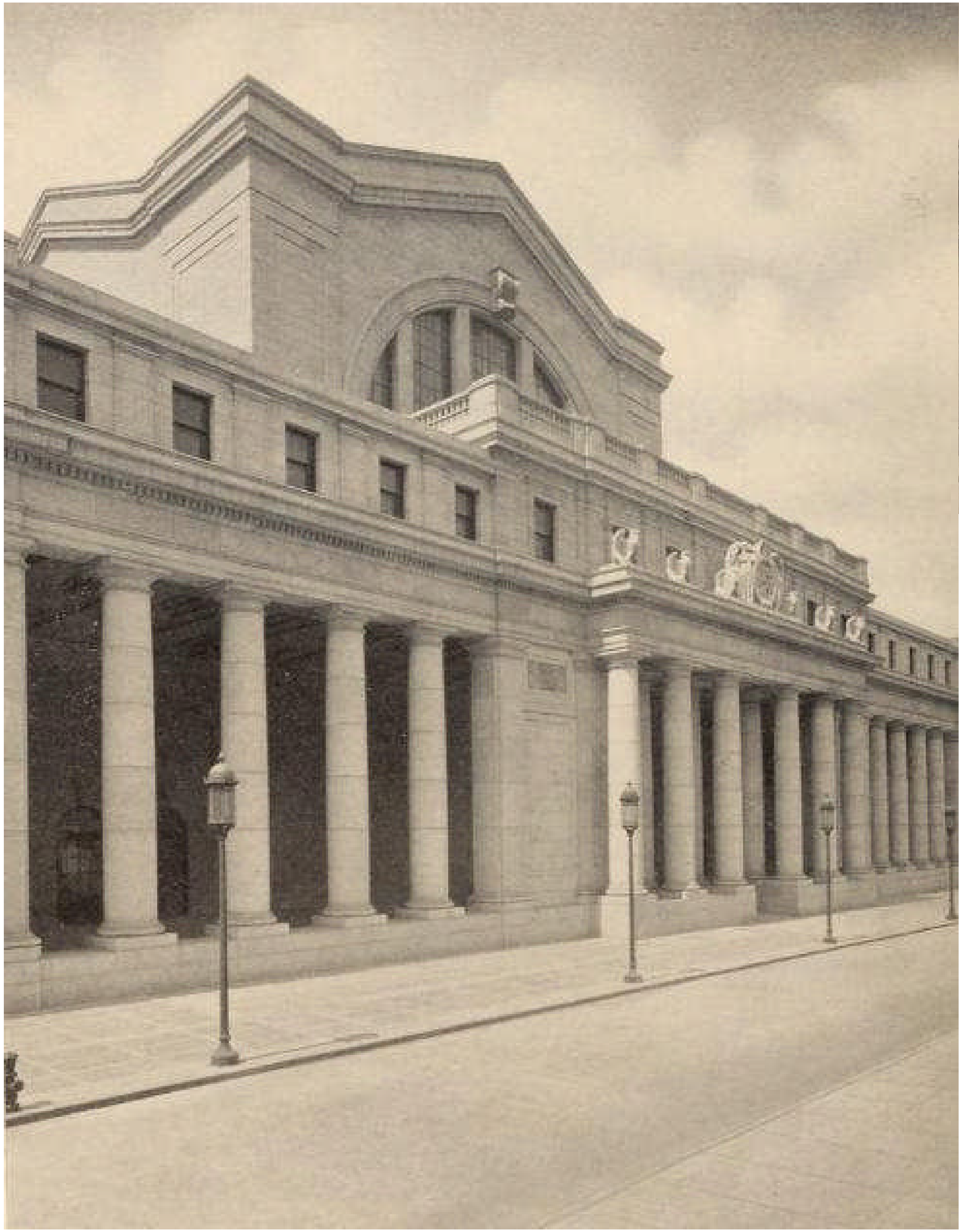
"…At the terminal station site there are about twenty-eight acres enclosed by retaining walls, making a total length of such walls of seventy-eight hundred feet and requiring the excavation of two million five hundred thousand cubic yards. There will be about forty-five thousand tons of steel required for the terminal station, and such station will have ultimately a maximum capacity for about fourteen hundred and fifty trains per day, accommodating about five hundred thousand passengers daily. Within the station area there will be about sixteen miles of track…"

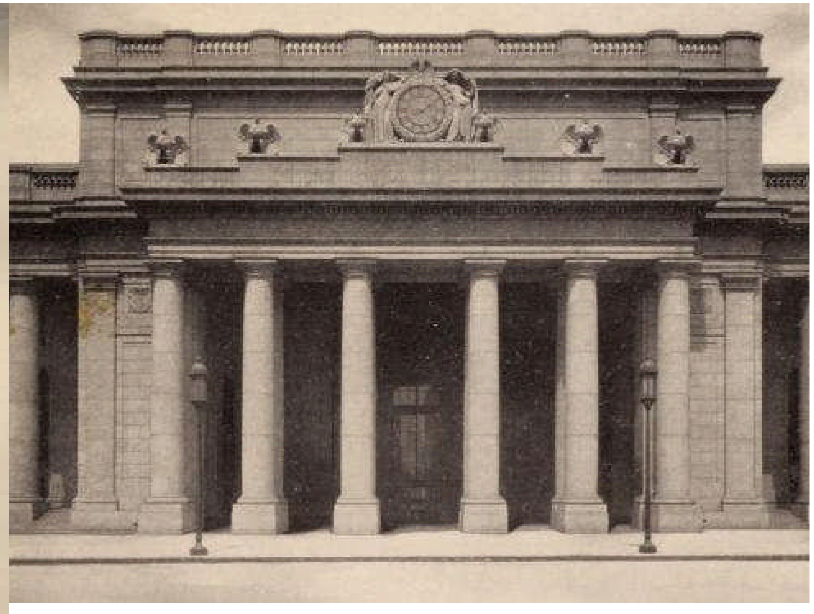
RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*


LEADING
CIGARS
SHORPY

"…In designing the exterior of the building, Messrs. McKim, Mead & White, the architects, were at pains to embody two ideas: To express in so far as was practicable, with the unusual condition of tracks below the street surface and in spite of the absence of the conventional train shed, not only the exterior design of a great railway station in the generally accepted form, but also to give to the building the character of a monumental gateway and entrance to a great metropolis…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*





Above: caption: "Main Entrance on Seventh Avenue"
Left: caption: "Thirty-third Street Entrance to Main Waiting Room"

"…While the facades of the station were designed to suggest the imposing character of the ancient Roman temples and baths, the impression intended to be made upon the layman approaching the station, in full view of the exterior of the general waiting room with its huge semi-circular windows, is that of one of the leading railway stations of the world…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Above</u>: caption: "General View of Main Waiting Room"
<u>Left</u>: caption: "View of Main Waiting Room, looking from Entrance to Concourse toward Seventh Avenue, showing Grand Stairway"

"…The grand stairway…leads from the arcade into the general waiting room, and from it one gets a view of the main entrance to the arcade and of the entire waiting room. At the head of this stairway, in the Travertine wall is placed the statue of Alexander Johnston Cassatt, the dominant personality in the Pennsylvania Railroad tunnel and station project. No greater tribute could be paid to his genius than the inscription at the base of the statue, which reads as follows:

ALEXANDER JOHNSTON CASSATT
PRESIDENT PENNSYLVANIA RAILROAD COMPANY
1899 1906
WHOSE FORESIGHT, COURAGE AND ABILITY
ACHIEVED THE EXTENSION OF THE
PENNSYLVANIA RAILROAD SYSTEM INTO
NEW YORK CITY

The Statue is the work of Adolph Alexander Weinman…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania RR*


AVENUE
AVENUE

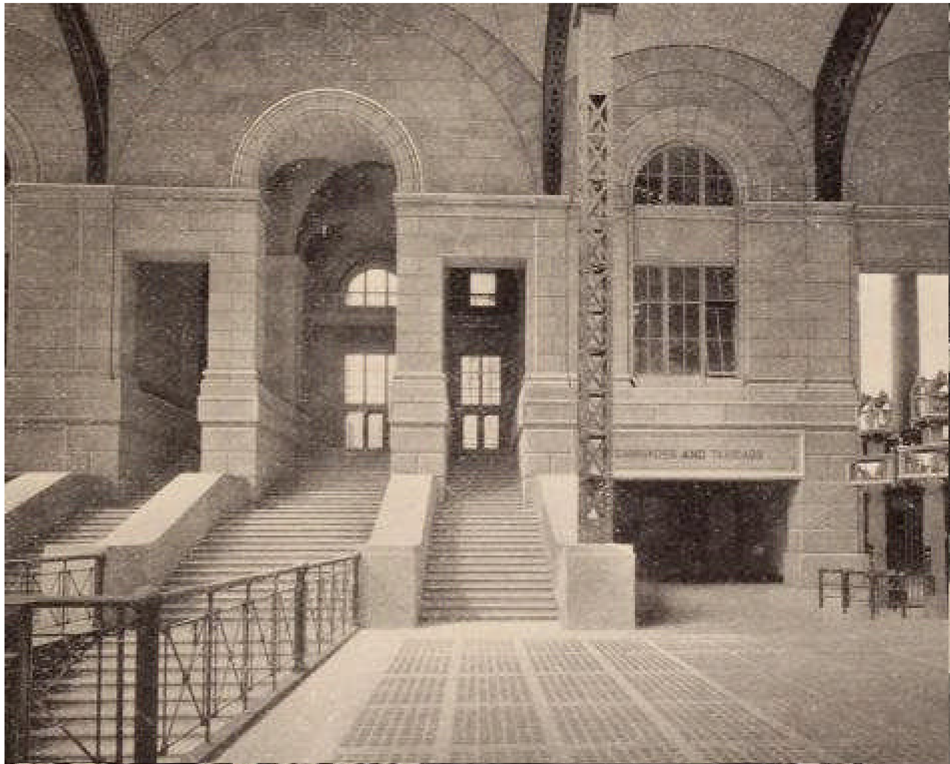
Above: caption: “Concourse. Looking toward Thirty-third Street, showing Train Gates and Indicators”

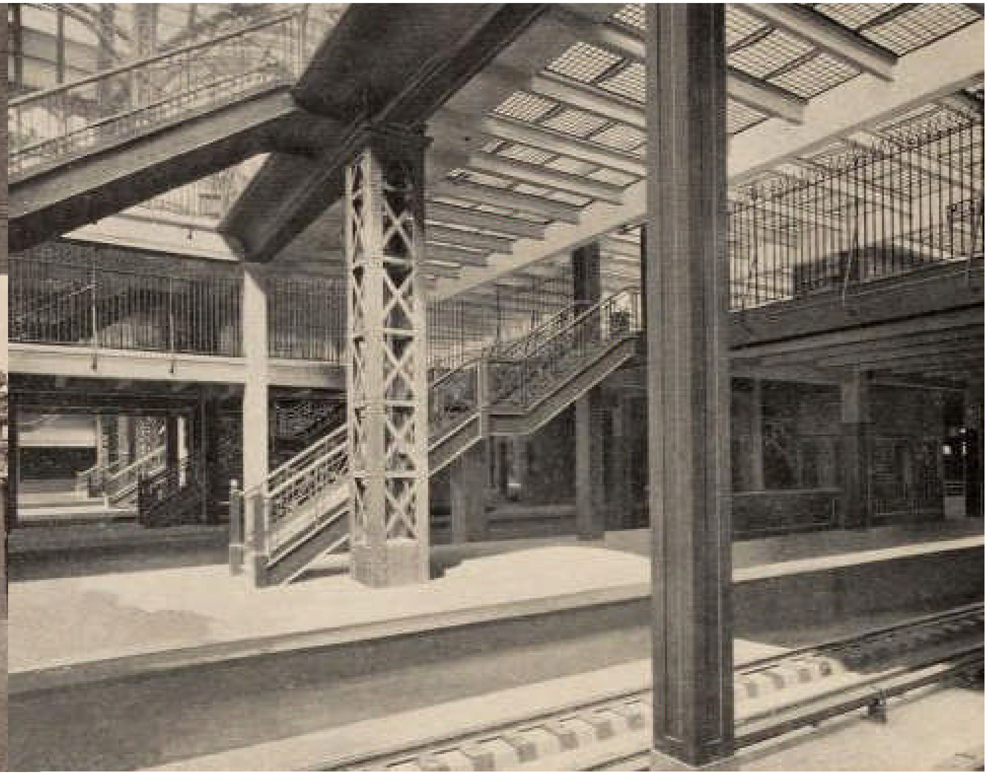
Left: caption: “Portion of the West Wall, Main Waiting Room, Looking toward Concourse”

A Monumental Bridge

“…the plan of the Station was designed to give the greatest number of lines of circulation. The structure is really a monumental bridge over the tracks, with entrances to the streets on the main axis and on all four sides. In this respect the building is unique among the railway stations of the world, affording the maximum of entrance and exit facilities…”

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*





<u>Top Left</u>: caption: "Concourse, showing one of the Exits to Thirty-third Street"

<u>Top Right</u>: caption: "Track Level, showing Stairway and Elevators leading to Exit Concourse"

<u>Left</u>: caption: "Exit Concourse, showing one of the Exit Elevators, and a Stairway leading to Thirty-third Street"

“…For the first time in this country, a station has been planned in such a way as to provide for the complete separation, above the train platform level, of the incoming and outgoing traffic; this, to a great extent, should avoid much confusion. The Station is so located and designed that the traffic may enter or leave the building on any of the four adjoining streets and avenues, and in this manner congestion is avoided…”

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

"…Underlying the main concourse and located between it and the tracks is the exit concourse, 60 feet wide, which will be used for egress purposes only. The exit concourse is eighteen feet above the train platforms and is connected to them by two stairways and one elevator from each platform. From the exit concourse ample staircases and inclines lead directly to the two side streets, Thirty-fourth Street and Eighth Avenue. In addition, the Company has arranged for direct connection with subways in Seventh and Eighth Avenues, when these lines are built…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

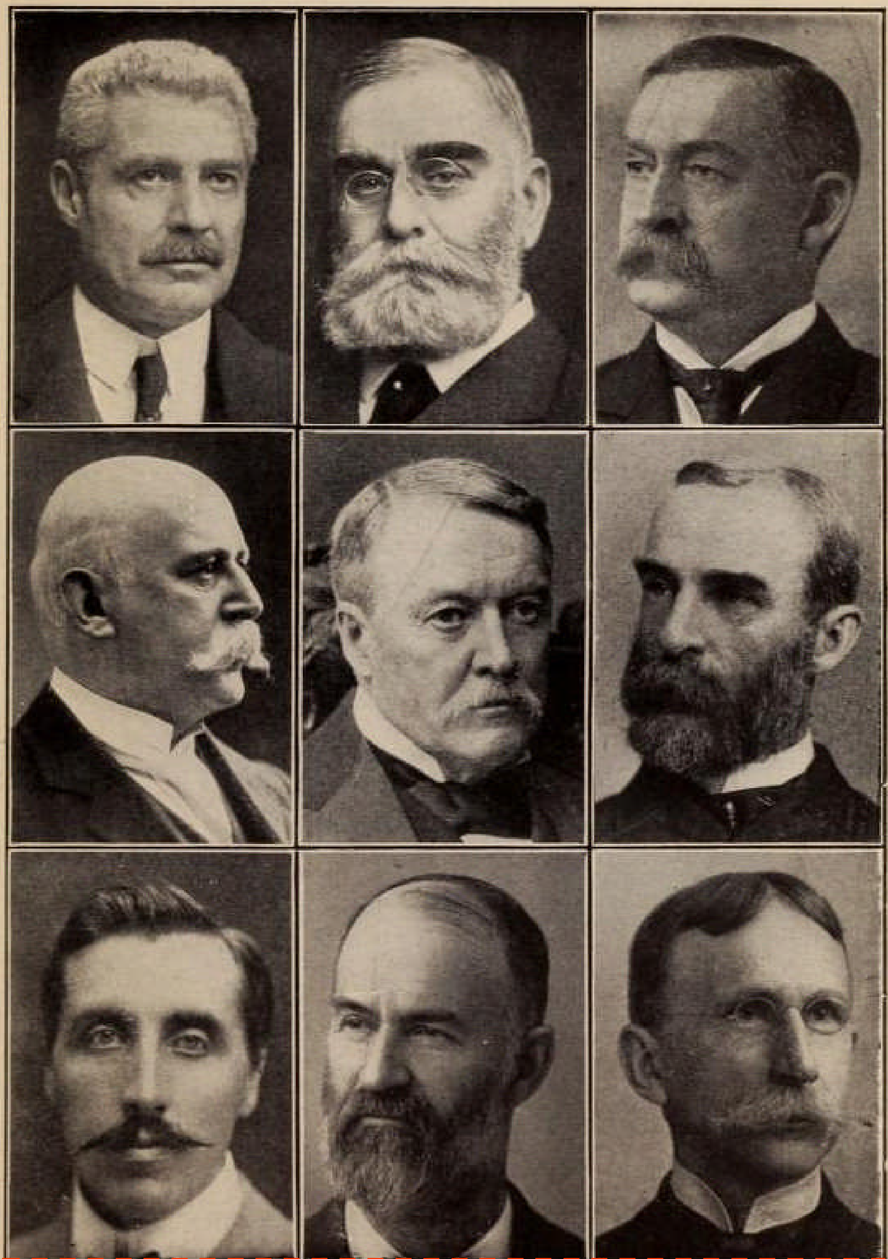
Pennsylvania Tunnel and Terminal RR Co.

"…To carry this tunnel scheme into effect required the formation of two companies, one in New Jersey and the other in New York, which are known as the Pennsylvania, New Jersey and New York railroad Company and the Pennsylvania, New York and Long Island Railroad Company, respectively. The first named company was incorporated on February 13, 1902, in the State of New Jersey…The Pennsylvania, New York and Long Island Railroad Company was incorporated April 21, 1902, under the laws of the State of New York…"

RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*

“This tablet is erected by the Board of Directors of the Pennsylvania Railroad Company to commemorate the extension of its Railroad System into New York City by the completion and opening on the Eighth day of September, A.D. 1910, of the tunnels and Station, and to record the names of the Directors and Officers who shared the responsibility of authorizing and constructing the undertaking. The tunnels and Station were planned and constructed under the executive direction and supervision of Alexander Johnston Cassatt, President, and Samuel Rea, Vice-President, of the Companies, incorporated in 1902 in the States of New York and New Jersey, and later merged constituting the Pennsylvania Tunnel and Terminal Railroad Company.”

RE: inscription on one of two tablets placed on the side/s of the main entrance to Penn Station (on Seventh Avenue)



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.

Board of Directors of the Pennsylvania Railroad Company

Alexander Johnston Cassatt, President, died December 28, 1906.
Sutherland M. Prevost, Vice-President, died September 30, 1905.
William L. Elkins, died November 7, 1903.
Amos R. Little, died December 16, 1906.
Alexander M. Fox, died October 6, 1907.
John P. Green, Vice-President, retired March 24, 1909.

N. Parker Shortridge,	Thomas DeWitt Cuyler,
Clement A. Griscom,	Lincoln Godfrey,
William H. Barnes,	Rudolph Ellis,
George Wood,	Henry C. Frick,
C. Stuart Patterson,	Charles E. Ingersoll,
Effingham B. Morris,	Percival Roberts, Jr.

W. W. Atterbury, Fifth Vice-President.
Henry Tatnall, Fourth Vice-President.
John B. Thayer, Third Vice-President.
Samuel Rea, Second Vice-President.
Charles E. Pugh, First Vice-President.
James McCrea, President.

Left: caption: "Samuel Rea, 3rd v.p. P.R.R; James McCrea, Pres. P.R.R.; Chas. E. Pugh, 2nd 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."

“The franchise from the City of New York authorizing the construction, maintenance and operation of the Tunnel Extension and Station of The Pennsylvania Railroad System was granted October 9, 1902 by the

BOARD OF RAPID TRANSIT RAILROAD COMMISSIONERS

Alexander E. Orr, Chairman.
John Claflin, Edward M. Grout,
Morris K. Jesup, Woodbury Langdon,
Charles Stewart Smith, John H. Starin,
Mayor, Seth Low.

The Construction of the Tunnel Extension was begun June 10, 1903. The two tunnels under the North River and the four tunnels under the East River were built by shields driven from each side of the respective rivers, and union was completed by the junction of the last tube on the following dates:”

North River Tunnels, October 9, 1906.
East River Tunnels, March 18, 1908.

RE: inscription on the other tablet placed on the side/s of the main entrance to *Penn Station* (on *Seventh Avenue*)

"…These were the first tunnels for standard railroad trains constructed under these rivers. The construction of the New York Station building was begun May 1, 1904 and trains were first operated from it on regular schedule September 8, 1910…It is impossible to insert in these tablets the names of all those discharging responsible duties on the Tunnel Extension, but the Management fully appreciates and recognizes the ability and fidelity which secured the completion of the work, and especially displayed by the Assistant Chief Engineers and their staffs engaged in the hazardous as well as unique task of constructing the tunnels under North and East Rivers…This great work must, however, be regarded as representing the united effort and experience of the Pennsylvania Railroad Organization…"

RE: inscription (cont'd.) on the other tablet placed on the side/s of the main entrance to *Penn Station* (on *Seventh Avenue*)

Farewell Penn Station

"Any city gets what it admires, will pay for, and, ultimately, deserves. Even when we had Penn Station, we couldn't afford to keep it clean. We want and deserve tin-can architecture in a tinhorn culture. And we will probably be judged not by the monuments we build but by those we have destroyed."

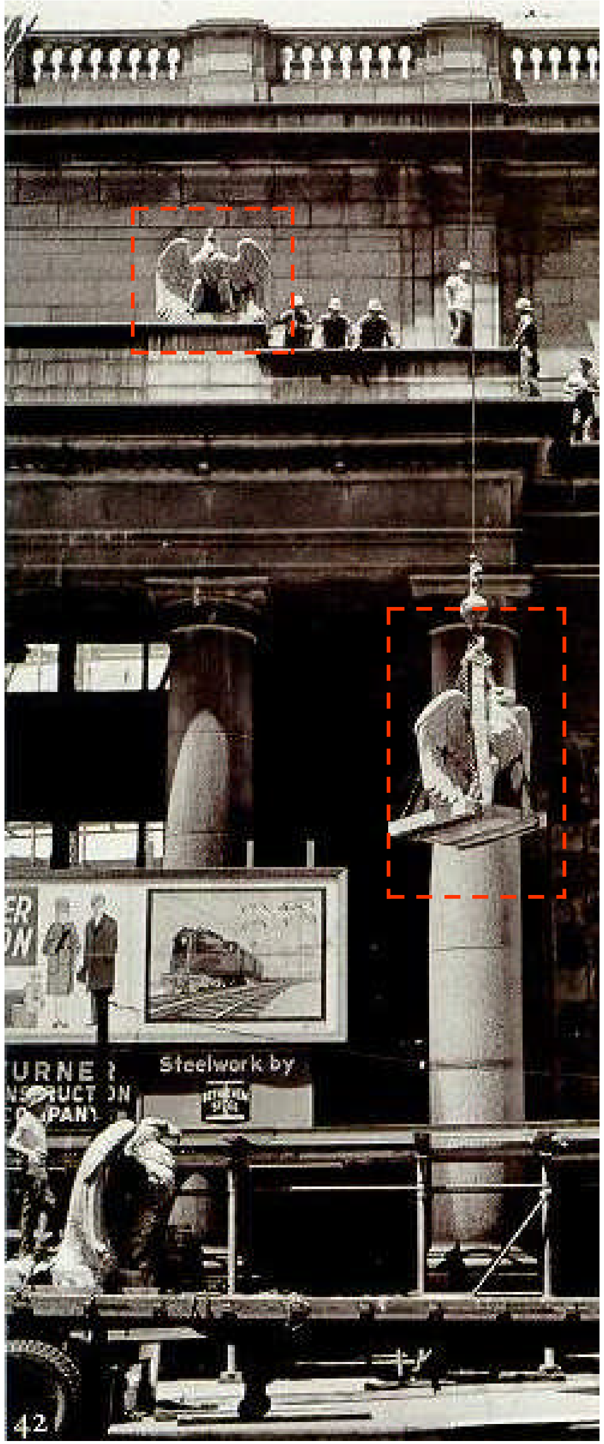
RE: "Farewell to Penn Station" - a *New York Times* editorial, October 30th 1963


SAVE OUR STATION
ACTION NOT APATHY
AGBANY
SAVE PENN STATION
SAVE OUR HERITAGE


AGBANY IS HERE
SAVE PENN STATION

"Until the first blow fell, no one was convinced that Penn Station really would be demolished, or that New York would permit this monumental act of vandalism against one of the largest and finest landmarks of its age of Roman elegance"

RE: excerpt from a *New York Times* editorial



"Like ancient Rome, New York seems bent on tearing down its finest buildings. In Rome, demolition was a piecemeal process which took over 1,000 years; in New York demolition is absolute and complete in a matter of months. The rise of modern archaeology put an end to this kind of vandalism in Rome, but in our city no such deterrent exists."

***New York Chapter* of the *American Institute of Architects* (AIA), 1963**

RE: in April 1963 – before demolition of *Penn Station* had begun, NYC Mayor *Robert F. Wagner* named a twelve-member *Landmarks Preservation Commission* (LPC). Too late however to save Penn Station from its ignominious fate. In 1965, over the objections of the city's powerful real estate interests, the city council codified the LPC with police power and the right of *Eminent Domain.* Property owners could seek tax relief under the new law as well. During its first two years, the LPC designated nearly two-hundred structures worthy of landmark status.

<u>Left</u>: one of Penn Station's carved stone eagles is carefully removed from the *7th Avenue* facade



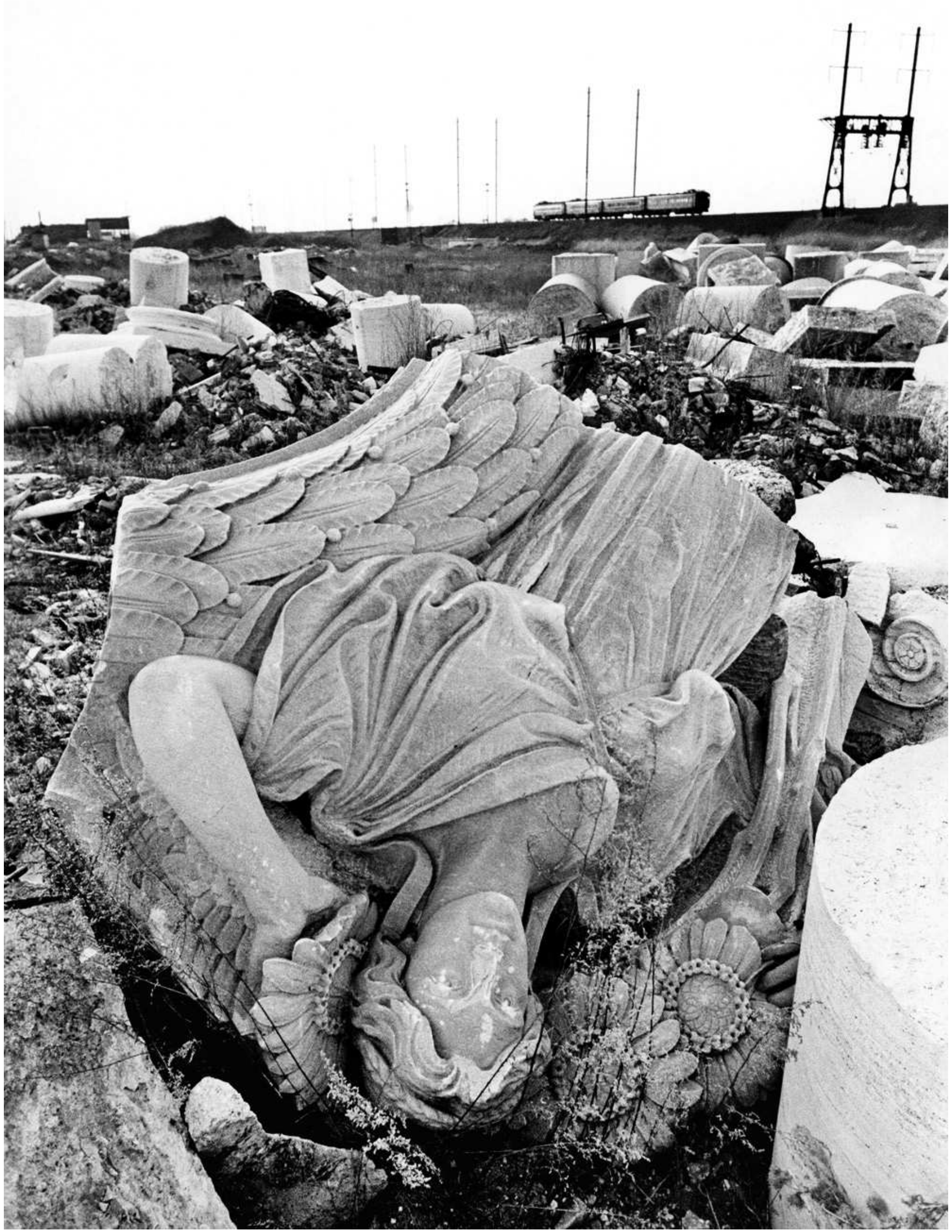
EASTERN STANDARD
TIME


TIME
BETHLEHEM

"The message was terribly clear. Tossed into the Secaucus graveyard were about 25 centuries of classical culture and the standards of style, elegance and grandeur that it gave to the dreams and constructions of Western man."

***Ada Louise Huxtable, New York Times* Architecture Critic**

RE: the demolition of *Pennsylvania Station, New York City* in 1963



<u>Left</u>: caption: "Feb. 28, 1966: This image of wreckage from Pennsylvania Station's original facade was published in The New York Times on several occasions. It helped create a law establishing the Landmarks Preservation Commission. Ada Louise Huxtable of The Times described this site in Secaucus, N.J., containing twenty-five decades of debris from New York City, as a 'pretty classy dump' of classical culture, style and elegance – 'a setting of macabre surrealist verite.'"

Just Like a Rat

"One entered the city like a God. One scuttles in now like a rat."

Vincent Scully, **Architectural Critic**

Above: the fourth incarnation of NYC's *Madison Square Garden* – under construction on the site of the old *Penn Station* (March 1967)

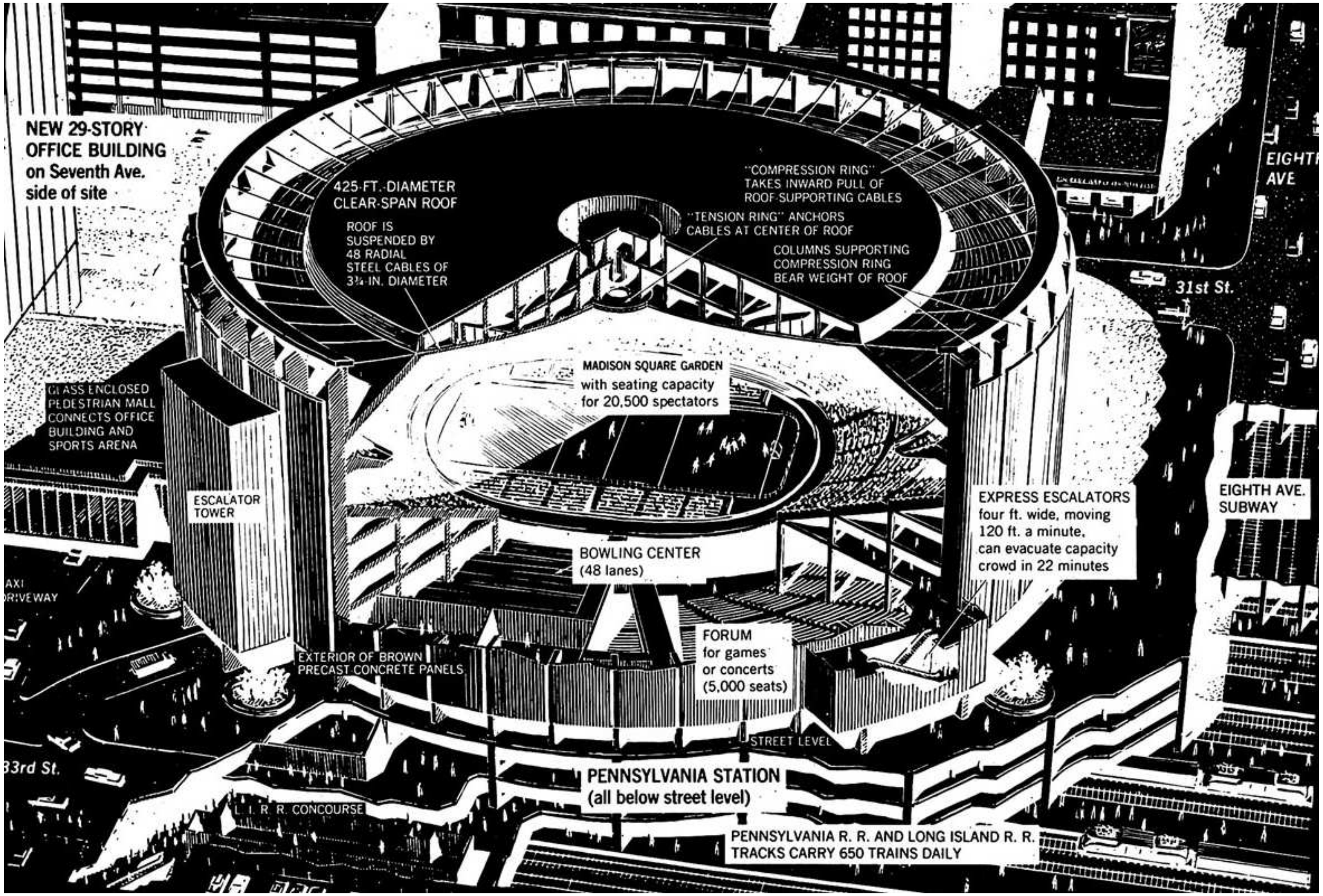
Left: MSG rising from the ashes of the demolished Penn Station (September 1964)

MADISON SQUARE GARDEN CENTER • *architect:* CHARLES LUCKMAN ASSOCIATES; *general contractor:* TURNER CONSTRUCTION CO. & DEL E. WEBB CORP.; *consulting engineers:* SYSKA & HENNESSY, INC.; *plumbing contractor:* WACHTEL PLUMBING CO., INC.; *plumbing wholesaler:* GLAUBER, INC.; *fixture manufacturer:* KOHLER CO.

TWO PENNSYLVANIA PLAZA • *architect:* CHARLES LUCKMAN ASSOCIATES; *general contractor:* TISHMAN REALTY & CONSTRUCTION CO., INC.; *consulting engineers:* JAROS, BAUM & BOLLES; *plumbing contractor:* WACHTEL PLUMBING CO., INC.; *plumbing wholesaler:* GLAUBER, INC.; *fixture manufacturer:* KOHLER CO.

Madison Square Garden Center

—*a new international landmark*


NEW 29-STORY OFFICE BUILDING on Seventh Ave. side of site
425-FT.-DIAMETER CLEAR-SPAN ROOF
ROOF IS SUSPENDED BY 48 RADIAL STEEL CABLES OF 3¼-IN. DIAMETER
"COMPRESSION RING" TAKES INWARD PULL OF ROOF-SUPPORTING CABLES
"TENSION RING" ANCHORS CABLES AT CENTER OF ROOF
COLUMNS SUPPORTING COMPRESSION RING BEAR WEIGHT OF ROOF
EIGHTH AVE
31st St.
GLASS ENCLOSED PEDESTRIAN MALL CONNECTS OFFICE BUILDING AND SPORTS ARENA
MADISON SQUARE GARDEN with seating capacity for 20,500 spectators
ESCALATOR TOWER
EXPRESS ESCALATORS four ft. wide, moving 120 ft. a minute, can evacuate capacity crowd in 22 minutes
EIGHTH AVE. SUBWAY
BOWLING CENTER (48 lanes)
FORUM for games or concerts (5,000 seats)
EXTERIOR OF BROWN PRECAST CONCRETE PANELS
STREET LEVEL
33rd St.
PENNSYLVANIA STATION (all below street level)
L. I. R. R. CONCOURSE
PENNSYLVANIA R. R. AND LONG ISLAND R. R. TRACKS CARRY 650 TRAINS DAILY


PENNSYLVANIA STATION


PENN STATION


KFC

Bravo, Jackie O

"Is it not cruel to let our city die by degrees, stripped of all her proud monuments, until there will be nothing left of all her history and beauty to inspire our children? If they are not inspired by the past of our city, where will they find the strength to fight for her future? Americans care about their past, but for short term gain they ignore it and tear down everything that matters. Maybe this is the time to take a stand, to reverse the tide, so that we won't all end up in a uniform world of steel and glass boxes."

Jacqueline Kennedy Onassis

Left: *Jacqueline Kennedy Onassis* and *Bess Myerson* (center), are flanked by *Philip Johnson* (left) and *Ed Koch* (right) as they leave GCT after holding a news conference. At the time of Penn Station's demise, JKO was First Lady. In 1978, Grand Central Terminal's landmark status was upheld by the *U.S. Supreme Court*, sparing it the wrecking ball. In large part, it was due to her heroic efforts to spare GCT the ignoble fate of *Penn Station*.

"I really believe Grand Central Terminal was saved because of what happened at Penn Station."

Peter Samton, **Architect**

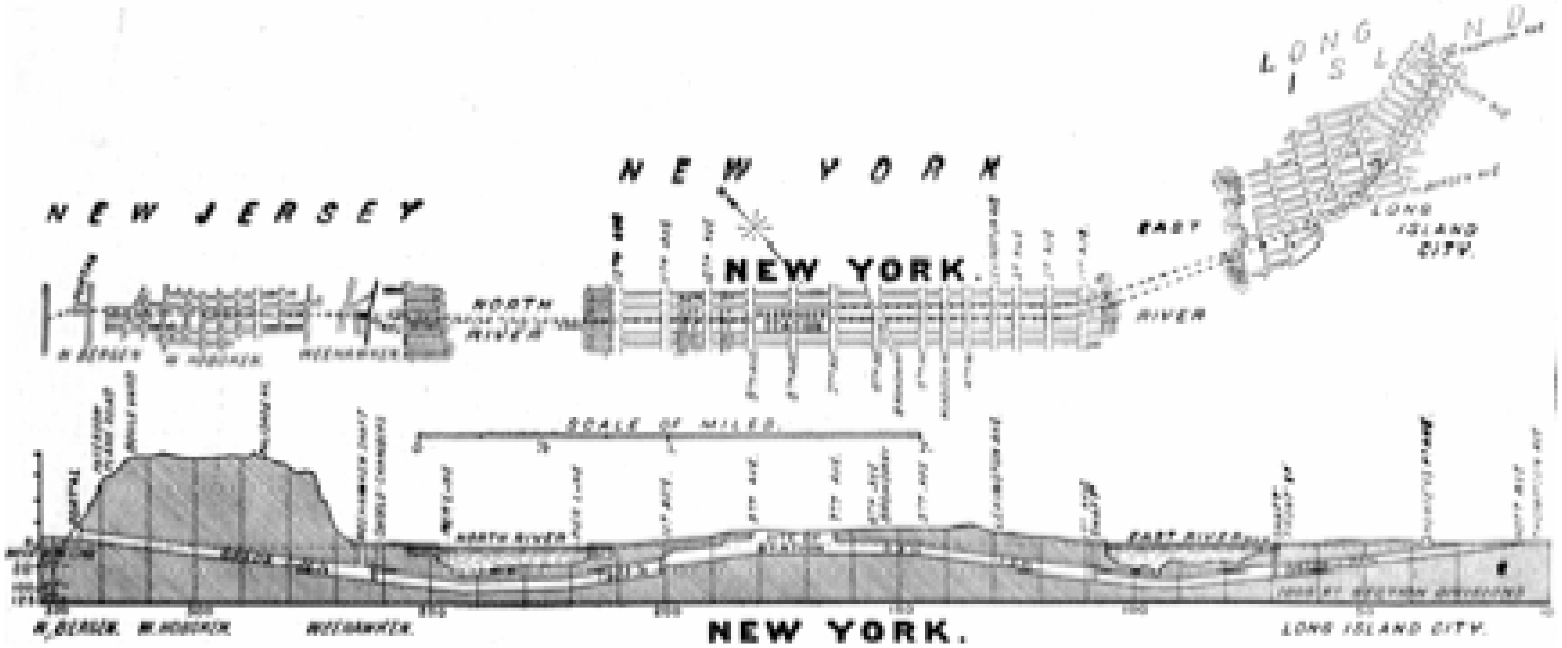
<u>Left</u>: one of the last remnants of the original Penn Station; a staircase between Tracks 3 and 4. As a civic leader and architect, Samton was active in trying to save both *Penn Station* and GCT.

Part 6

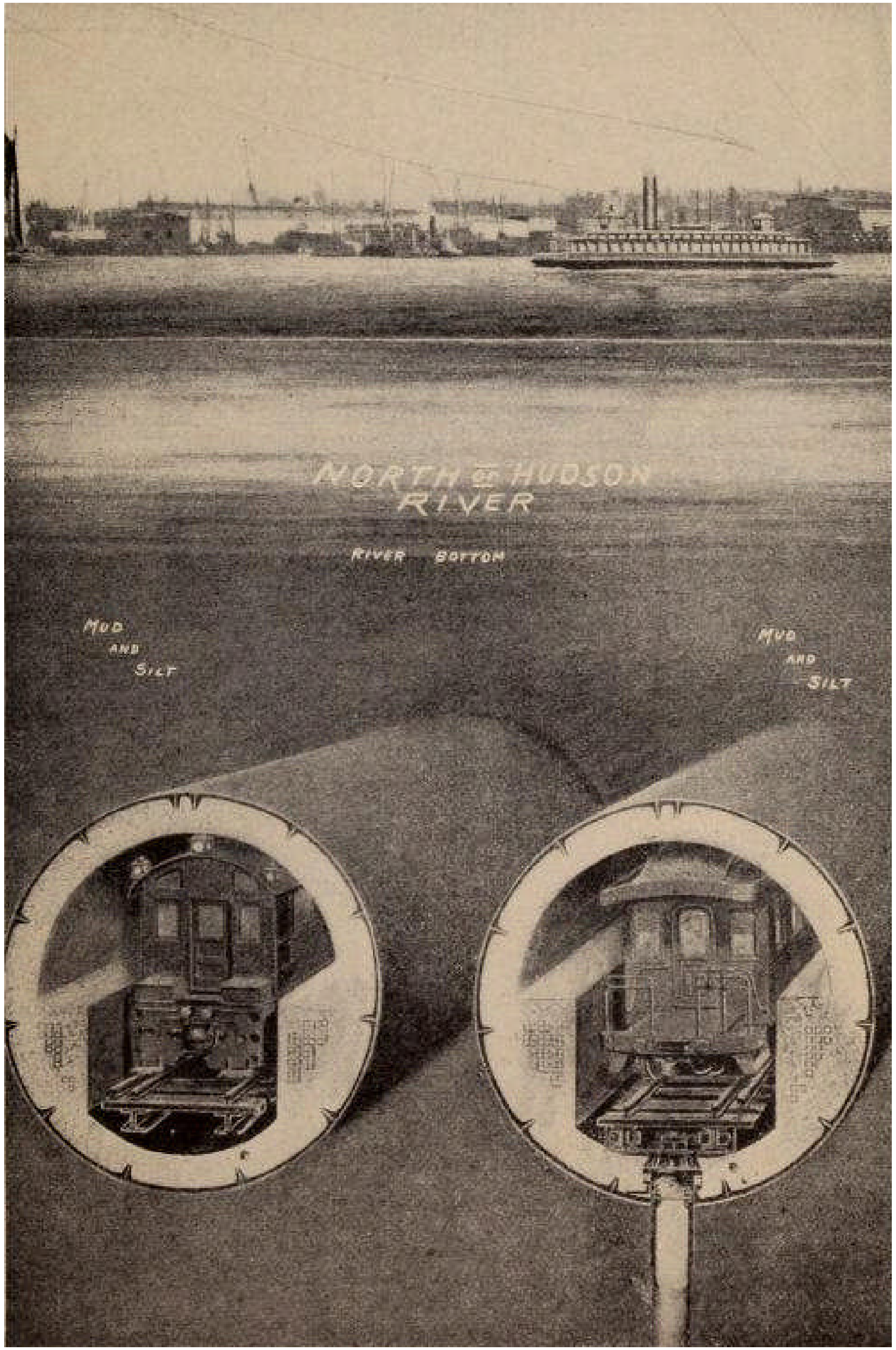
To Wrought a Great Triumph

"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 $90,000,0000, 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…"

RE: excerpt from *The Pennsylvania Railroad Tunnels and Terminals in New York City*



<u>Above</u>: caption: "This drawing from the May 14,1910, issue of Scientific American Supplement shows the alignment and profile of the Pennsylvania's New York tunnels, from the Hackensack portal in New Jersey to Long Island City." The most challenging portion of the work was the construction of twin tunnels extending 2.76 miles from the *Hackensack* portal on the west-side of *Bergen Hill* to a point under the corner of *32nd Street* and *Ninth Avenue* in *Manhattan*. It was necessary to drill the tubes under the *Hudson River* at a sufficient depth below the dredging plane established by the *War Department* (40-feet below mean low water) to protect them against damage from heavy anchors or sunken vessels, and to ensure that they could pass below existing piers and bulkheads. The tubes would also have to be far enough below the bottom of the river to provide sufficient cover to prevent a blowout during compressed air tunneling. The tunnels descended on a 1.3% grade from the Bergen Hill portal to a low-point at which the bottom of the tubes was 97-feet below mean high water, providing an average cover depth of 25-feet between the top of the tunnel and the river bottom. From this low point, the tunnels climbed for a distance of 5K-feet on grades of 0.53% and then 1.93% to level off 35-feet below street level between Ninth and *Tenth Avenue/s*. Surveys, soundings, and borings confirmed that the tubes would lie in a fluid silt composed principally of clay, sand and water. The Board of Engineers selected shield-driven, compressed-air tunneling as the most suitable for the work. The method had the advantage of avoiding any work from the surface that might obstruct navigation.



Left: caption: “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, 1906, south, Nov. 18, 1906.” The two single-track tunnels were drilled on 3-foot centers. Each had a circular cast-iron shell with an outside diameter of 23-feet. Where unusual stresses were expected, such as a transition from soft to hard ground, cast-steel was used instead of cast iron. Each tunnel ‘ring’ was bolted together from eleven segments plus a closing ‘key’ segment, each 2-feet. 6-inches long and 1½-inches thick. This shell was lined with reinforced concrete with a normal thickness of 2-feet from the outside of the shell. Concrete ‘benches’ served as walkways, provided space for signals and served to confine a train to the center of the tunnel in case of derailment.”

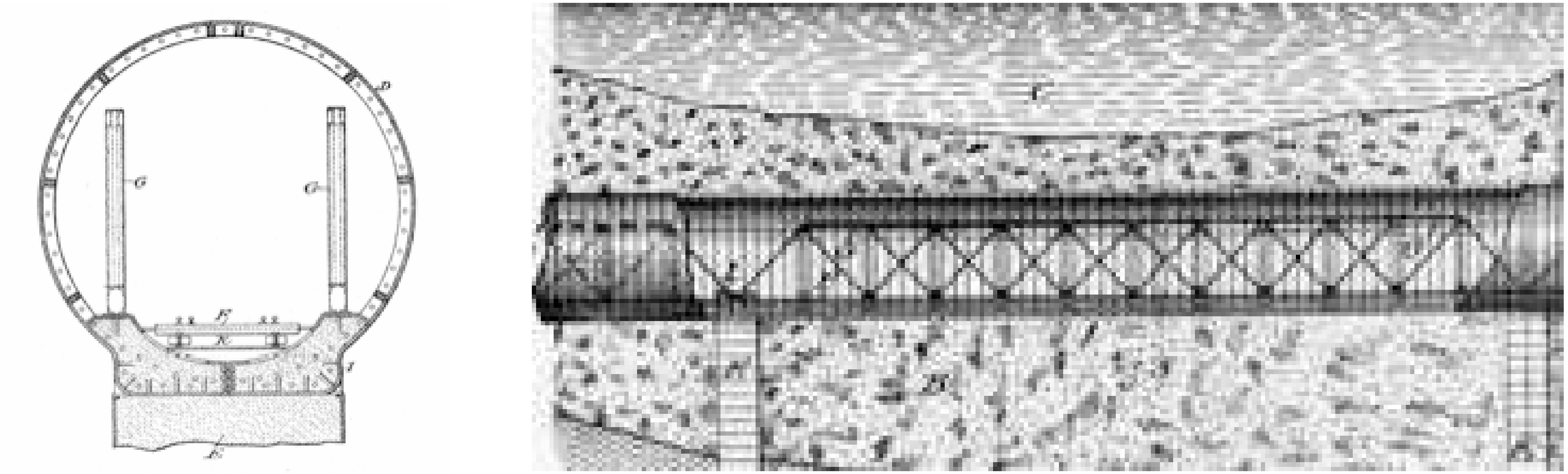
"…In each of the tunnels different difficulties were encountered. While the Pennsylvania tubes went from shore to shore, under the Hudson, through silt, the McAdoo north tubes encountered rock, and blasting had to be resorted to; in the East River tunnels the tops of the bores came so close to the river 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…"

RE: excerpt from *The Pennsylvania Railroad Tunnels and Terminals in New York City.* During the construction of the *East River* tunnels, frequent blowouts (escaping air) caused by fissures opened in the riverbed were checked by laying a continuous blanket of clay on the river bottom over the tunnel below. Other methods of tunneling were considered such as the "Freezing Process." This process used a pilot tunnel and the insertion of pipes to freeze the ground around the pilot tunnel then, the pilot tunnel was removed and the full-size tunnel excavated in the frozen material and its iron lining placed in position. This method negated the need to use compressed-air in material of variable character such as was encountered in the East River and/or on the *New Jersey* side of the *North River.* Tests were conducted in the East River, but it was found that the freezing process took too long. As well, since the shield/compressed-air method was making steady process, the freezing experiment was abandoned.

"…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 grid Manhattan, the builders encountered a very soft mud, un-stable 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…"

RE: excerpt from *The Pennsylvania Railroad Tunnels and Terminals in New York City*

The character of the material through which the PaRR tunnels were to be constructed differed greatly in the two rivers. The bed of the *North River*, at the level of the tunnels, consisted principally of clay, sand and water while that of the *East River* was composed of a variety of materials such as quicksand, sand, boulders, gravel, clay and bedrock. Deciding on the method of construction was difficult since there were few precedents to follow for either river. A gas tunnel had been constructed under the *East River*, the *St. Clair Tunnel* under the *St. Clair River*, the *Blackwell* and several other tunnels under the *Thames River* in *London* and, of course, there were the partially constructed (at the time) H&MRR tunnels under the *North River*. Except for the latter, these tunnels were designed for a lighter traffic. Useful information from these other tunnel projects was obtained, but the *Board of Engineers* determined it was prudent to consider a variety of methods from various sources (the Board spent the first year reviewing these proposals). Most of the proposed methods involved temporary structures or the use of floating plant in the navigable channels of the river/s. Due to the high volume of river traffic in both rivers, this method was deemed unsuitable. Ultimately, the Board decided on the "Shield Method" with compressed-air as the most practical, expedient, non-interruptive and safe method for constructing the tunnels under both the North and East River/s.



<u>Above</u>: caption: “These Patent Office drawings, reproduced from the February 11, 1902, issue of Scientific American, show the ‘tunnel bridge’ scheme devised by Charles M. Jacobs to support a tunnel driven through silt or other loose material. The track was to be carried by steel trusses, which were to be surrounded by the tunnel shell and supported by piers sunk through the river bottom silt to rock or other firm material.” An early problem was that of assuring adequate stability of the tubes in the soft silt of the riverbed under heavy loads. In 1901, Chief Engineer ***Charles Jacobs*** proposed and, in 1902, patented a “subterranean tunnel bridge” design for the crossing consisting of piers carried to a solid foundation in the riverbed, a truss bridge carried on the piers and a tunnel shell surrounding the bridge and attached to the piers. The bridge structure would carry the live load of trains directly to the piers, avoiding any deflection of the tunnel. The v-truss bridge scheme was soon discarded in favor of one that called for the use of shorter girders that would support the track and the trains. They would be carried on piers spaced at 15-foot intervals. The method was tested near the ***New Jersey*** bank of the river.

The Board of Engineers

"You are requested to procure all additional information that may be needed, sparing neither time nor any necessary expenses in doing so, for I am sure it is not necessary for me to say that, in view of the magnitude and great cost of the proposed construction, and of the novel engineering questions involved, your studies should be thorough and exhaustive, and should be based on absolute knowledge of the conditions."

***Alexander J. Cassatt,* PaRR President**

RE: the *Board of Engineers* was organized on January 11th 1902 (when it held its first session) and continued in the performance of its duties until April 30th 1909 (when it was dissolved), having completed its assigned task successfully

BOARD OF ENGINEERS AND CHIEF ENGINEERS

Chairman, General Charles W. Raymond.

Gustav Lindenthal, resigned December 15, 1903.

Chief Engineer, North River Division, Charles M. Jacobs.

Chief Engineer, East River Division, Alfred Noble.

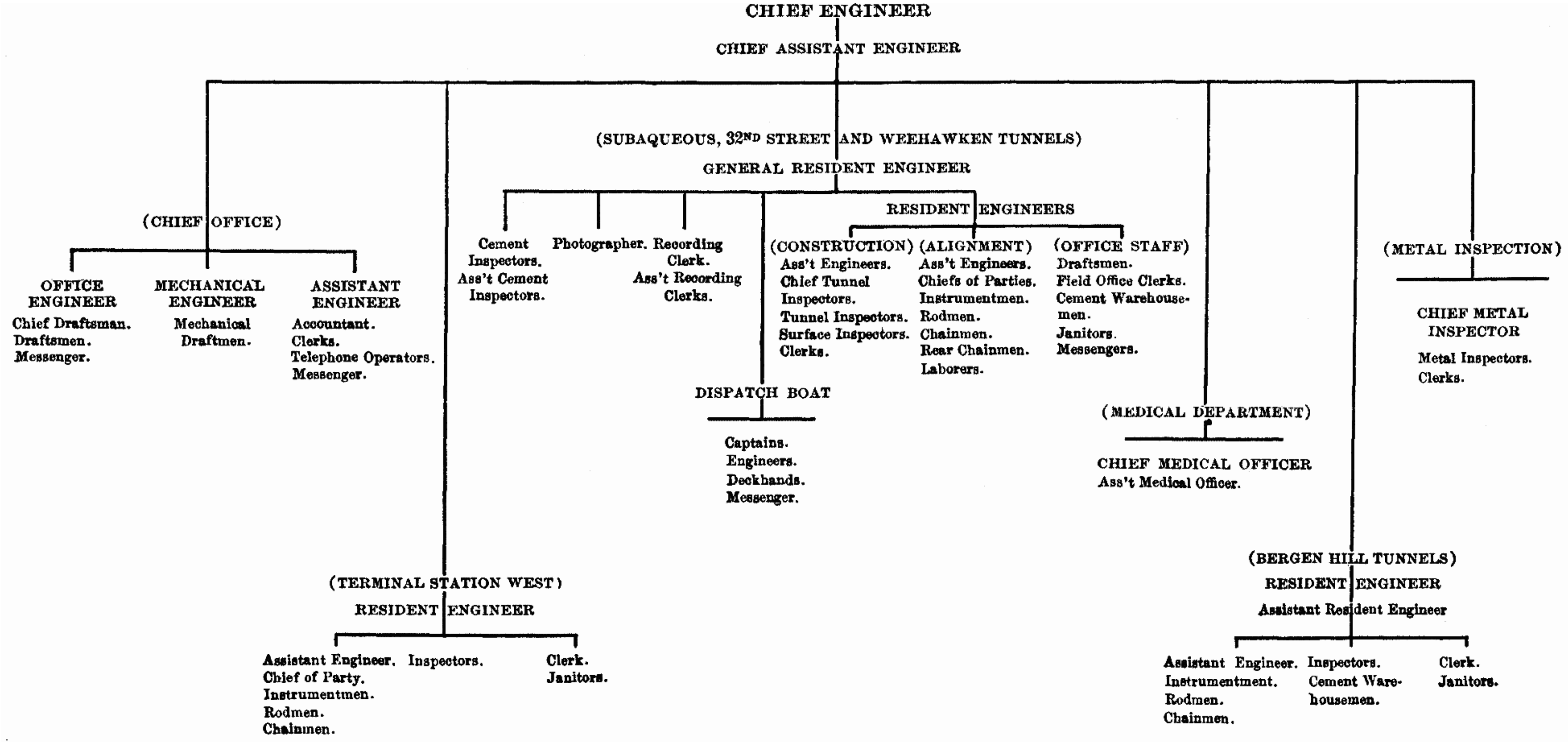
Chief Engineer, Electric Traction and Station Construction, George Gibbs.

Chief Engineer, Meadows Division, William H. Brown, retired March 1, 1906, succeeded as Chief Engineer by Alexander C. Shand.

Architects, New York Station, McKim, Mead & White.

"…The importance of the project, and the engineering questions to be solved in its construction, caused the company to create a Board of Engineers, eminent in their profession, to supervise the preparation of all plans and have general direction of the undertaking, reporting to the executives. The work was then divided into three construction sections, the North River Division, the East River Division and the Meadows Division, and consists of about 13.10 miles of new railroad, the part in the open embracing about 7.66 miles and in tunnels about 5.5 miles…"

RE: excerpt from *The Economic Necessity For The Pennsylvania Railroad Tunnel Extension Into New York City*

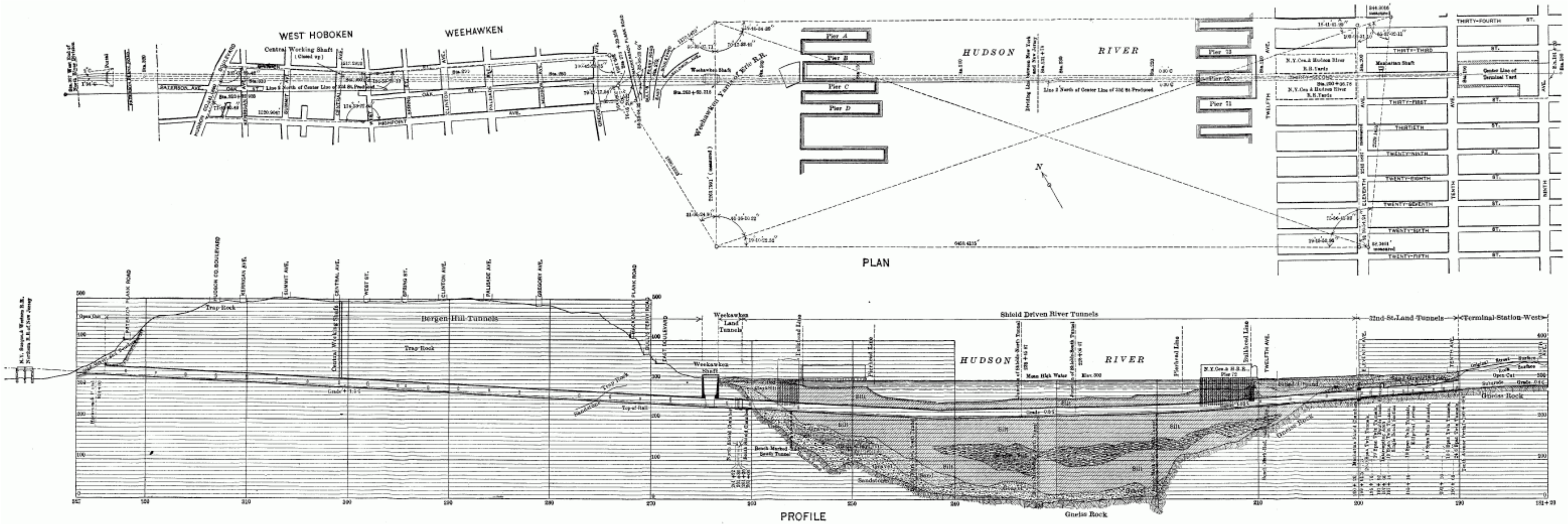


Above: caption: "Engineering Staff Organization"

First Things First

"…Surveys, soundings, and borings were commenced in the latter part of 1901 on an assumed center line of tunnels which was the center line of 32d Street extended westward. The soundings were made from a float stage fastened to a tugboat, the location being determined by transits on shore and the elevation by measuring from the surface of the water, a tide gauge being continually observed and the time of soundings and gauge readings kept. In the river wash-borings were made from a floating pile-driver on which was installed a diamond-drill outfit of rods, pump, etc. Fourteen borings were completed in the river. Considerable difficulty was found in holding the pile-driver against the current, the material in the bottom being very soft, and several borings were lost owing to the drifting of the pile-driver. Each boring was continued, and the depth of several was more than 250 ft. below the surface of the water. The borings on land were mostly core borings, and were generally made with the chilled shot boring machine…"

Charles M. Jacobs, **Chief Engineer**



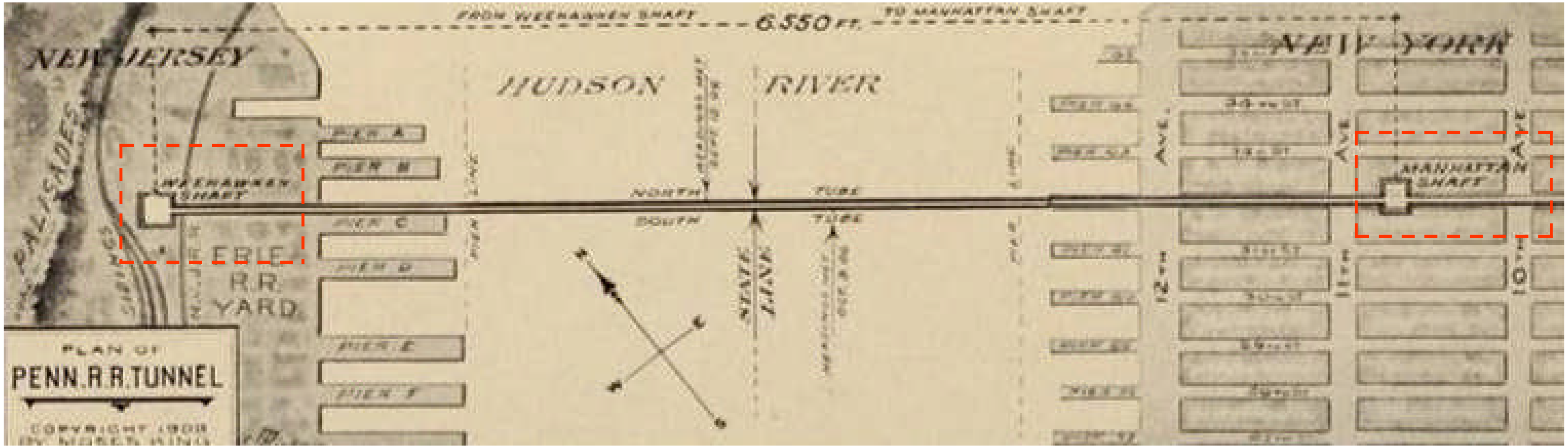
"…Base lines, about 2,250 ft. in length, were measured on each side of the river, and observation points established. It was necessary to build a triangulation tower 60 ft. high on the New Jersey side as an observation point. The base lines were measured with 100-ft. steel tapes which were tested repeatedly, and the work was done at night in order to obtain the benefit of uniform temperature and freedom from traffic interruptions. From the base line on the New Jersey side, which passed over the Weehawken Shaft, an elevated point on the assumed center line on the side of Bergen Hill was triangulated to, and from this point westward a closed polygon was measured along the streets to the top of the hill on the west side and thence along the assumed center line to the portal. The level transfer across the river was made by sighting across in opposite directions simultaneously, and also by tide gauges. The outline of the final triangulation system is shown on Plate VII…"

Charles M. Jacobs, **Chief Engineer**

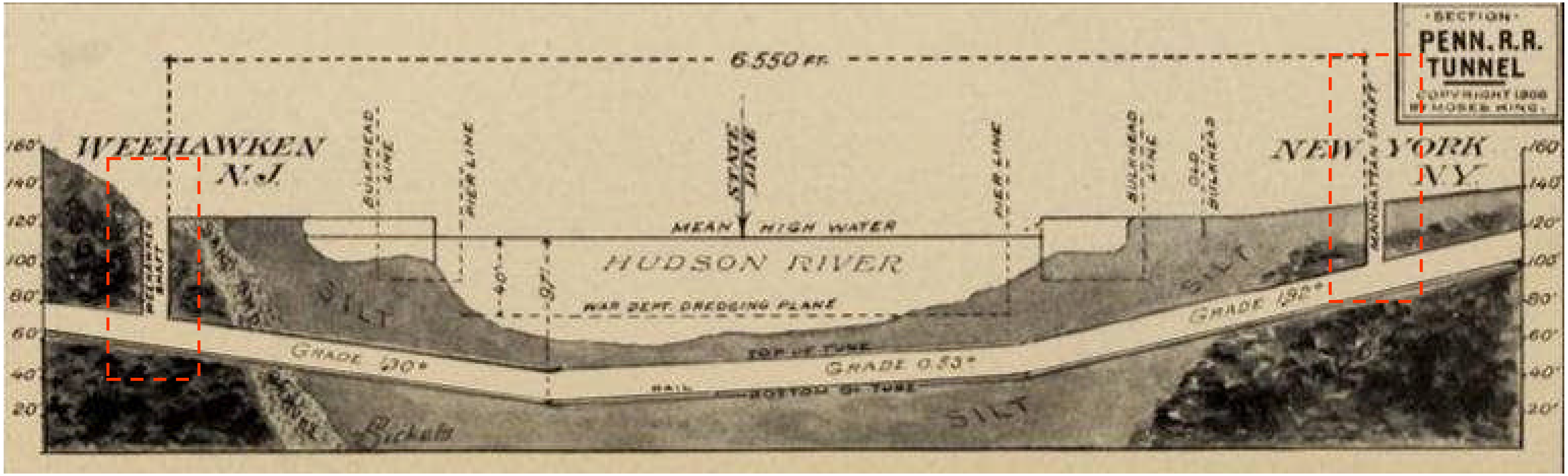
<u>Above</u>: caption: "Plate VII – Plan, Profile and Triangulation, North River Tunnels"

"…The decision as to the locations of the shafts on both sides of the river, for construction purposes and finally for permanent use, was a comparatively simple matter, and, all circumstances considered, they are unquestionably in the most suitable places. On the New York side the shaft was as near as practicable to the line dividing the sub-aqueous iron-lined tunnels from the land tunnels, and on the New Jersey side the shaft was placed centrally on the line of the tunnels and on the nearest available ground to the river, while at the same time beyond the other end of the river tunnels, thus necessitating driving the sub-aqueous tunnels only from east and west to meet under the river. A caisson shaft on the New York side, on the line of the tunnels near the river bulkhead, was at one time considered, but was not adopted as it entailed the driving of two shields both east and west, in addition to the two from New Jersey, adding to the plant outlay while not affording any material saving in the time of construction. It was thought desirable to construct the shafts on the two sides of the river in advance of letting the main contracts for the tunnels. The Manhattan Shaft is north of the line of the tunnels, on the north side of 32d Street, east of Eleventh Avenue. The Weehawken Shaft is on the line of the tunnels in the yards of the Erie Railroad on the New Jersey side, and the distance between the shafts is about 6,575 ft. The contracts for these shafts were let in June, 1903, to the United Engineering and Contracting Company, and they were completed and ready for use at the time of letting the main contract for the tunnels, thus saving considerable time…"

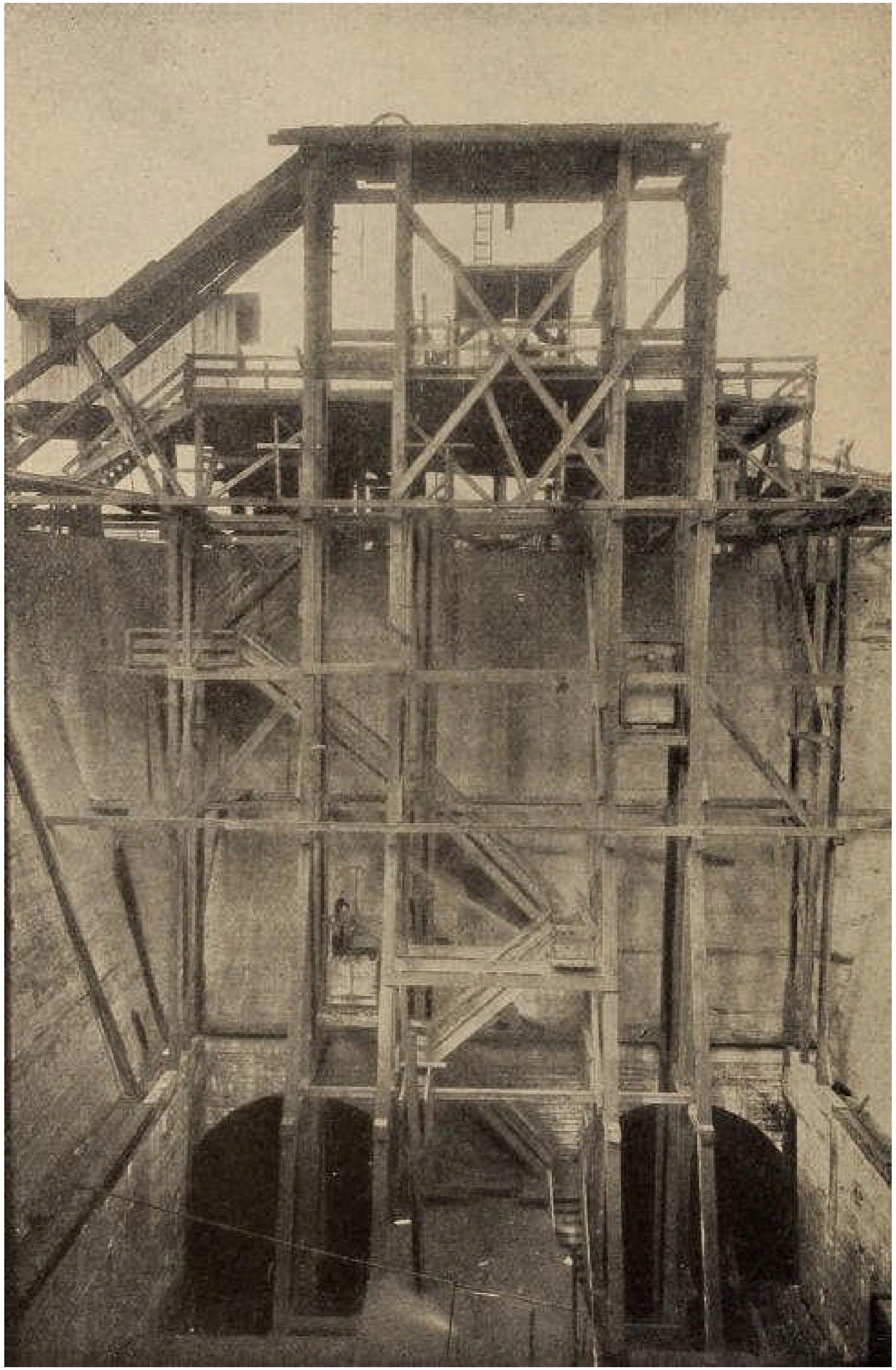
Charles M. Jacobs, **Chief Engineer**



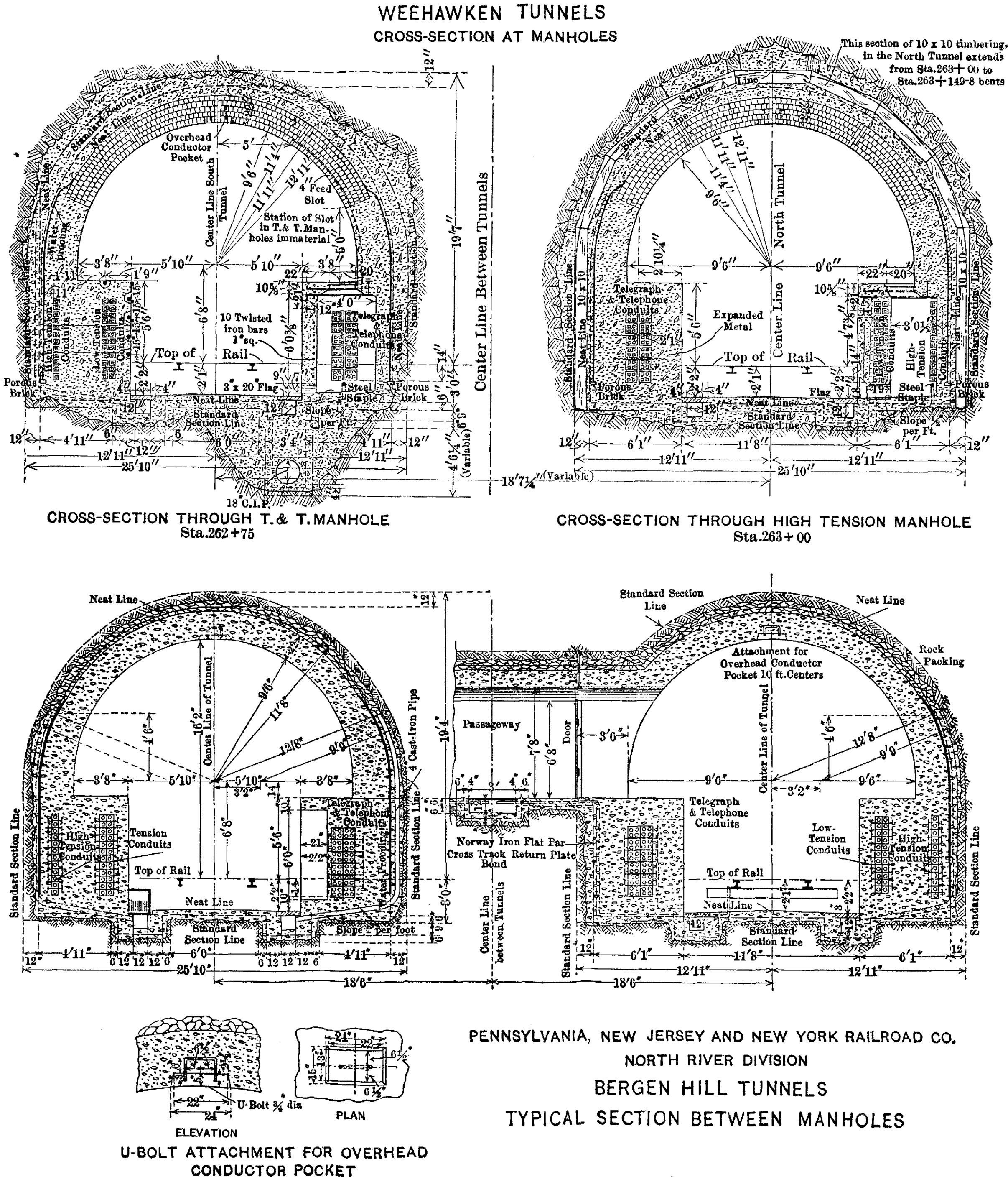
Above: caption: "Pennsylvania Tunnel Plan; contract let May 2, 1904, to O'Rourke Eng. Con. Co.; work began in Manhattan shaft April 1, 1904, in Weehawken shaft Sept. 1; shields of north tube met 168 ft. west of state line Sept. 12, 1906, south tube, 370 ft. east of state line, October 9, 1906."



Above: caption: "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 23,737 to 30,318 lbs.; length of tube-lined portion, 6,118 ft.; column foundation sunk to bedrock."



Left: caption: “Weehawken Shaft, 100x154 ft. at top; 56x116 ft. at bottom; 76 ft. deep; lined with 9,810 cu. ft. concrete; begun June 11, 1903, finished Sept. 1, 1904. Manhattan Shaft, 22x32 ft.; 55 ft. deep; begun June 10, 1903; finished Dec. 11. Built by United Eng. & Con. Co.”



"…It was possible to excavate in full rock cover about 250 ft. of the tunnels eastward from the Weehawken Shaft and 225 ft. westward from the Manhattan Shaft. At these points the rock cover was very thin, and there shield chambers were made for the erection of two sets of shields, about 6,100 ft. apart. A typical cross-section of the Weehawken Land Tunnel is shown on Plate VIII…"

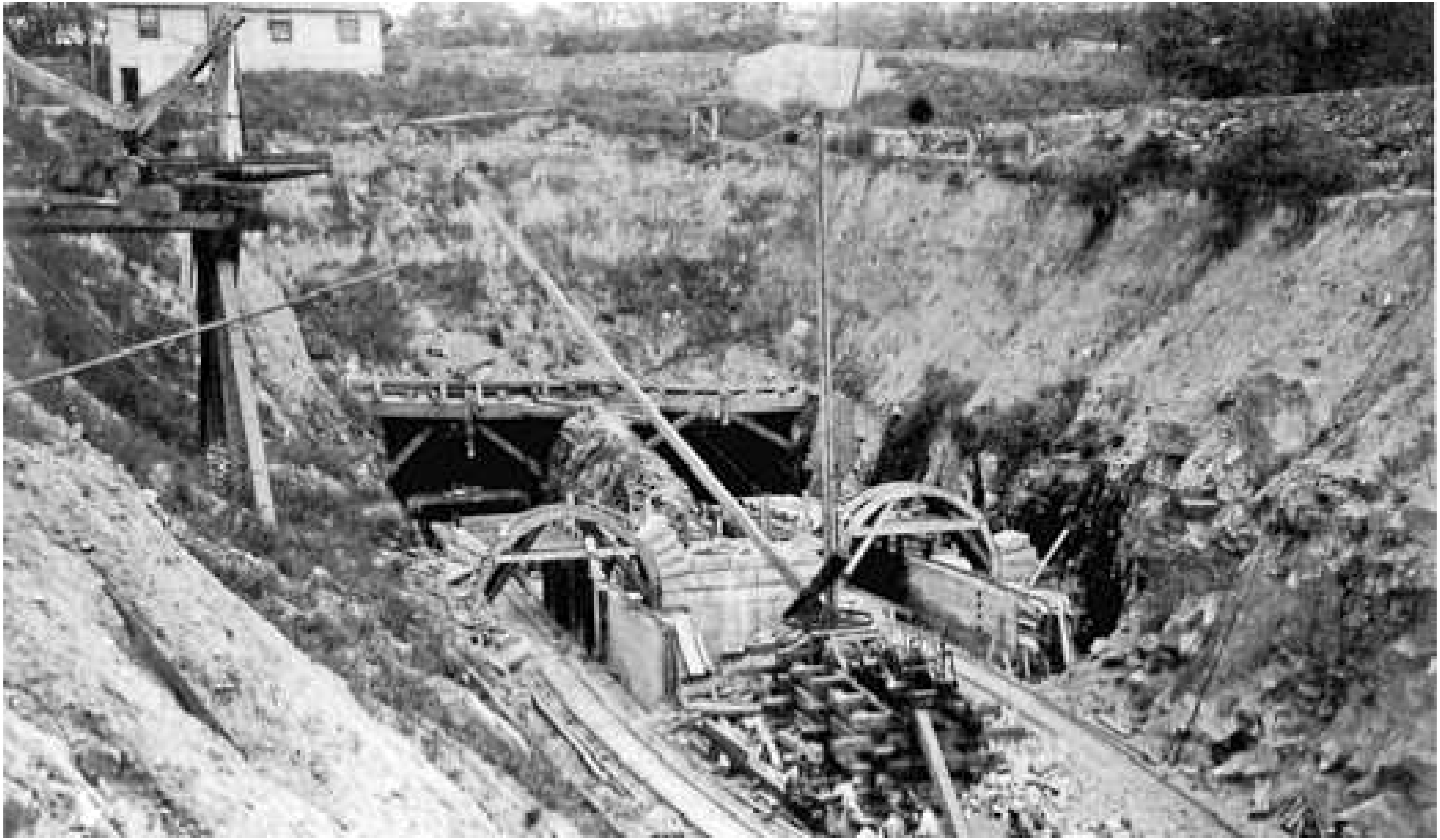
Charles M. Jacobs, Chief Engineer

<u>Left</u>: caption: "Plate VIII - Typical Section Between Manholes, Bergen Hill Tunnels"

“The Bergen Hill Tunnels are two single-track tunnels, 37 ft. from center to center, and extend for a distance of 5,940 ft. from the Weehawken Shaft to the Hackensack Portal. They were built almost entirely through trap rock. The contract was let on March 6th, 1905, to the John Shields Construction Company, but was re-let on January 1st, 1906, to William Bradley, the Shields Company having gone into the hands of a receiver. About 1,369 ft. of the tunnel excavation was done by the Shields Company, but no concrete lining. The maximum monthly progress for all headings was 622 ft., and the average progress was 338 ft. A working shaft 216 ft. deep was sunk from the top of the hill, to facilitate construction. The tunnels are lined with concrete throughout. Typical cross-sections of these tunnels are shown on Plate VIII…”

***Charles M. Jacobs,* Chief Engineer**

RE: cross-passages, at intervals varying from 50 to 300-feet, were included in the *Bergen Hill* tunnels, the land portions of the *North River* tunnels and in the tunnels under *Manhattan* as a safety measure. Sub-aqueous cross-passages were considered for both the North and *East River* tunnels. The conclusion was that such passages increased rather than diminished the danger in case of accident (only the East River tunnels have a combination cross-passage/pump chamber).



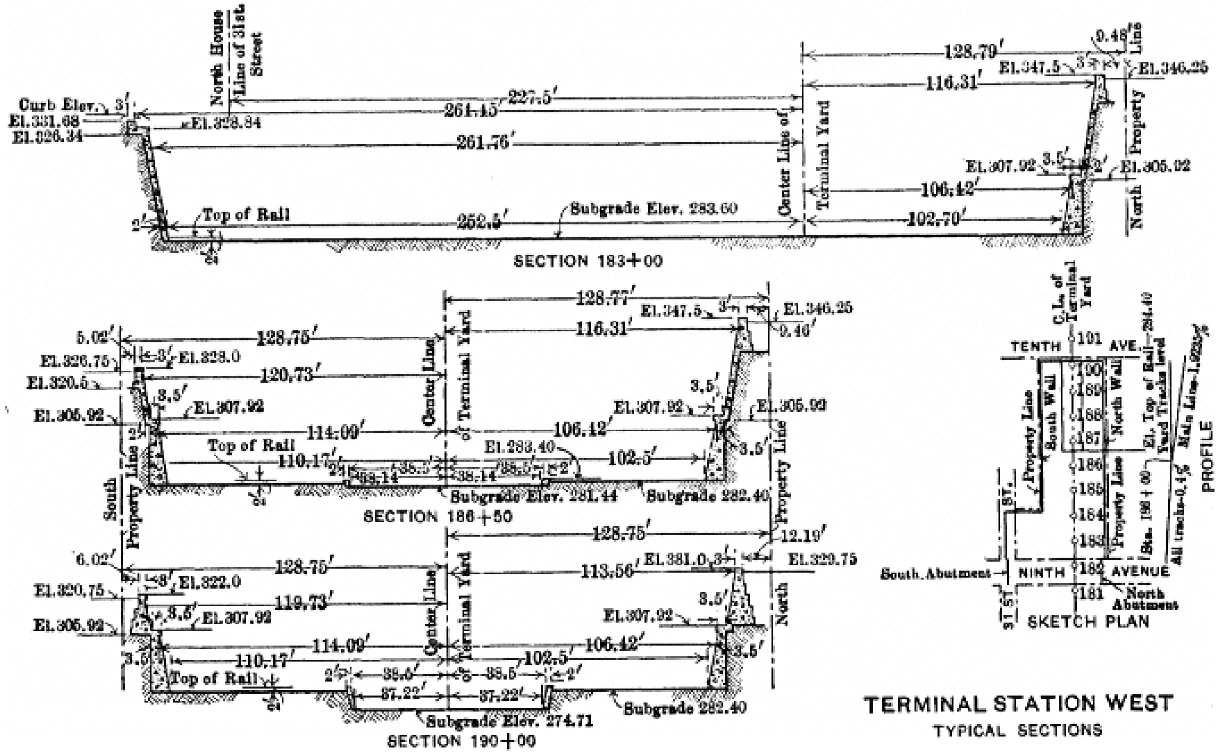
<u>Above</u>: caption: "View at Hackensack Portal; shows the concrete tunnel lining and masonry portal construction in progress (ca. June 1907). Pennsylvania twin tunnels enter west face of Bergen Hill, south end of Palisades, passing through rock 5,910 ft., thence under Hudson River through tubes 6,118 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."

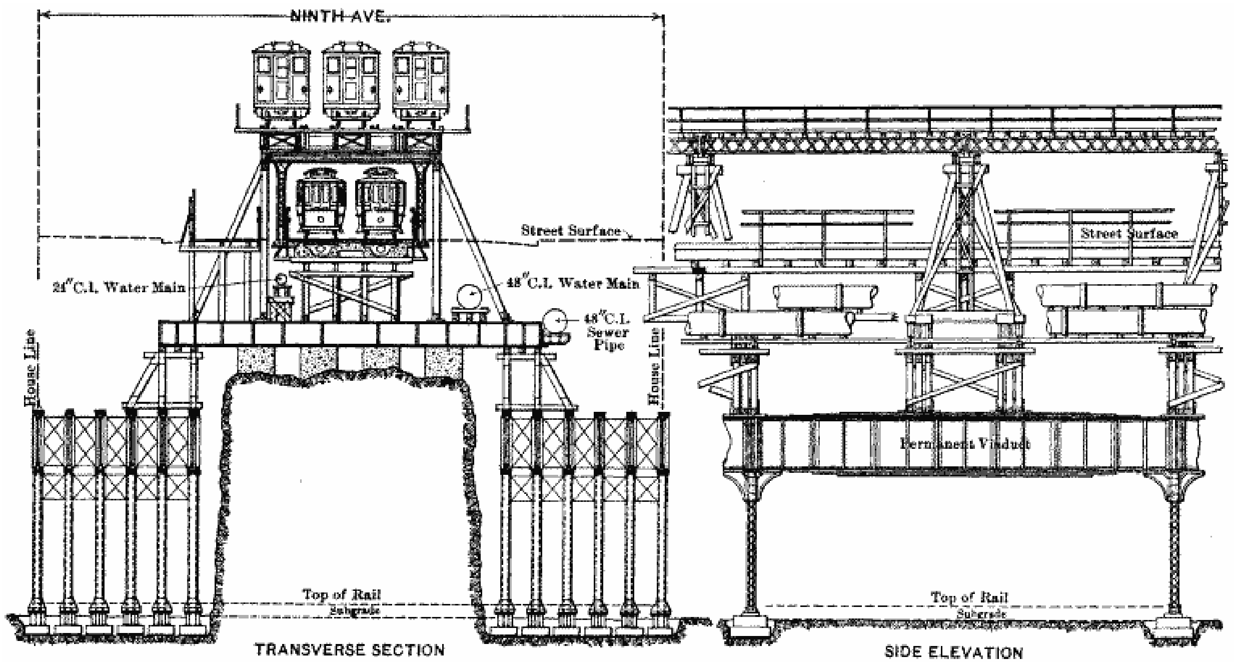
"…In the original design it was contemplated to have a four-track tunnel under 32d Street from Ninth to Eleventh Avenues, but owing to the necessity for having additional yard facilities, property was bought for about 100 ft. north and 100 ft. south of 32d Street, between Ninth and Tenth Avenues, and an open excavation, lined with concrete retaining walls and face walls, was made. Between Ninth and Tenth Avenues, 32d Street was closed, and the property formerly the street was bought by the Tunnel Company from the City of New York for a consideration by deed dated April 18th, 1906. The Church, Rectory, and School of St. Michael's, which was located on the west side of Ninth Avenue between 31st and 32d Streets, was acquired by the Tunnel Company after it had acquired property for and had built a similar institution on the south side of 34th Street west of Ninth Avenue…"

Charles M. Jacobs, **Chief Engineer**

"…Probably the most interesting feature of this contract was the support and maintenance of Ninth Avenue, which has a three-track elevated railway structure and a two-track surface railway structure, on which it was necessary to maintain traffic while excavation was made to a depth of about 60 ft., and a viaduct was erected to carry Ninth Avenue. The length of this viaduct is about 375 ft., and the steelwork and its erection was done apart from the North River Division work, but all excavation and underpinning was included in this division. The contract for this work on the Terminal Station-West was let to the New York Contracting Company-Pennsylvania Terminal, on April 28th, 1906, and included about 517,000 cu. yd. of excavation, about 87% being rock, the construction of about 2,000 lin. ft. of retaining and face walls containing about 18,500 cu. yd. of concrete, and a large quantity of structural steel (1,475,000 lb.) for temporary use in underpinning Ninth Avenue…"

***Charles M. Jacobs,* Chief Engineer**

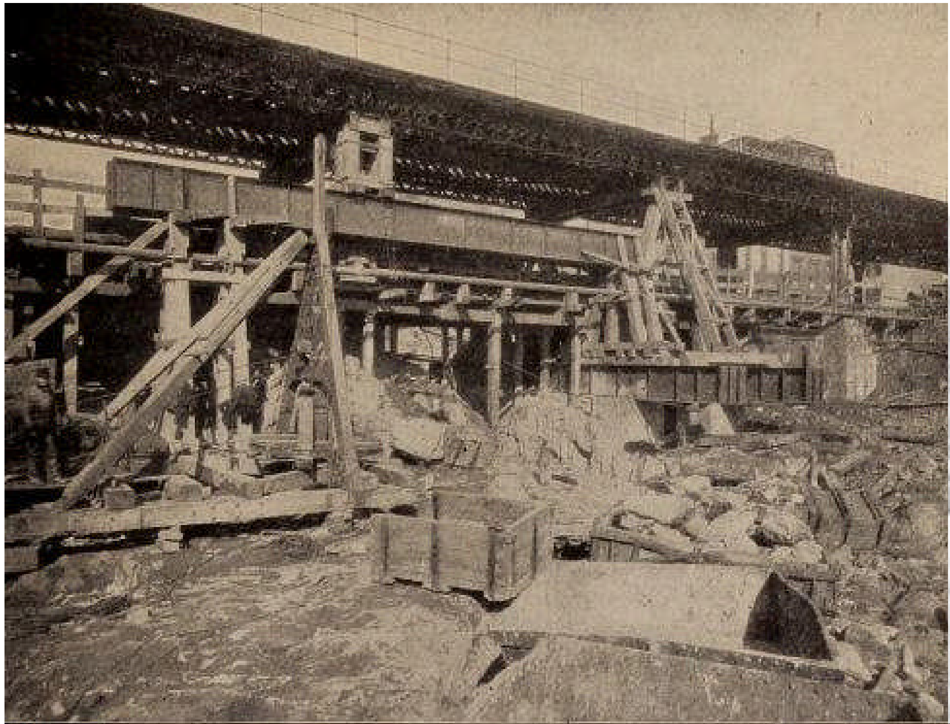


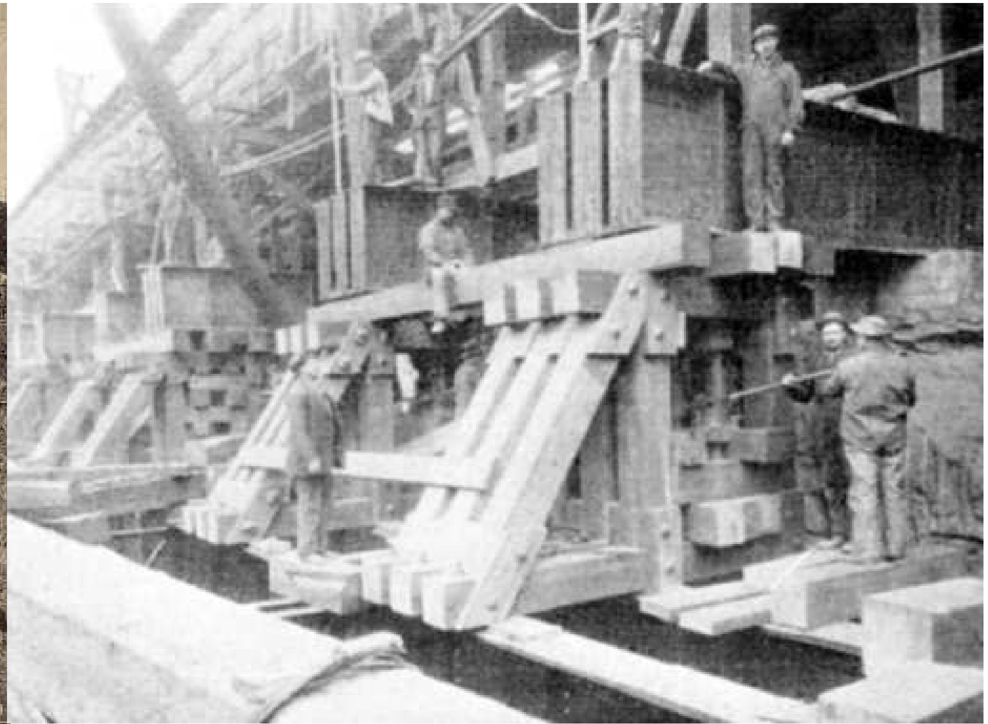


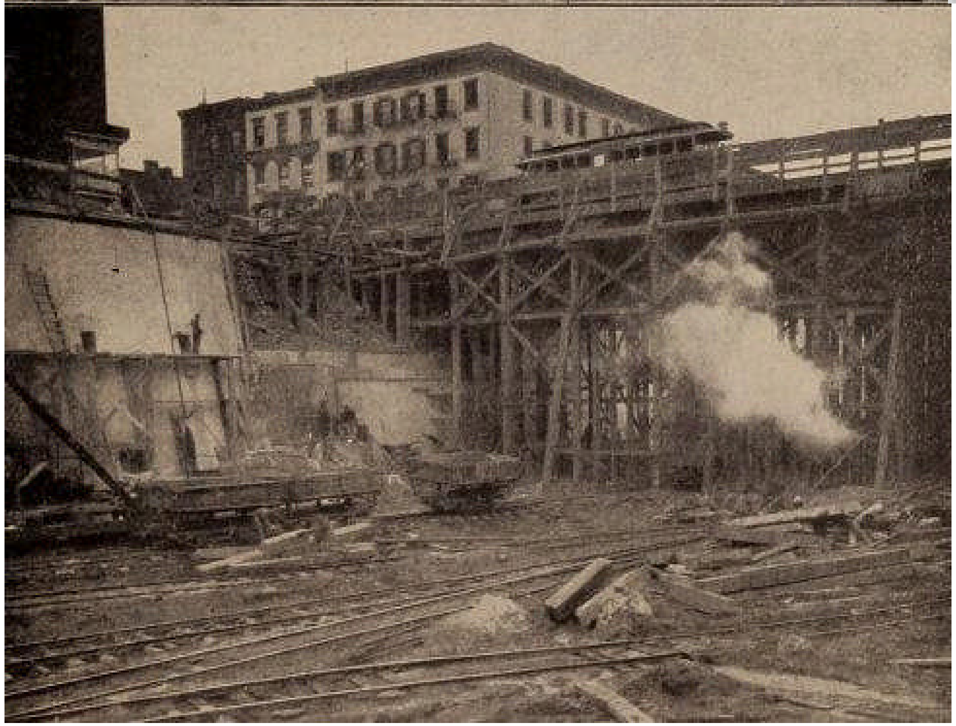
"…Fig. 4 shows cross-sections of the Terminal Station - West yard, and Fig. 5 shows the general method of underpinning the Ninth Avenue structures…"

<u>Top</u>: caption: "Fig. 4 – Terminal Station West Typical Sections"

<u>Bottom</u>: caption: "Fig. 5 – Arrangement of Structures Supporting Ninth Ave. during Progress of Excavation"



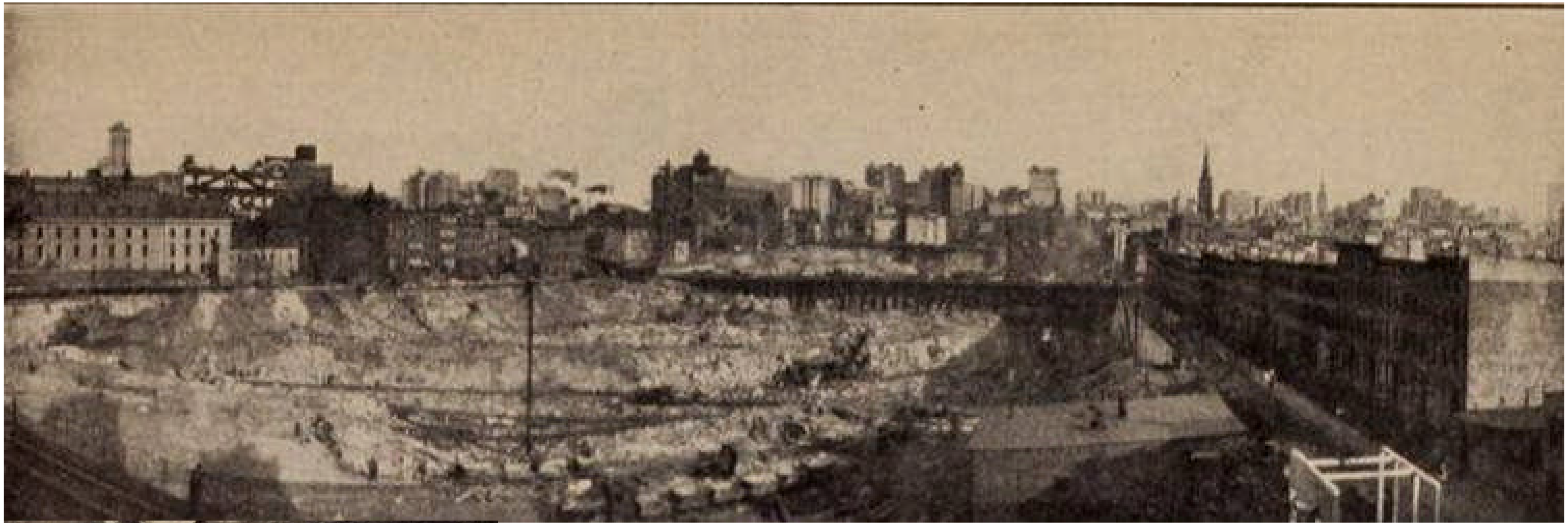


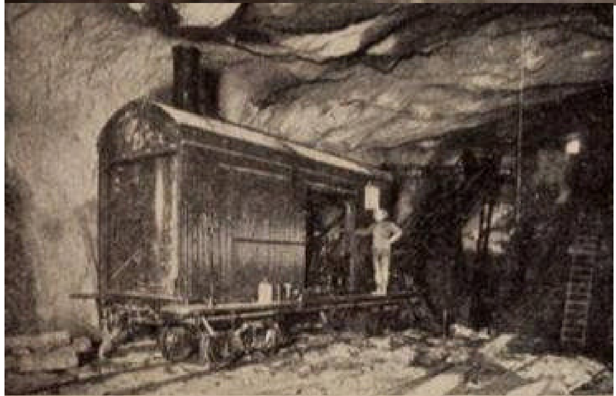


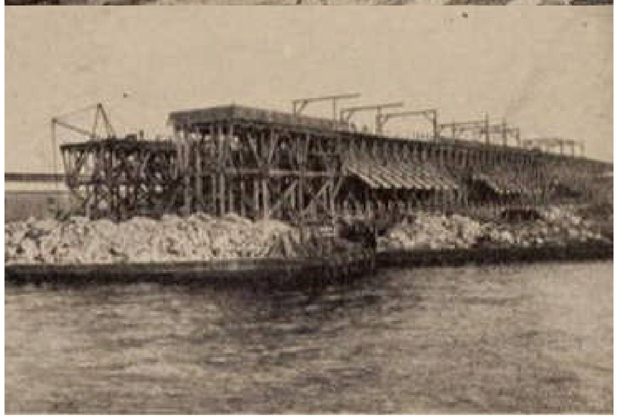
<u>Above</u>: caption: “West side of Ninth Avenue, Jacking up Girders ‘C’ at Elevated Railroad Column 491, showing method of taking weight on permanent Viaduct Girders, Nov. 14, 1908”

<u>Top Left</u>: caption: “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”

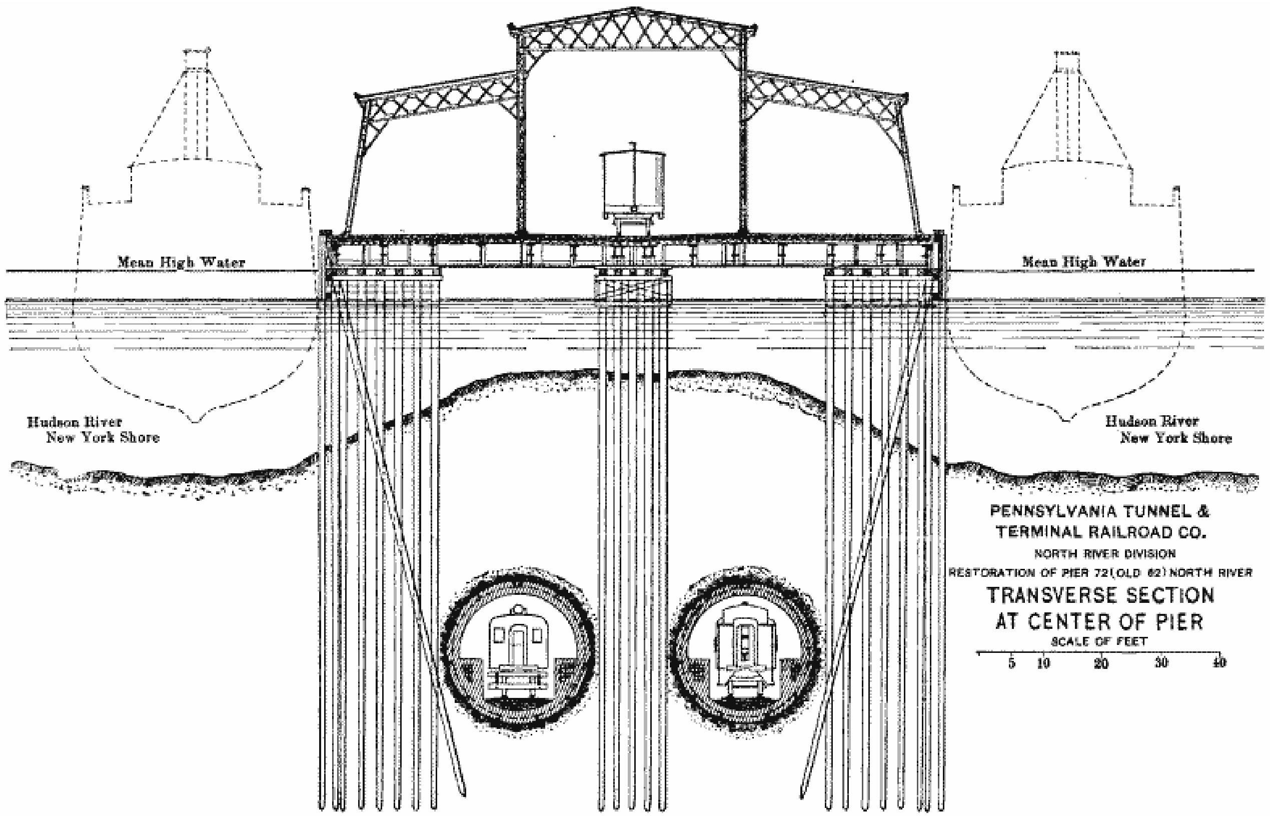
<u>Left</u>: caption: “Eighth Avenue, with trolley line supported on trestle during work on station excavation”







<u>Above</u>: caption: “Station Excavation, begun July 1, 1904, after removing 400 buildings; completed 1907; 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.”
<u>Top Left</u>: caption: “Under Fifth Ave., tunnels built by United Eng. & Con. Co.”
<u>Bottom Left</u>: caption: “Loading Scows with material taken from big station excavation”

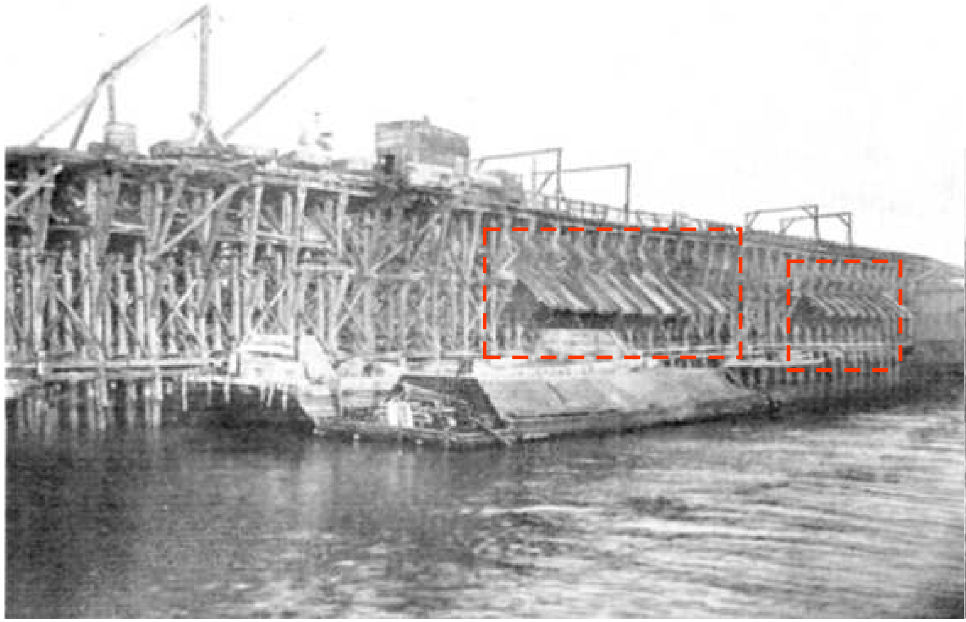


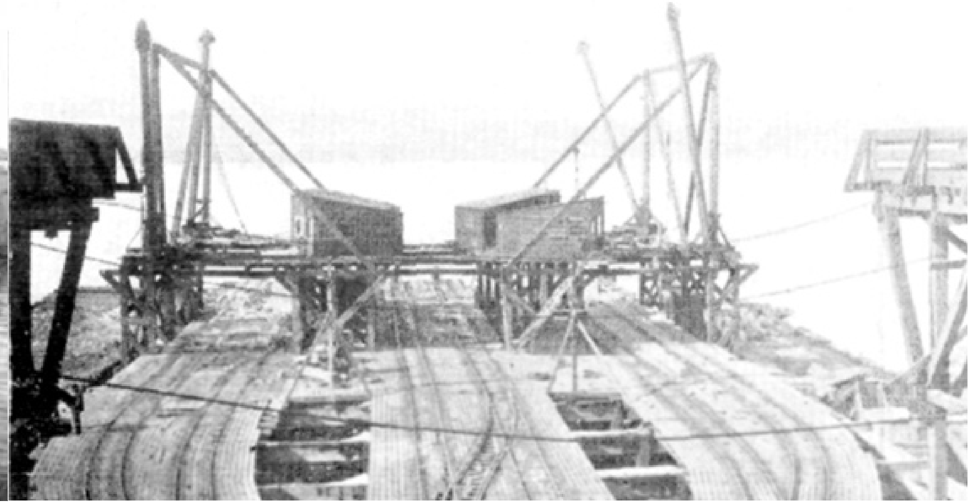
"…Contractor's plants were established at the Weehawken Shaft and at the Manhattan Shaft, including at each, low-pressure air compressors of a capacity of 13,000 cu. ft. of free air per minute and also high-pressure air compressors for drills, hydraulic pumps, electric generators, etc. The river tunnels passed under Pier 72, North River (old No. 62), which was occupied by the New York Central and Hudson River Railroad Company. The Tunnel Company leased this pier and withdrew all the piles on the lines of the tunnels prior to the commencement of construction, and on the remaining piles constructed a trestle for the disposal of the excavation from the tunnels and the terminal. At the completion of the work this pier had to be restored, and Fig. 10 shows the general arrangements of the location of the piles and the pier structure with reference to the tunnels…"

Charles. M. Jacobs, **Chief Engineer**

Above: caption: "Fig. 10 – restoration of Pier 72 (Old 62) North River-Transverse Section at Center of Pier"

Some problems were encountered as the tubes pushed out under the Hudson from the *Manhattan* side. Where the tubes passed under the bulkhead wall at the edge of the river, the tunnelers had to bore through pilings and stone riprap supporting the heavy stone bulkhead wall. As the shield cut into the loose riprap the compressed-air blew out into the ground behind the bulkhead and into the river. A clay "puddle" (mud made from the excavated silt) was used to plug the holes in the riprap. Each stone had to be removed individually by a tunnel worker with a pry bar, while another waited to plug the hole with puddle. After making their way through the riprap, the tunnelers encountered the wood piling supporting the bulkhead along the river and a hundred wood pilings had to be cut out of the path of each shield. Even after the bulkhead was passed, the loss of compressed-air continued, since there was only a few feet of light silt over the tunnel. This was finally stopped by dumping 28K cement bags filled with mud into the hole.



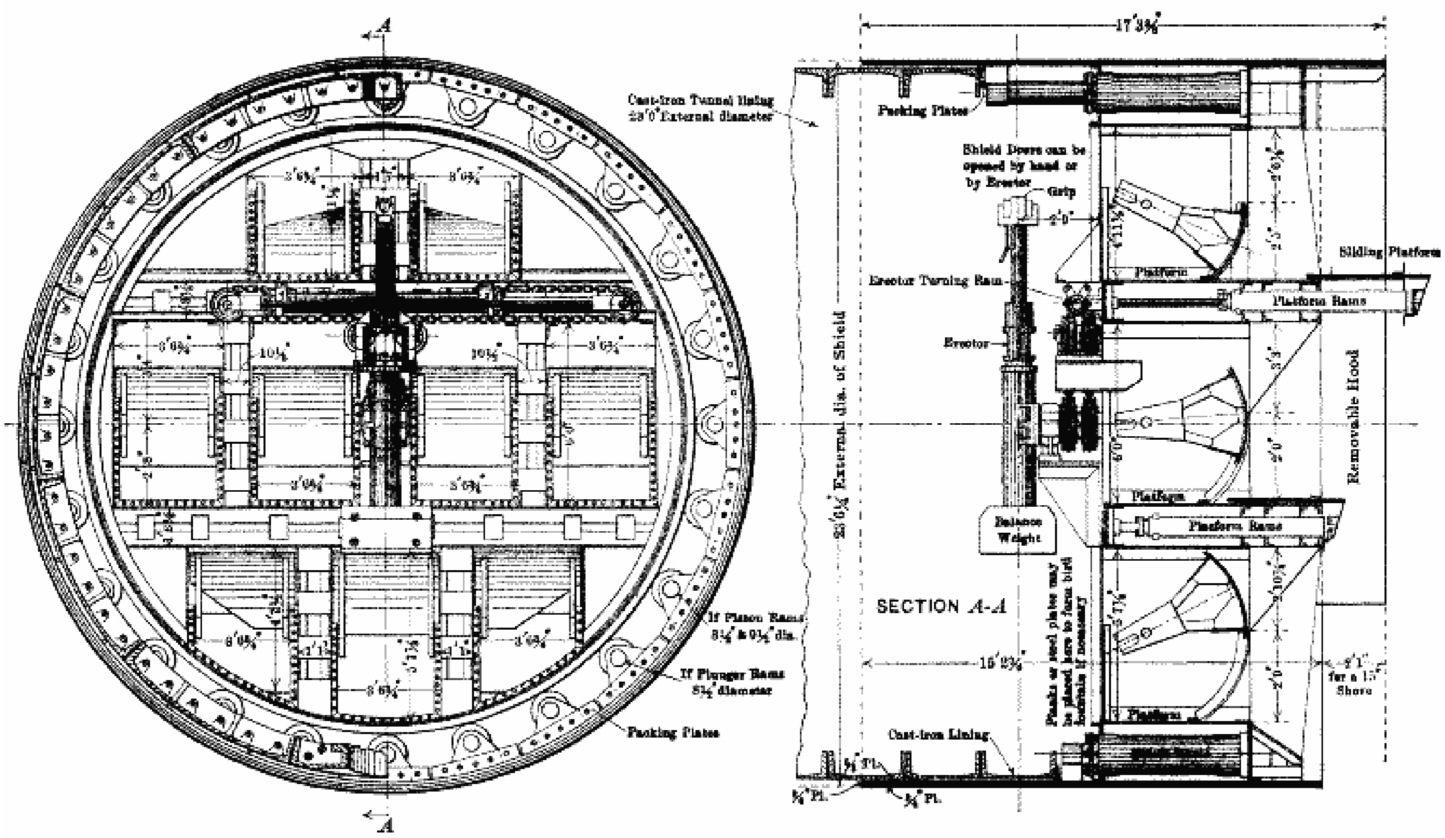


The disposal pier (old No. 62, new No. 72) at the foot of *West 32d Street, North River*, was leased by the PaRR. The entire pier, with the exception of the piles, was taken down (piles in the path of the tunnel were removed). Subsequent to the driving of the tunnels, there was a considerable settlement of the pier and it had to be abandoned. The photograph at left shows the chutes through which the earth was dumped on the decks of the scows to form a padding on which to dump the heavier rock. The photograph at right shows the derricks at the end of the pier which were used for loading heavy materials (i.e. stone, sand etc.) used in the work. Large quantities of pipe, conduit, brick etc. were also brought to this pier.

The Hydraulic Shield Method

"…The Board of Engineers decided, and it was so stated in the contract and specifications, that the river tunnels should be constructed by means of hydraulic shields, but bidders were permitted to present to the Board any scheme on which they might desire to bid, but, of course, the decision as to the practicability of such plans rested with the Board. Inasmuch as the shield method of construction was required, the writer designed a shield for use in the North River Tunnels. The shield was about 18 ft. long, over all, and was provided with a rigid but removable hood extending beyond the normal line of the cutting edge, for use in sand, gravel, and ballast, to be removed when the shield reached the silt. The shields were thrust forward by twenty-four rams capable of exerting a pressure of 3,400 tons at a hydraulic pressure of 5,000 lb. per sq. in. Taking into account 30 lb. air pressure, this pressure was increased to 4,400 tons. The shield was fitted with a single hydraulic erector and hydraulic sliding platforms, and when complete weighed 194 tons…"

Charles M. Jacobs, **Chief Engineer**



BACK VIEW OF SHIELD

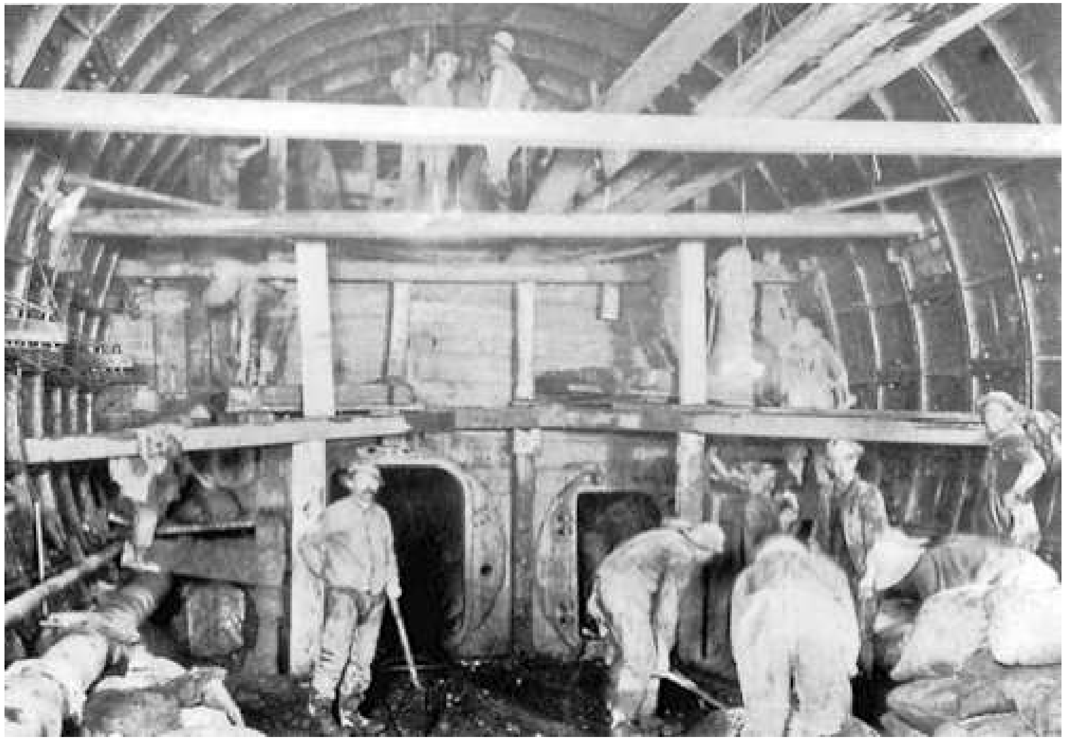
"…Fig. 9 is a back elevation and section of the shield. The contract for the river tunnels was let to the O'Rourke Engineering Construction Company on May 2d, 1904. The shields were built in accordance with the design previously referred to, and proved entirely satisfactory. Generally, the materials passed through were as follows: Starting out in full face rock, from it into a mixed face of rock and sand, thence into sand and gravel, full face of sand, piles, rip-rap, and the Hudson silt; and all were fully charged with water. Compressed air, at an average gauge pressure of about 25 lb. and a maximum of 40 lb. per sq. in., was used in the tunnels from the time the shields emerged from full rock face until the tunnel lining had been joined up and all caulking and grummeting had been done…"

Charles M. Jacobs, **Chief Engineer**

<u>Above L&R</u>: caption: "Proposed Shield for Sub-Aqueous Tunneling general Elevation"

"…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…"

RE: excerpt from *The Pennsylvania Railroad Tunnels and Terminals in New York City*



Left: caption: “A photograph taken in the North tunnel on May 17, 1906, shows the 10-foot-thick concrete bulkhead wall and air locks that separated the pressurized section of tunnel under construction from the section at lower pressure. Two of these were built about 1,200 feet apart in each tunnel heading. This one was installed in the north tunnel, almost directly below the Manhattan shoreline of the Hudson.”

"…Hydraulic rams, placed against the flanges every few inches around the tube, were used to push forward the huge shields with which the tunnels were bored. This type of shield weighed 194 tons. It had nine doors in it, and through these came the rock, or sand, or silt, or whatever material the tube penetrated…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad.* Each time the shield was advanced there was a slight "blow" of compressed-air, dropping the pressure within the tunnel. Twice the blow was much greater, dropping the tunnel pressure enough to allow water to enter the tunnel. Escaping air created a geyser at least 20-feet high in the river and water rose to about 4-feet in the tunnel before it could be stopped. For the worst of these, some 5K barrels of cement and sand had to be forced through the tunnel lining behind the shield to reduce the loss of air.

"…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 of the cutting edge of the shield. On the platforms the 'sand hogs' worked at the silt, passing the excavated material back through the pocket 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 the silt while cast-iron lining was being put in…"

RE: excerpt from *The Pennsylvania Railroad Tunnels and Terminals in New York City*

"…In the tunnels which were constructed in silt farther down the river, by the writer as Chief Engineer for the Hudson Companies, it had been possible to shove the shield through the silt with all the doors closed, displacing the ground and making great speed in construction owing to the absence of all mucking. It was thought that this procedure might be pursued in the larger tunnels of the Pennsylvania Railroad, and it was tried, but it was almost immediately found to be impossible to maintain the required grade without taking a certain quantity of muck into the tunnels through the lower doors, the tendency of the shield being to rise. By taking in about 33% of the excavation displaced by the tunnel, the grade could be maintained. It was considered desirable, owing to this rising of the shields, to increase the weight of the cast-iron lining, and this was done, making the weight of the completed tunnel more nearly equal to the weight of the displaced material. The weight of the cast-iron lining (with bolts) was increased from 9,609 to 12,127 lb. per lin. ft. of tunnel. The weight of the finished tunnel with this heavier iron is 31,469 lb. per lin. ft. The weight of the silt displaced per linear foot of tunnel, at 100 lb. per cu. ft., is 41,548 lb. The weight of the completed tunnel with the maximum train load is 42,869 lb. per lin. ft. The maximum progress at one face in any one month was 545 ft., working three 8-hour shifts, and the average progress in each heading while working three shifts was 18 ft. per 24 hours; while working one shift with the heavier lining referred to above, the delivery of which was slow, the average progress was 11 ft. per 24 hours…"

Charles M. Jacobs, **Chief Engineer**

"…until it was found they could be steered vertically by admitting more, or less, silt into the tunnel."

***James Forgie*, Assistant Chief Engineer**

RE: as the tubes advanced into the *Hudson River* silt, Chief Engineer Jacobs expected that the shield doors could be closed and the shield forced through the soft material without taking any excavated material into the tunnel, as had been his experience with the smaller *Hudson & Manhattan* RR tunnel he had completed a short time before. It was discovered, however, that the shield tended to rise under these conditions, and it proved impossible to keep the tunnel on the correct grade. Jacobs solved the problem by directing that some of the shield doors be opened to take in about a third of the displaced material. This corrected the tendency of the shield to rise as it progressed (for a time, the tunnels even went downward). It was also found desirable to increase the weight of the tube to make the weight of the completed tunnel closer to that of the displaced material. This was done by increasing the thickness of the cast-iron tunnel lining segments to two inches. About 2,800 linear feet of each tube under the main river channel was laid with this "heavy iron," adding over 3,500 tons to the weight of each tunnel.

"…During the investigations in the tunnels, borings were made to determine exactly the character of the underlying material, and it was then found that the hard material noted in the preliminary wash-borings was a layer of gravel and boulders overlying the rock. When the borings in the tunnels reached this material it was found to be water-bearing and the head was about equivalent to that of the river…"

Charles M. Jacobs, **Chief Engineer**

"…Rock cores were taken from these borings, and the deepest rock was found at about the center of the river at an elevation of 302.6 ft. below mean high water. Rods were then inserted in each bore hole and thereby attached to the rock and used as bench-marks in the tunnels. From these bench-marks, using specially designed instruments, very accurate observations of the behavior of the tunnels could be made, and from these the very interesting phenomenon of the rise and fall of the tunnels with the tide was verified, the tunnels being low at high tide and the average variations being about 0.008 ft. in the average tide of about 4.38 ft.: the tidal oscillations are entirely independent of the weight of the tunnels, since observations show them to have been the same both before and after the concrete lining was in position. There was considerable subsidence in the tunnels during construction and lining, amounting to an average of 0.34 ft. between the bulkhead lines. This settlement has been constantly decreasing since construction, and appears to have been due almost entirely to the disturbances of the surrounding materials during construction. The silt weighs about 100 lb. per cu. ft. (this is the average of a number of samples taken through the shield door, and varied from 93 to 109 lb. per cu. ft.), and contains about 38% of water. It was found that whenever this material was disturbed outside the tunnels a displacement of the tunnels followed. The tunnels as above noted have been lined with concrete reinforced with steel rods, and prior to the placing of the concrete the joints were caulked, the bolts grummeted, and the tunnels rendered practically water-tight; the present quantity of water to be disposed of does not exceed 300 gal. per 24 hours in each tunnel 6,100 ft. long…"

Charles M. Jacobs, **Chief Engineer**

Screw Pile Supports

"…The Board of Engineers early in 1902 took up the question of supports for the tunnels under the North River, and various plans and schemes were considered. It was finally decided to support the tracks on screw-piles carried through the lining of the tunnels, as originally proposed by the writer…"

Charles M. Jacobs, **Chief Engineer**

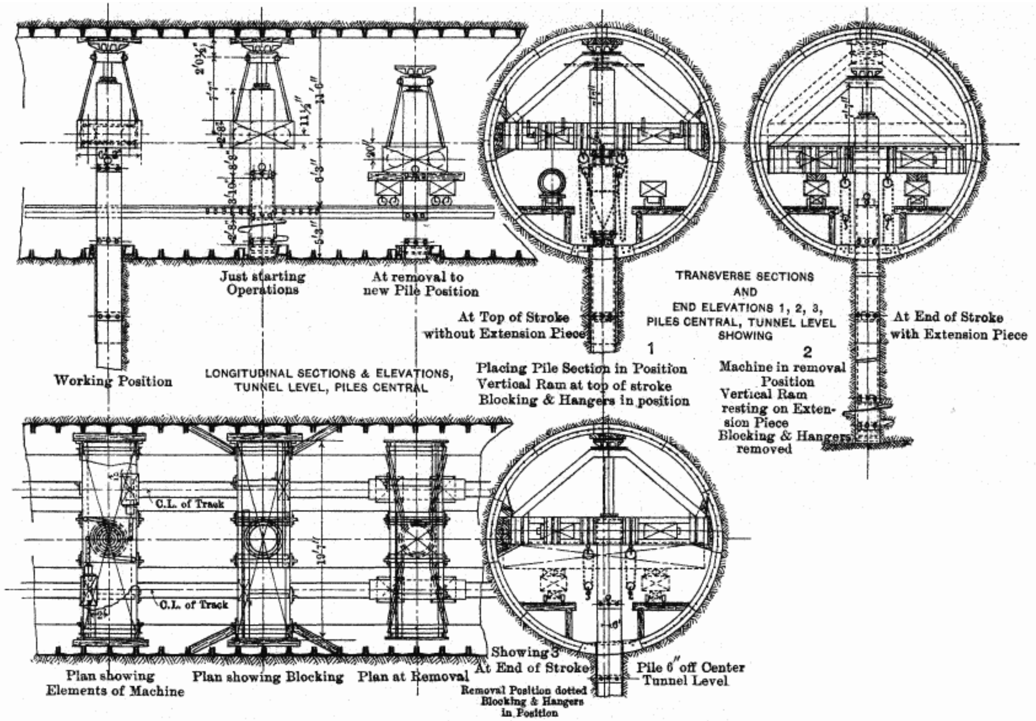
RE: one of the greatest concerns regarding the design of the *North River* tunnels was their stability under the continuous action of heavy and fast train traffic. Even when the great weight of the live-load (i.e. trains) is included, the tunnel/s are lighter than the materials they displace. It was first thought that some system of supports would be required in the soft silt of the North River to guard against displacement. Instead, it was proposed to sink screw piles through the bottom of each tunnel into and through the underlying silt until a satisfactory bearing material was reached. These pile supports were included in the construction contract documents with provision for their omission. "Sliding Joints" (where the piles pass through the tunnel floor) allowing the live-load to be carried directly to the pile heads by a system of girders (and allowing attachment of the piles directly to the tunnel) was an alternative design included in the construction contract.

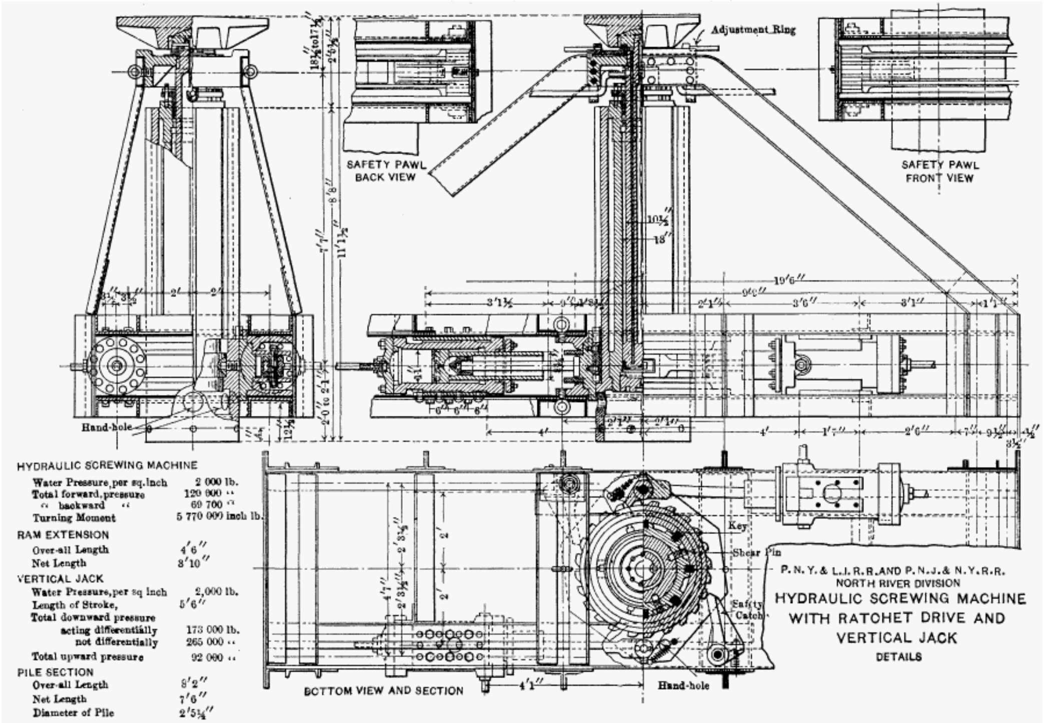
"…In order to know something of the capacity of screw-piles in the actual material to be passed through, it was resolved to test them. A caisson was sunk at the end of one of the Erie Railroad piers on the New Jersey side near the line of the tunnels, and, to obtain parallel conditions as much as possible, the excavation was carried down to the proposed grade of the tunnel. Various types of screw-piles were sunk therein and tests were made, not only of the dead load carrying capacity, but also with the addition of impact, when it was found that screw-piles could be sunk to hard ground and carry the required load. The final part of the test was the loading. The screw-pile, having a shaft 30 in. in diameter and a blade 5 ft. in diameter, was loaded with 600,000 lb., with the result that, for a month - the duration of this loaded test - there was no subsidence…"

***Charles M. Jacobs,* Chief Engineer**

"…Again, and after the iron tunnel lining had been constructed across the river, tests were made of two types of supports: One a screw-pile 29-1/2 in. in diameter with a blade 4 ft. 8 in. in diameter and the other a wrought-iron pipe 16 in. in external diameter. Tests were made, not only for their carrying capacity, but also for their value as anchorages, and it was found that the screw-pile was more satisfactory in every way; it could be put down much more rapidly, it was more easily maintained in a vertical position, and it could carry satisfactorily any load which could be placed on it as a support for the track. The 16-in. pipe did not prove efficient either as a carrier or as an anchorage…"

Charles M. Jacobs, **Chief Engineer**



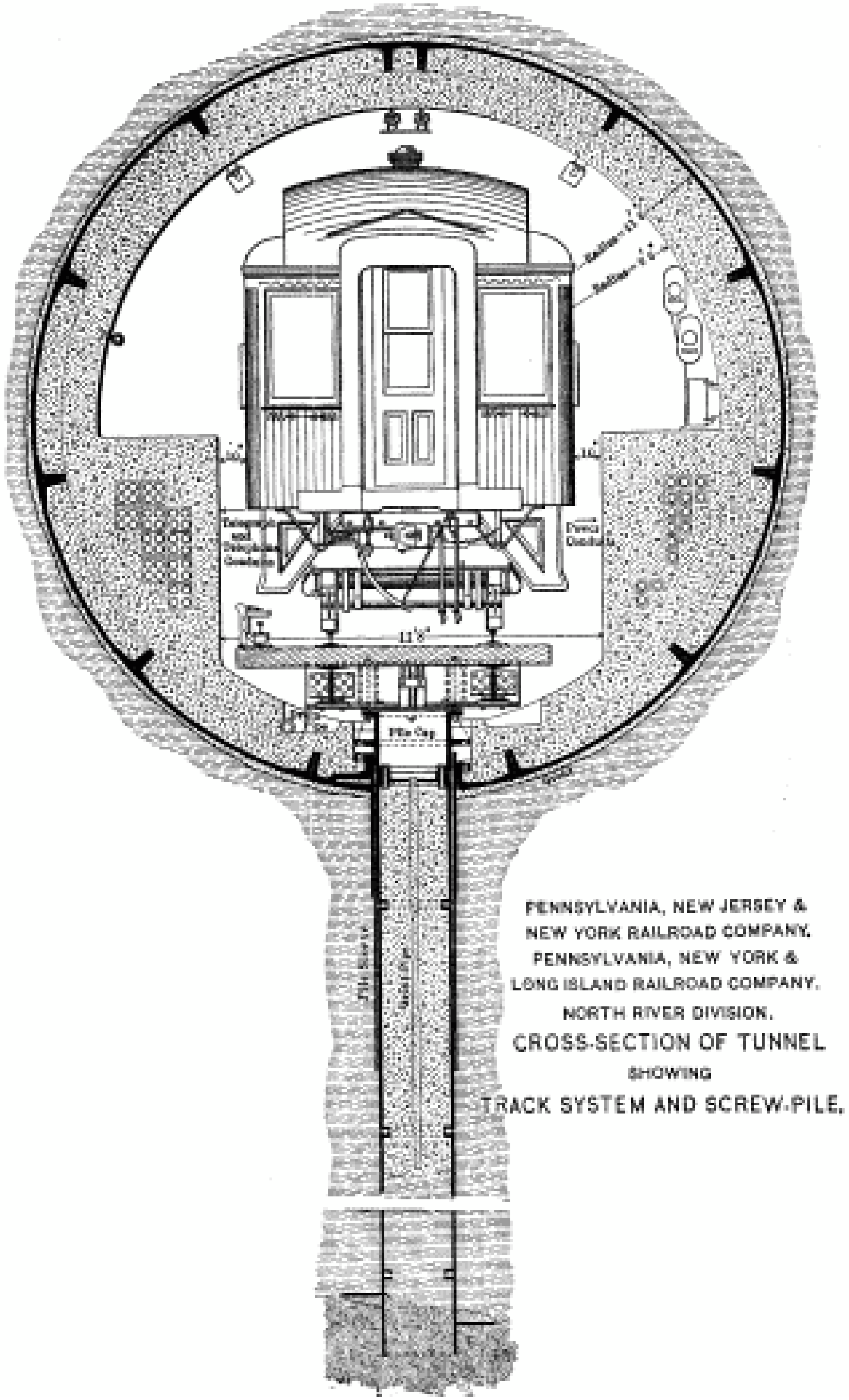


"…Figs. 2 and 3 illustrate the general arrangement and details of the machine designed by the writer and used for sinking the test piles in the tunnels. This machine had been used originally on the New Jersey side on the test pile at Pier C, and the adoption was not exactly as shown on these drawings, but if the screw-piles had been placed in the tunnels, the arrangement shown would have been used…"

Charles M. Jacobs, **Chief Engineer**

<u>Top</u>: caption: "Figure 2 - Hydraulic Screwing Machine with Ratchet Drive and Vertical Jack General Arrangement"

<u>Bottom</u>: caption: "Figure 3 - Hydraulic Screwing Machine with Ratchet Drive and Vertical Jack Details"



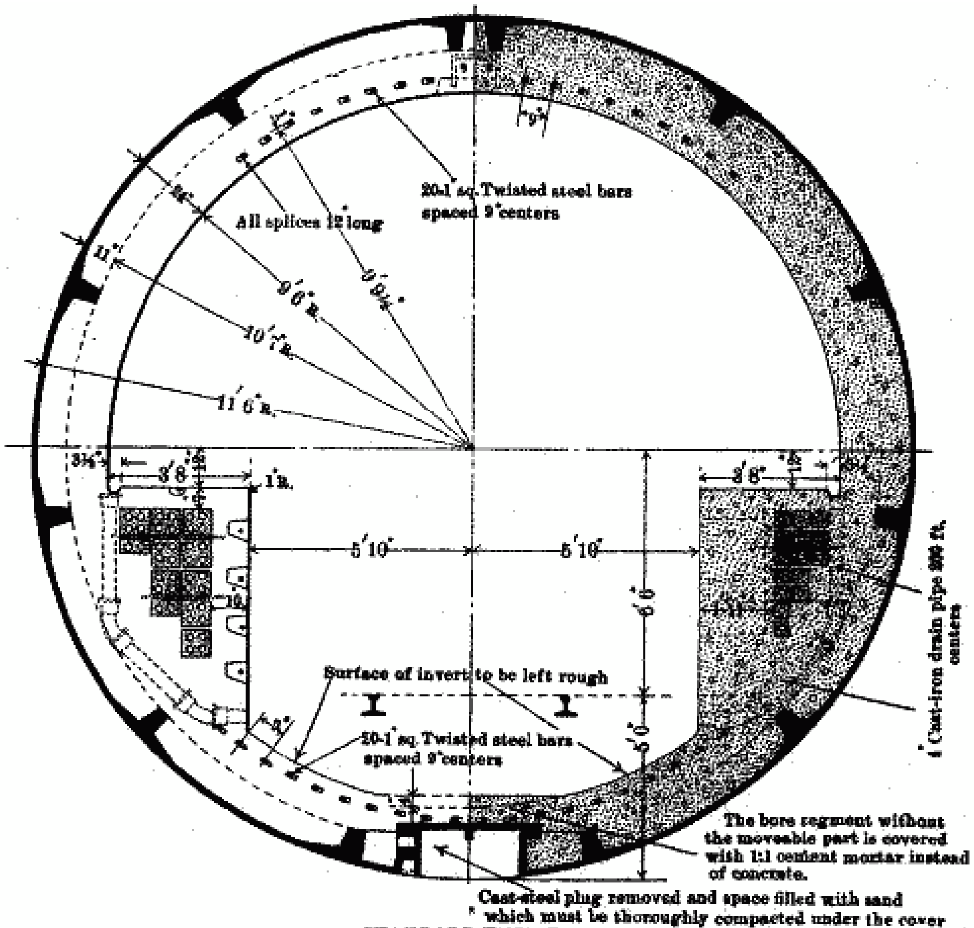
"…In order to permit the screw-piles to be put in place through the lining, cast-steel bore segments were designed, and placed in the invert at 15-ft. centers; these are of such a design as to permit the blade and shaft of the screw-pile to be inserted without removing any portion of the lining. Fig. 11 is a typical cross-section of the river tunnel, as originally planned, with these pile supports…"

Charles M. Jacobs, **Chief Engineer**

<u>Left</u>: caption: "Cross-Section of Tunnel showing Track System and Screw Pile"

"…In lining the tunnels, on the bottom centre line, a cast-steel shoe or plug 2 feet 7 inches in 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…"

RE: excerpt from *The Pennsylvania Railroad Tunnels and Terminals in New York City*



STANDARD TYPE *D*

"…After the shields had met and the iron lining was joined up, various experiments and tests were made in the tunnel; screw-piles, and 16-in. pipes, previously referred to, were inserted through the bore segments in the bottom of the tunnel, thorough tests with these were made, levels were observed in the tunnels during the construction and placing of the concrete lining, an examination was conducted of the tunnels of the Hudson and Manhattan Railroad Company under traffic, and the result of these examinations was the decision not to install the screw-piles. The tunnels, however, were reinforced longitudinally by twisted steel rods in the invert and roof, and by transverse rods where there was a superincumbent load on the tunnels; it might also be noted that on the New York side, where the tunnels emerge from the rock and pass into the soft material, the metal shell is of cast steel instead of cast iron. Fig. 12 is a typical cross-section of the river tunnels as actually constructed…"

Charles M. Jacobs, **Chief Engineer**

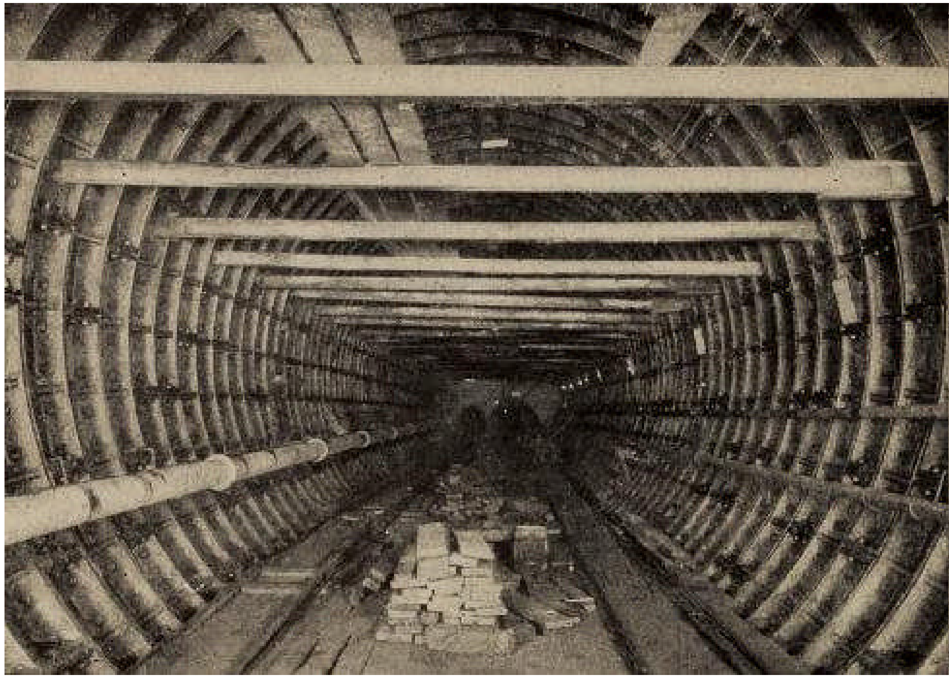
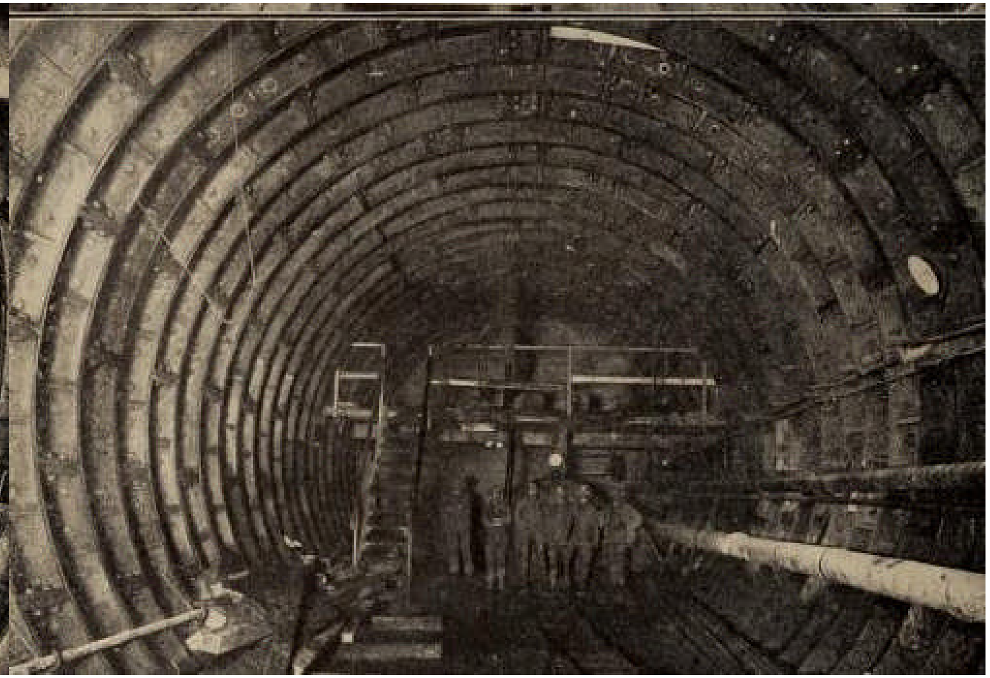
Left: caption: "Sub-Aqueous Tunnels Cross-Section"

"…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…"

RE: excerpt from *The Pennsylvania Railroad Tunnels and Terminals in New York City*

Above: caption: "This full-size section of the Hudson River tunnels was displayed by the Pennsylvania RR at the 1904 Louisiana Purchase Exposition at St. Louis. Clearly visible are the concrete benches on either side of the track proposed by A.J. Cassatt. At the bottom of the tube can be seen the planned track support system carried on screw piles driven to a solid foundation every 15 feet. These were never installed, and the openings left for them in the cast-iron tunnel were later closed."

Shell

"…The tunnels or tubes themselves consist of a series of iron rings, and the installation of every ring meant an advance of two and a half feet. Eleven segments and a key piece at the top complete the circumference, and an entire ring weighs about fifteen tons. The cast-iron plates, or sections of the ring, have flanges at right angles to the surface, and it is through these that the successive rings are held together with bolts. The record progress in one day of eight hours was five of these rings, or twelve and one-half feet…"

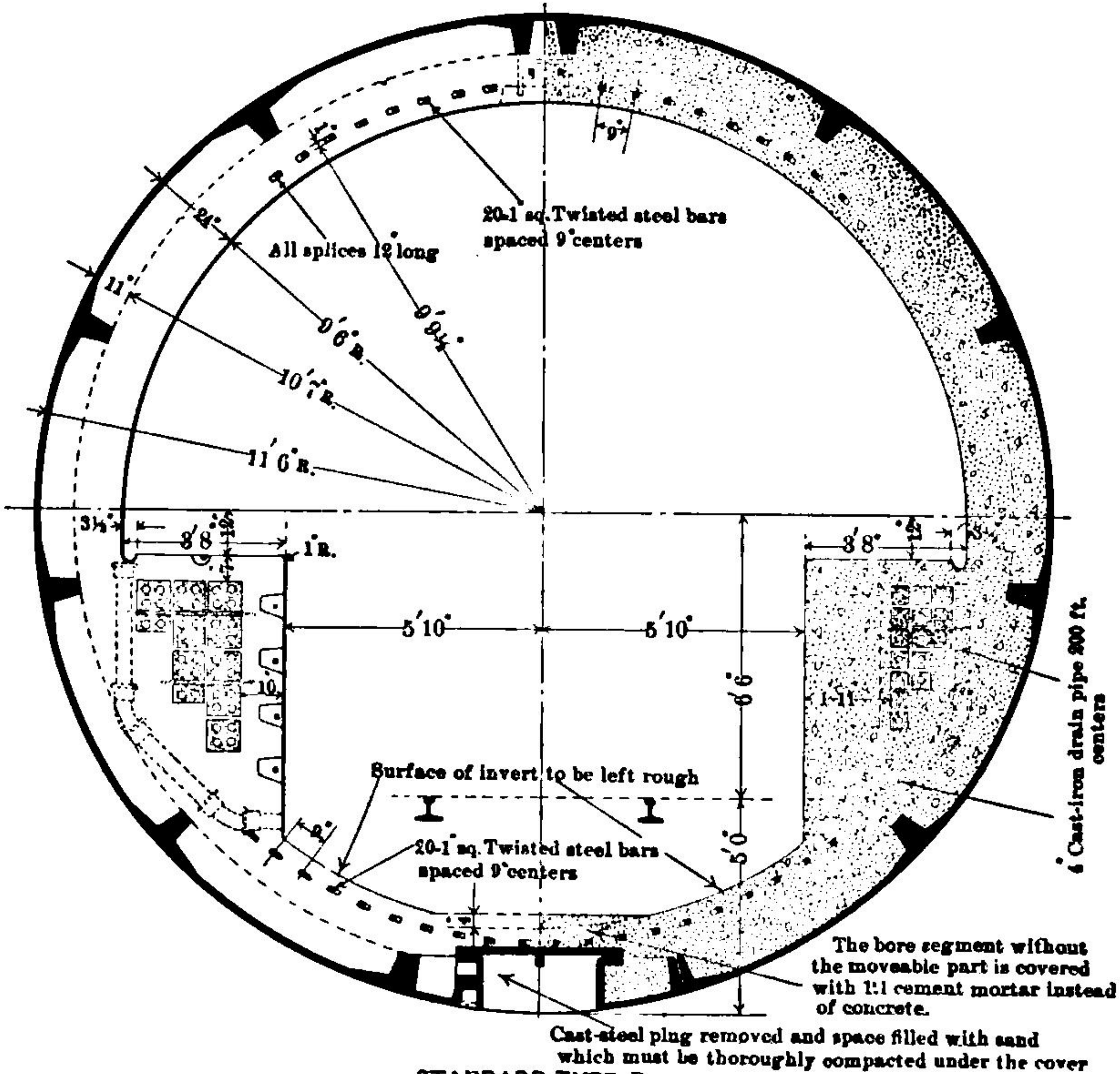
RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Left</u>: caption: "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."

<u>Right</u>: caption: "Air-Lock, normal side bulkhead wall, 10 ft. thick; three locks into pneumatic section."

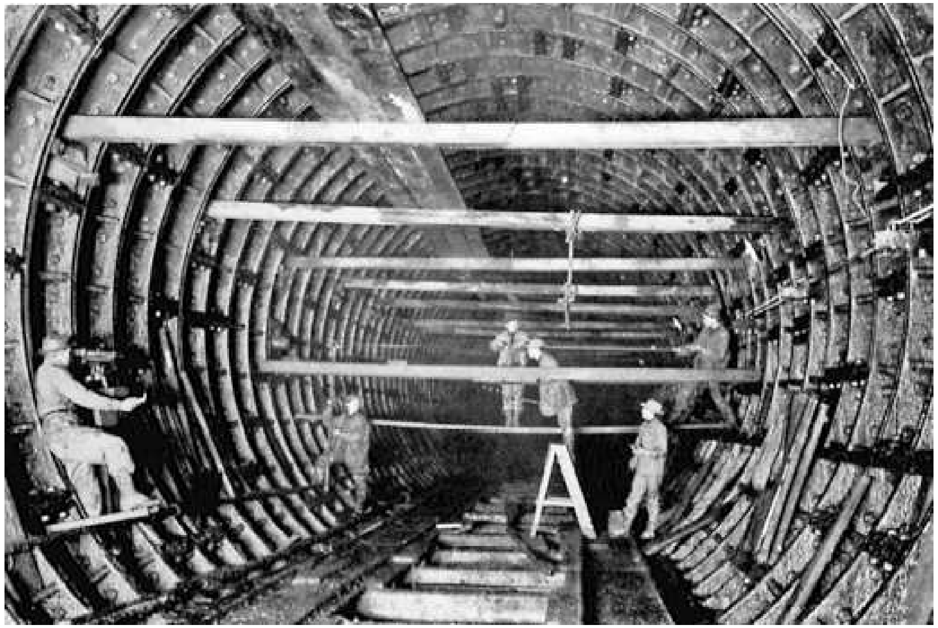
The sub-aqueous tunnel/s consist of a circular cast-iron shell of the segmental, bolted type, having an outside diameter of 23-feet, lined with concrete having an average thickness of 2-feet from the outside of the shell. Through each plate of the shell there is a small hole, closed with a screw plug, through which grout was forced into the surrounding void spaces. Each tunnel contains a single track. A concrete "bench" chase-way is located on each side of the track, separated by a distance of 11-feet 8-inches. A single rather than double track configuration was adopted to avoid the danger of accidents due to the obstruction of both tracks by derailment or otherwise. The tunnels were made just large enough to allow the safe passage of a train, allowing ventilation via the motion of the train itself through the tunnel/s (a ventilating plant was also provided in the event of a stoppage of a train in the tunnel/s). Since hydrostatic pressure between the top and bottom of the shield increases with the diameter of the tunnel, the smaller the tunnel diameter the more efficient the operation of the hydraulic shield employed. The concrete lining strengthened the tunnel from external pressures and guard the inside of the tunnel/s from accidents which might occur from within. Besides providing space for electric/signal lines, the concrete benches (suggested by *A.J. Cassatt*) provide sidewalks on either side of the train eliminating the need to walk on the tracks. As well, they keep the train centered in the event of derailment.

PENNSYLVANIA TUNNEL & TERMINAL RAILROAD CO.
NORTH RIVER DIVISION
SUBAQUEOUS TUNNELS
CROSS-SECTIONS



STANDARD TYPE *D*

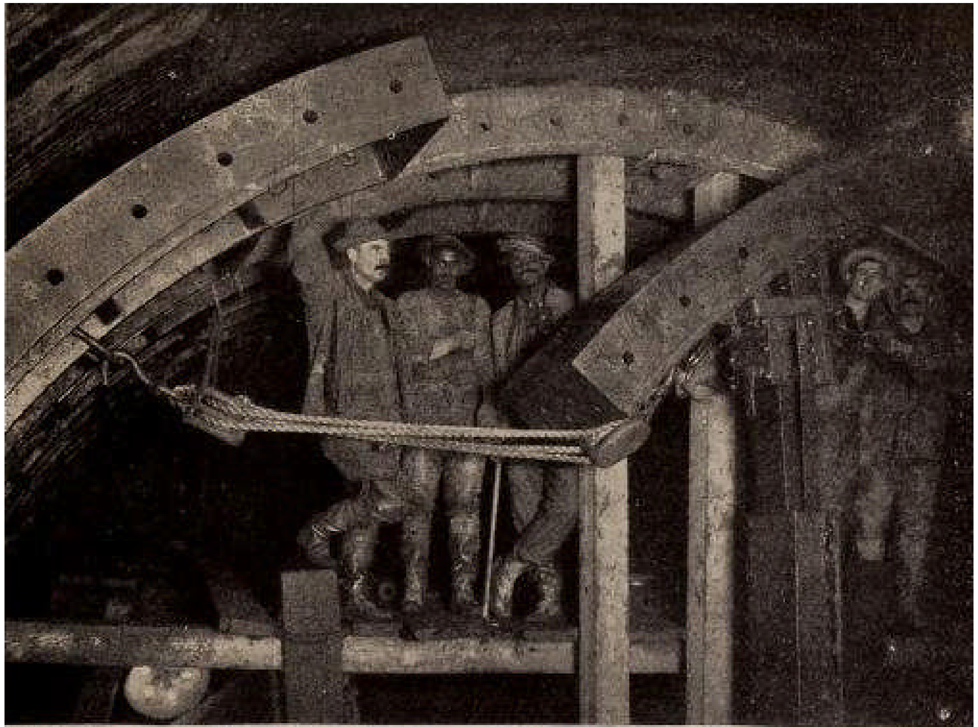
Left: caption: "North River Division / Sub-Aqueous Tunnels Cross-Sections." The tunnels were lined with concrete reinforced with longitudinal steel rods (in the arch and invert). Prior to the placing of concrete, the joints were caulked, the bolts grummeted and the tunnel/s rendered practically water-tight. Refuge niches were constructed in the side benches of the tunnels. Manholes, splicing chambers, pump chambers and other features in the handling of electric cables and/or drainage were established at intervals. At points of high stress (i.e. transition from rock to soft ground) steel rather than cast-iron plates were used to construct the shell.

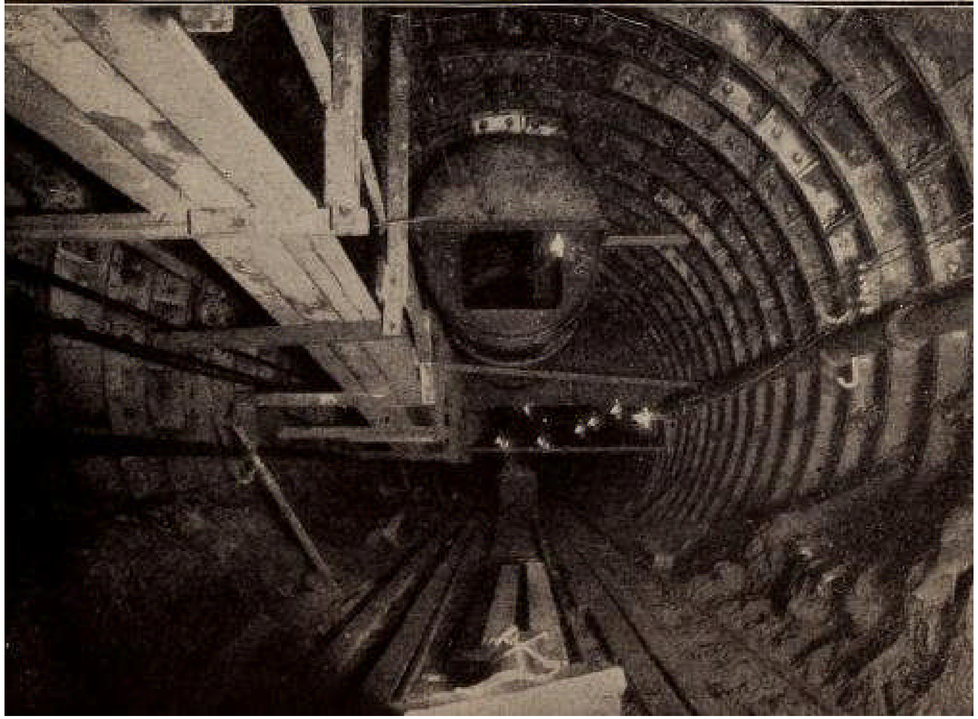


"…To insure that the east and west-bound shields would meet exactly, the engineers calculated the difficulties closely, and a really remarkable system of reports was in effect from the first day work was started. Every morning they knew the progress made in the tunnels the day before, to the very inch, and the amount of rock and soil excavated, to the cubic foot. The Pennsylvania Railroad Officers and the engineers hold this perfect system and the thoroughness of each day's work chiefly responsible for the accuracy of the meeting of the tubes…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Above</u>: caption: "Shown here is some of the surveying work that helped the tunnelers to work with such precision that the tubes were within 1/16 inch of perfect alignment when they met under the Hudson. In this photograph taken on January 17, 1907, the surveyors are checking line and level through a 6-inch pipe driven between the north tunnel from the Manhattan side and the south tunnel driven from the Weehawken side prior to the meeting of the north tunnel shields at mid-river."





"…The shields in the north tube under Hudson River met on September 17, 1906. Each had traveled some 3,000 feet through a river bed, yet the meeting was perfect. About a month later the shields in the south tube met in the same way. The shields in the south tube were united by a tunnel section, consisting of eight rings, that had been on exhibition at the St. Louis World's Fair. The shields in the four East River tunnels met as perfectly as those in the Hudson River tubes, and all were completed at about the same time…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

<u>Top</u>: caption: "Junction of South Tubes, building last rings, Nov. 14, 1906; 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."

<u>Bottom</u>: caption: "Emergency Air-Lock for refuge in case of flooding."

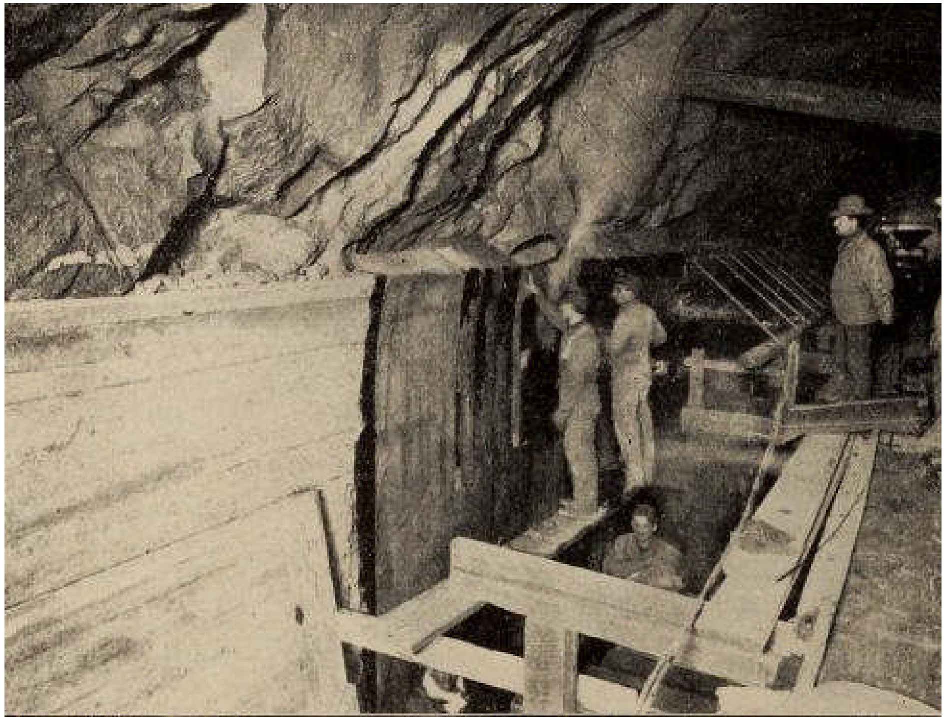
	Bergen Hill.	River Tunnels.	Term. Sta.-W.
Excavation disposed of (or displaced), in cubic yards	263,000	238,995	517,000
Cast metal used in tunnel, including cast iron and cast steel, in tons		64,265	
Steel bolts used, in tons		2,606	
Cement used (concrete and grout), in barrels	95,000	145,500	33,000
Concrete, in cubic yards	95,000	75,400	18,500
Dynamite for blasting, in pounds	600,000	100,400	206,000
Brickwork, in cubic yards		4,980	
Structural steel (including Pier 72), in pounds	50,000	3,141,000	1,475,000

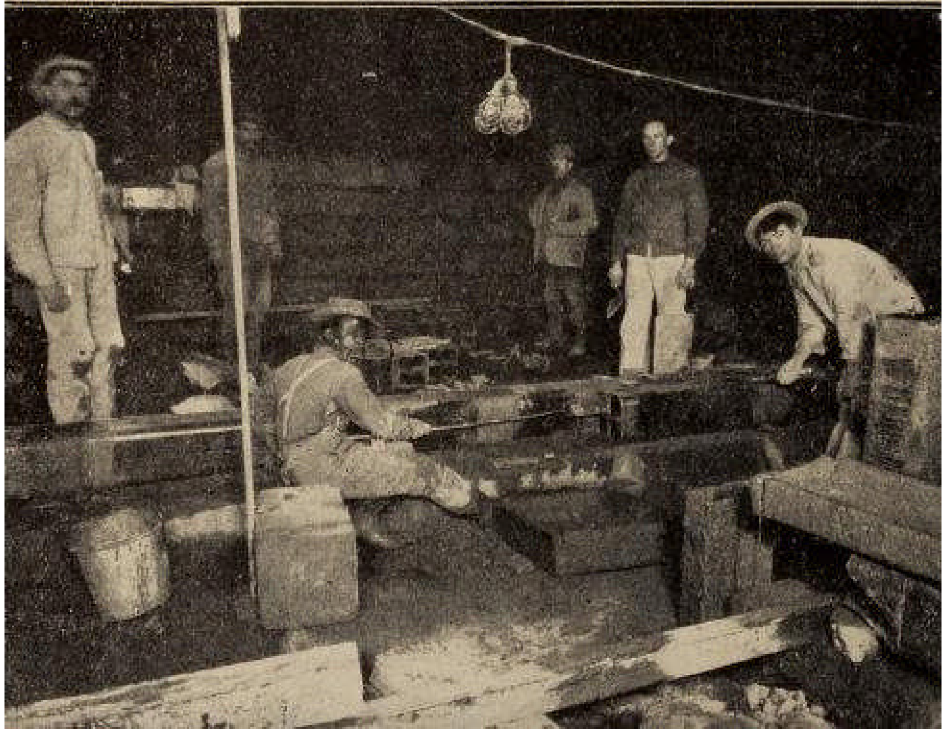
The tunneling progressed rapidly as the tunnelers gained experience. While it took as long as six hours to erect a single cast-iron tunnel ring in early stages of the work, this was later reduced to as little as thirty minutes for each ring. The much more cumbersome "heavy iron" rings were installed in an average of about 1-hour 44-minutes. With crews of twenty-four men at each shield working on three 8-hour shifts, the average rate of progress in each heading was about 18-feet per day. The two shields for the north tube met under the river on September 10th 1906, a full year ahead of the schedule called for in the PaRR's contract with the O'Rourke firm. As the two shields came together under the river, they were stopped about 10-feet apart while a large pipe was driven between them for a final check of line and level. It was found that they had met with a variation of less than 1/16-inch. The tunnelers ceremoniously passed a box of cigars, representing the first tunnel traffic, through the pipe from one shield to the other. The magnitude of the work is suggested by some of the meticulously detailed records maintained by the PaRR. Completion of the two 6,100-foot tubes under the river required almost 190K cubic-yards of excavation and the completed tunnels contained almost 67K-tons of iron and steel and nearly 57K cubic-yards of concrete.

Above: caption: "Table 1 - quantities of certain materials and other statistics regarding the North River Division"

On September 12th 1906, a party of PaRR and contractor officials walked through the tunnel from New Jersey to New York, and Chief Engineer Jacobs was given the honor of "first man through." The south tube was completed in October 1906 and the last ring was installed in November 1906, after which the work of waterproofing the lining began. This was done by caulking the joints between the cast-iron segments with a material made up of *sal ammoniac* and iron borings and by the installation of "grummets" - rings of yarn smeared with red lead - below washers on either end of each bolt. This work, followed by placement of the concrete lining, was completed by June 1st 1907.

Above: caption: "In May 1907, tunnel workers in the south Hudson River tunnel are shown, to the right, installing and hammering caulking material into the seams between tunnel segments. The two men at left are tightening the bolts that held the cast-iron segments together after installing 'grummets' of red-lead-soaked yarn behind washers to make the bolted joints watertight."



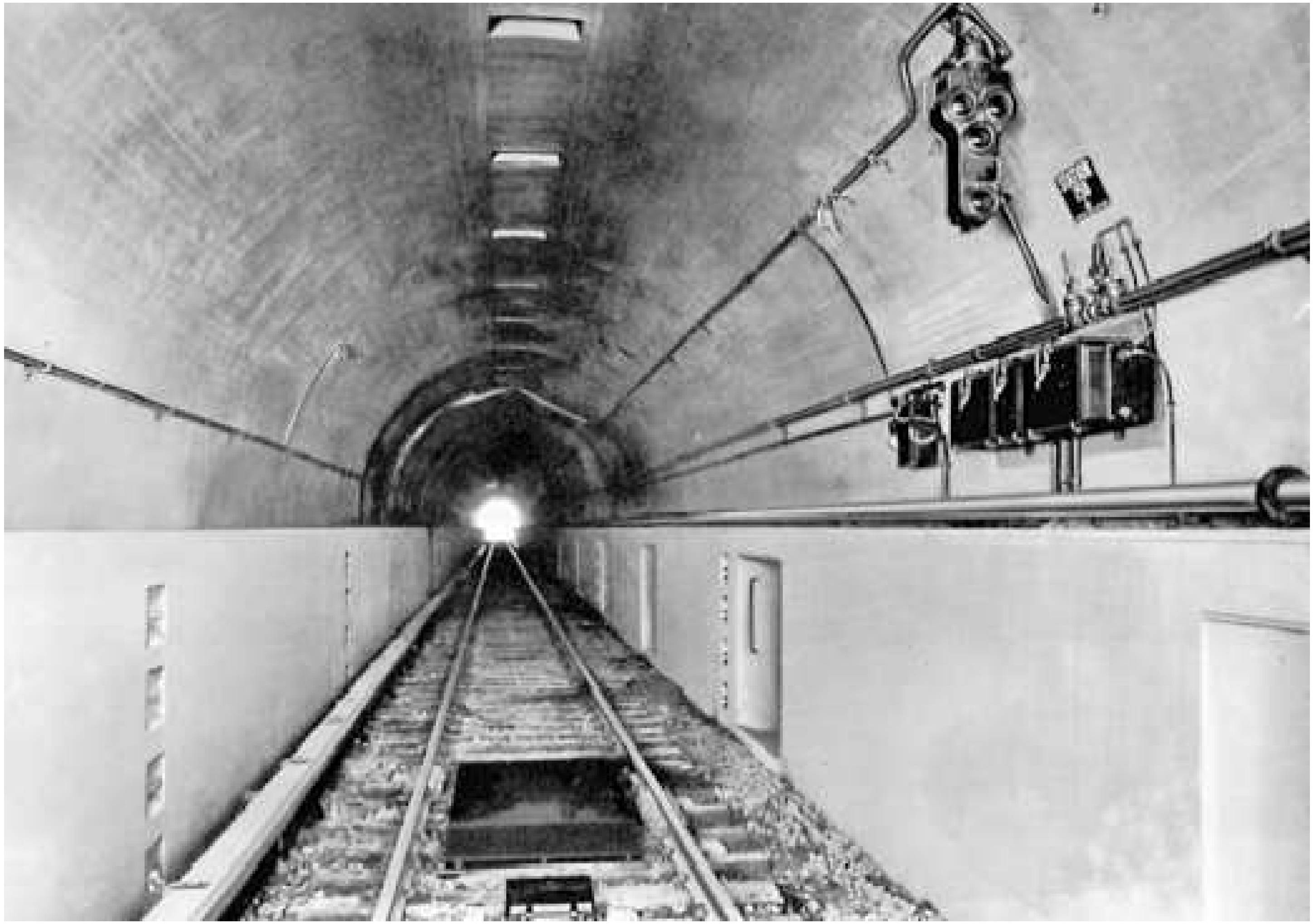


"…When the tubes were through from end to end, the work of putting in the 22-inch concrete lining was started immediately. On each side of the tunnel there is a so-called bench three feet wide, which serves as a walk, and under which are carried conduits for telegraph, telephone, signal and power wires…"

RE: excerpt from *The New York Improvement and Tunnel Extension of the Pennsylvania Railroad*

Top: caption: "Lining and Waterproofing rock section under Manhattan after excavation."

Bottom: caption: "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."



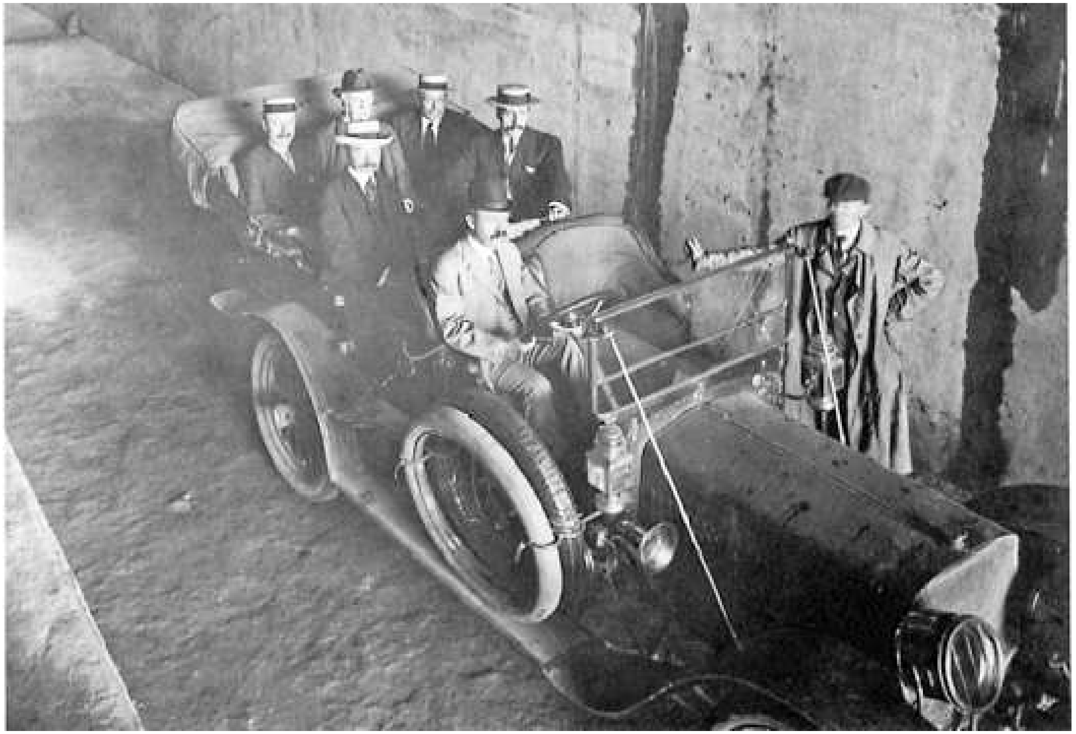
<u>Above</u>: caption: "The completed tunnel looked like this. The concrete 'benches' on either side of the track were designed to confine a train to the center of the track in case of a derailment, and provided, at the right, a walkway for the placement of signals and a place for signal maintainers to work safely, and, at the left, a safe exit from the tunnel. The 675-volt DC third rail is at the left of the track. The photograph was taken in the westbound tunnel, facing towards the Weehawken shaft."

A Tribute of Admiration

"…In concluding this account of the New York Tunnel Extension project, the writer desires to pay a tribute of admiration and respect to the memory of the late A.J. Cassatt, President of the Pennsylvania Railroad Company, to whom the conception, design, and execution of the project are mainly due. His education and experience as a civil engineer, his thorough knowledge of all the details of railroad construction, operation, and management, gained by long and varied service, the directness, clearness, and strength of his mind, and his great executive ability, placed him at the head of the railroad men of the country…Great as it is, the New York plan of improvement is only one item in a far-reaching scheme of development which became the policy of the Pennsylvania Railroad Company through Mr. Cassatt's advice and influence…It is the sincere regret of all connected with the design and execution of the project that he did not live to see its completion."

RE: excerpt from *New York Tunnel - Extension The Pennsylvania Railroad – Description of the Work and Facilities*

<u>Above</u>: caption: "Portrait of Alexander J. Cassatt, ca. 1880 by M. Cassatt." A.J. Cassatt was the brother of American impressionist painter *Mary Cassatt* (1844-1926).

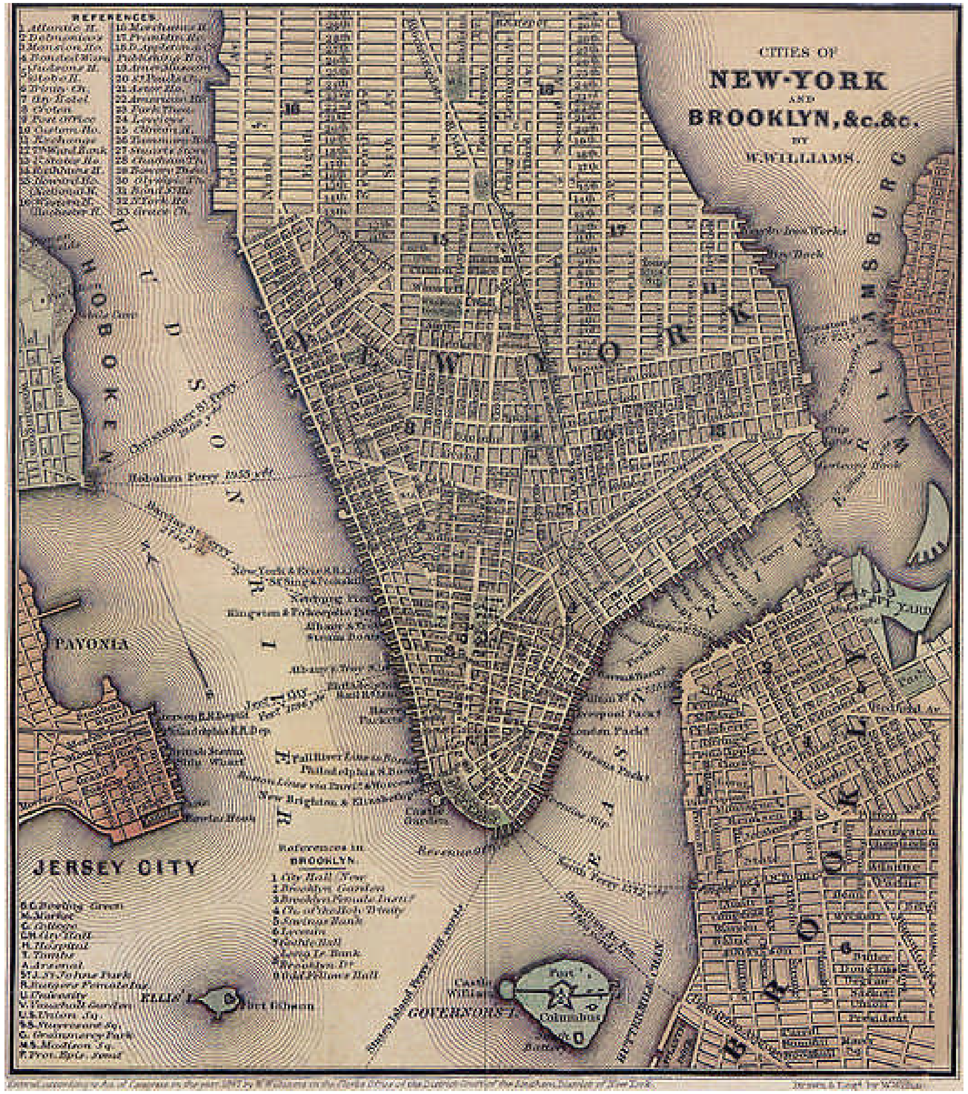


<u>Above</u>: caption: "To celebrate the completion of the tunnels, this group of PaRR and contractor officials boarded the first automobile ever driven under the *Hudson River* on June 21st 1909. Seated in the rear seat, from right to left, are PaRR first vice president *Samuel Rea* (who was in overall charge of the project); North River Division Chief Engineer *Charles M. Jacobs*; and *Albert J. County*, assistant to the PaRR's second vice president. Seated in the middle seat are tunneling contractor *John E. O'Rourke*, on the left, and Chief Assistant Engineer *James Forgie*. At the wheel is *Frederick Gubelman*, the owner of the Lozier automobile and vice president of the O'Rourke firm. Standing at the right is *George B. Fry*, O'Rourke's general tunnel superintendent."

Part 7

Mr. Holland’s Tunnel

Bridge or Tunnel?

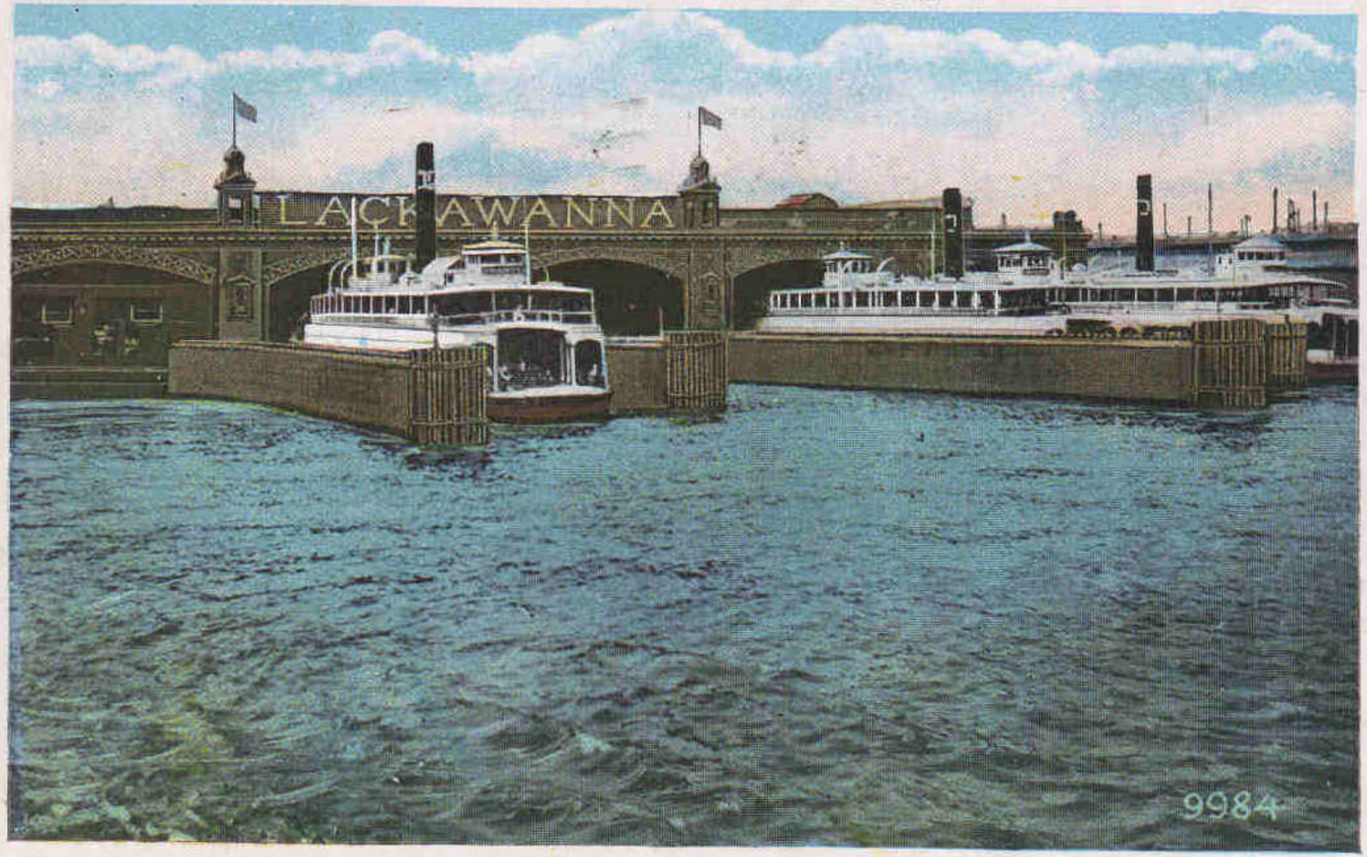


"…In 1906 the legislatures of the states of New York and New Jersey created for each state a Bridge Commission to investigate the feasibility of constructing a bridge over the Hudson River, uniting New York City with Jersey City. Legislative recognition was thus given to an increasingly vital problem – some means to supplement the ferries plying between these two ports…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Map of ferry service between lower Manhattan and Brooklyn on the East River, and Hoboken and Jersey City, N.J. on the Hudson River"

Lackawanna Ferries from Hoboken to New York.

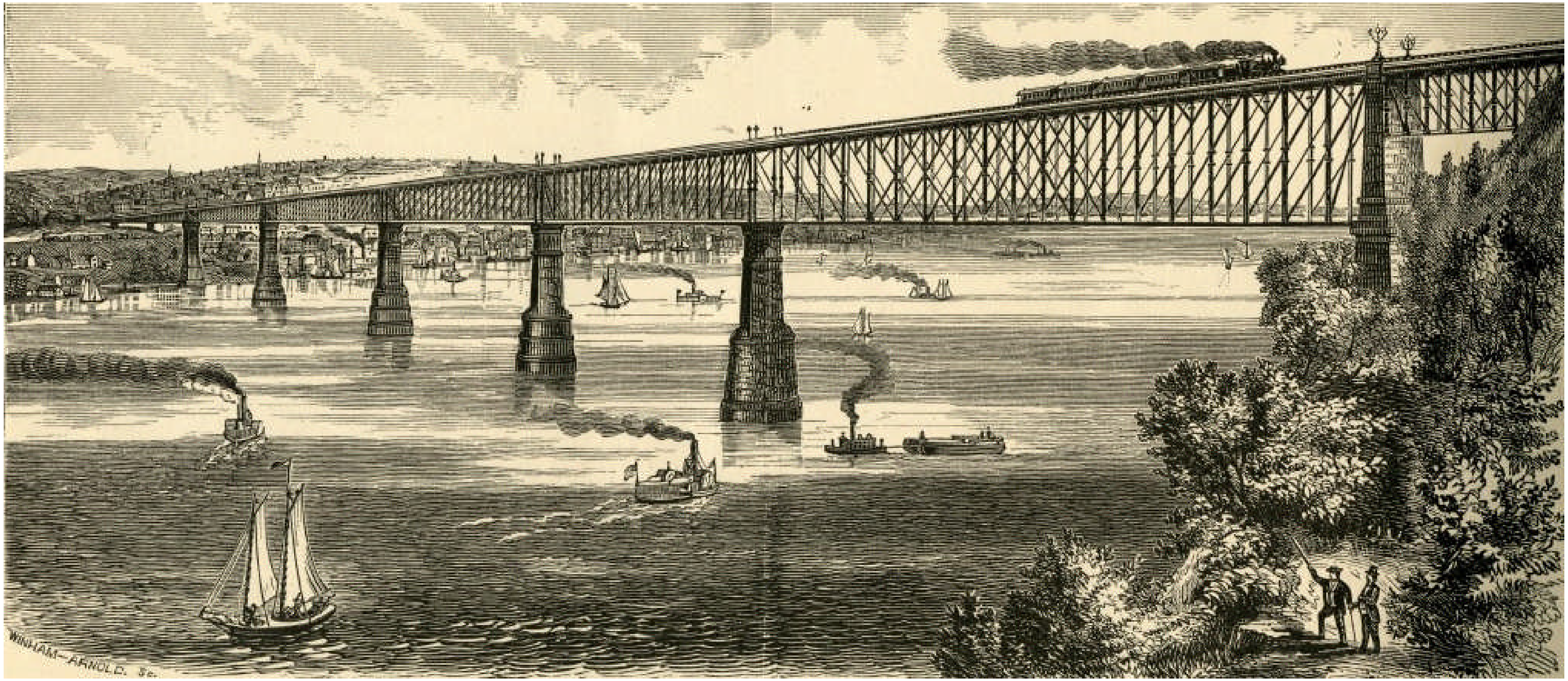


With the rapid rise of automobile and truck transport during the first decades of the *20th Century*, *Hudson River* ferries were carrying thirty million vehicles per year between *New York* and *New Jersey*. In 1906, a coalition of the *New York State Bridge and Tunnel Commission* and the *New Jersey Inter-state Bridge and Tunnel Commission* had begun feasibility studies for a bridge from lower *Manhattan* to *Jersey City, New Jersey*. However, there were drawbacks to the choice of a bridge crossing. A Hudson River bridge would require a minimum clearance of 200-feet. Since the Manhattan side of the Hudson did not meet the 200-foot elevation requirement for a bridge, long approaches (longer than that required by a tunnel) would have to be built on the New York side, consuming valuable real estate. Also, a bridge would be more vulnerable to inclement weather than a tunnel.

“A highway tunnel under the Hudson River at New York City, connecting the highway system of New York and New Jersey, is proposed by the Bridge and Tunnel Commissions of the two states instead of a bridge. There is but one bridge across the Hudson, south of Albany. That is at Poughkeepsie, 75 miles above New York City. The project for a bridge from Manhattan Island to the New Jersey shore has been agitated for a hundred years, but the great height at which it would have to be built to give sufficient clearance for shipping, and the value of the land that would have to be taken for terminals, would make a serviceable bridge cost $50,000,000, the commissions estimate, while a tunnel with two tubes, each having a 17-ft. roadway, could be built for $11,000,000. The average number of vehicles crossing the Hudson in ferry-boats is 19,660 per day. All but 2,000 of these cross below Twenty-third Street, and to make the highway tunnel accessible to this traffic it will have to be built below that point. A tunnel such as proposed would have a capacity of 5,000,000 vehicles a year, or about the number now crossing the river. Mechanical ventilation and means for maintaining perfect cleanliness are included in the plans.”

***Popular Mechanics,* 1914**

RE: as early as 1906, the governors of the states of *New York* and *New Jersey* proposed a bridge over the *Hudson River*. That year, the governors appointed an *Interstate Bridge Commission* for the purpose of constructing one or more trans-Hudson bridges at the joint expense of the two states. Alternately, they considered vehicular tunnel below *23rd Street* as a more economical conveyance. Ultimately, in 1913, they chose a tunnel over a bridge as the first vehicular trans-Hudson crossing, but the outbreak of WWI and America’s entry into the conflict (in April 1917) would delay the project.



<u>Above</u>: caption: "Hudson River Bridge at Poughkeepsie, New York." The *Poughkeepsie Highland Railroad Bridge* spans the *Hudson River* connecting *Poughkeepsie* and *Highland, New York*. Designed by *John F. O'Rourke*, it was built as a double track railroad bridge by the *Union Bridge Company* of *Pennsylvania*. Construction began in 1886 and the bridge operated from 1889 until 1974. At the time, it was the only fixed railroad crossing of the Hudson River between *New York City* and *Albany*, providing freight trains a more direct route between *New England* and the *Midwest*. Today, the bridge is operated by the *New York State Historic Park System* and is open to pedestrian and bicycle traffic only.

Coal Famine

"…was due almost entirely to the city's inability because of the ice-choked river to transport thousands of tons of coal that were literally in sight on the other side of the river, and yet as unattainable as if they were still in the mines"

Lt. Col. ***George Goethals***

RE: the "coal famine" during the winter of 1918 in NYC

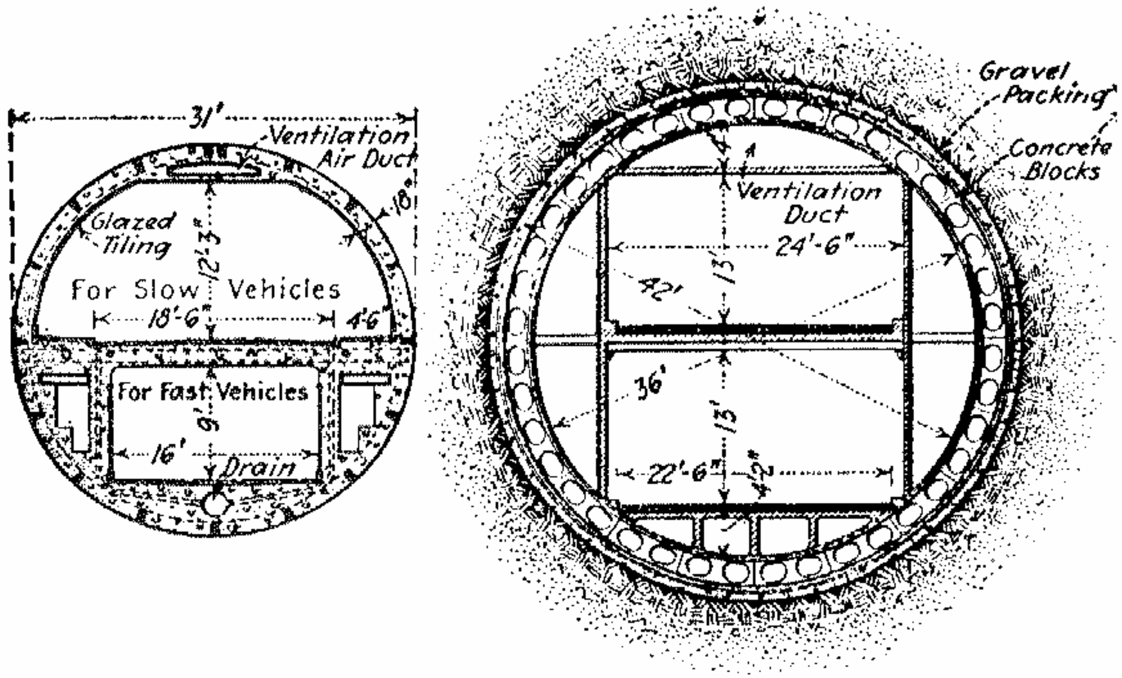
"A rising temperature yesterday brought no general relief in the desperate coal situation in New York. County Fuel Administrator Schley estimated that about 25,000 tons were brought in – a bit more than half of the normal consumption of the city. To make matters worse, the Weather Bureau at Washington sent out a storm warning last night, predicting a heavy snowfall here today or tomorrow, which may tie up all lines of land transportation. Each day draws New York closer to an absolute coal famine and makes the situation more serious. It developed yesterday that a large portion of the thousands of tons of coal said to be nearing the city was bunker coal, and entirely unfitted for the use of anything but ships…Kill von Kull, the main waterway by which coal reaches the city, was blocked again last night by heavy ice floes, after remaining open for only twenty-four hours. Tugs are trying to clear it…"

New York Tribune, **January 6th 1918**

Left: caption: "Ice-breakers in the Hudson"

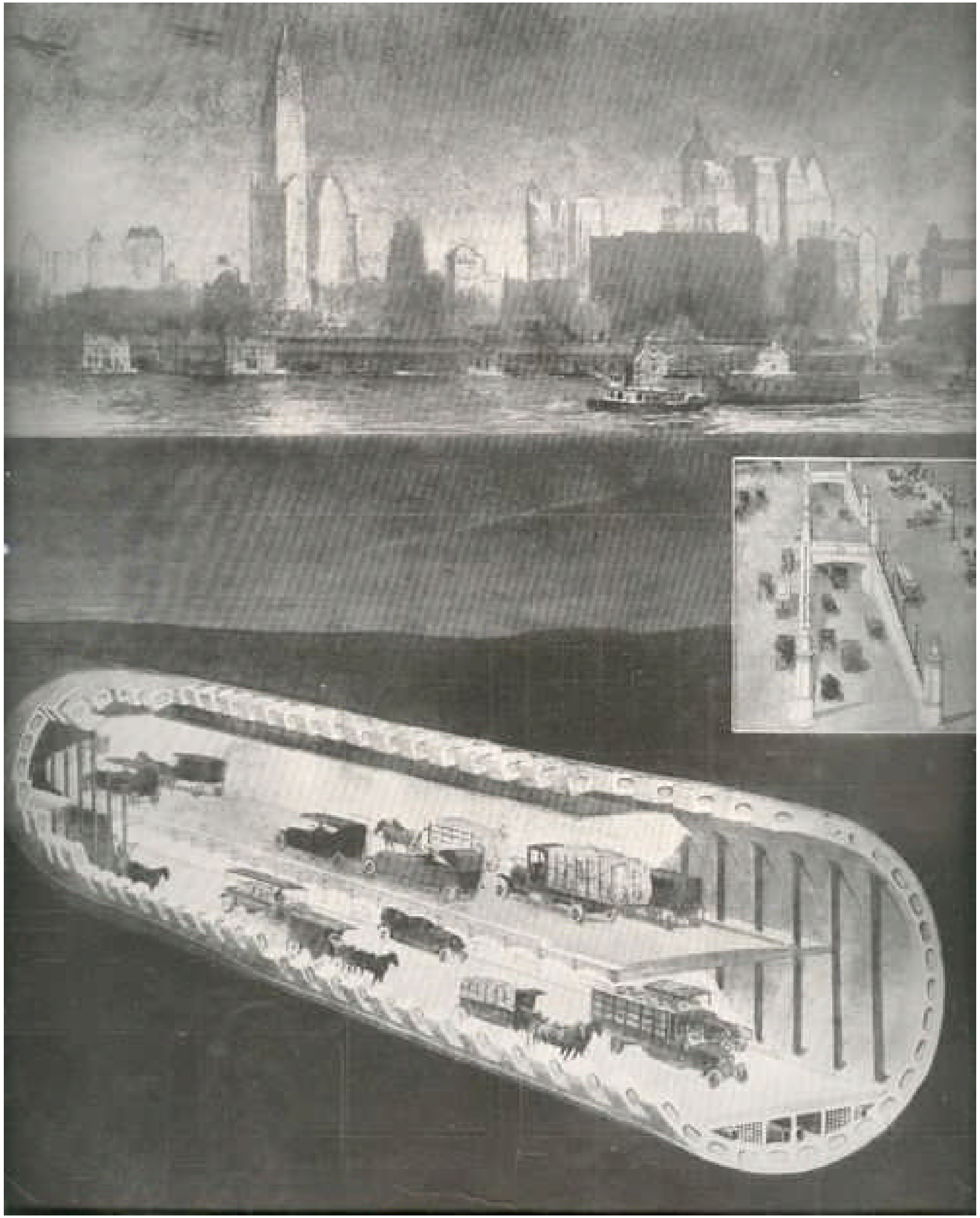
"…Mayor Hylan, who has been vitally interested in the coal famine since entering office…yesterday undertook a personal tour of inspection to look for coal hoards…The Police Department, on orders from Mayor Hylan, yesterday began taking a coal census, making a house to house canvass to learn if there were any domestic reserves that could be drawn on to tide the poor over the coal shortage…At the end of a strenuous day, the police had collected and distributed 386 tons of coal and six loads of wood to 3,082 families that had no fuel…"

***New York Tribune,* January 6th 1918**



Two proposals were initially floated for the "Hudson River Vehicular Tunnel" (a.k.a. "Canal Street Tunnel"). The first proposal, presented by the firm of *Jacobs & Davies*, called for a bi-level tunnel measuring 31-feet in diameter. The upper level, which was to carry slower vehicles, was to have an 18-foot-wide roadway and a clearance of 12-feet, flanked by sidewalks 4-feet wide. The lower level (to be reserved for express vehicles) was to have a 16-foot-wide roadway and a nine-foot clearance. Both levels were to carry two-way traffic. The second proposal, presented by army engineer *George Goethals,* was a bi-level design measuring 42-feet in diameter. Each level was to carry opposing lanes of traffic, two lanes in each direction. The roadway was to measure 23-feet wide and was to have 13-feet of clearance.

Above L&R: caption: "Two unrealized proposals for Hudson River vehicular tunnels, by the firm of Jacob & Davies in 1910 (left) and by O'Rourke & Goethals (right) in 1919"



<u>Left</u>: caption: "Image from *The Illustrated London News* (5 April 1919) presents a cross-section of a proposed Hudson River tunnel connecting the Jersey City and New York City"

"…Further legislation, enacted from time to time, continued the life of these Commissions. In 1913 they were authorized to consider the possibility of a vehicular tunnel. Finally, on April 10, 1919, authority was granted them to proceed with the construction of a tunnel, or tunnels, between a point in the vicinity of Canal Street on the island of Manhattan and a point in Jersey City…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Hudson River Vehicular Tunnel"

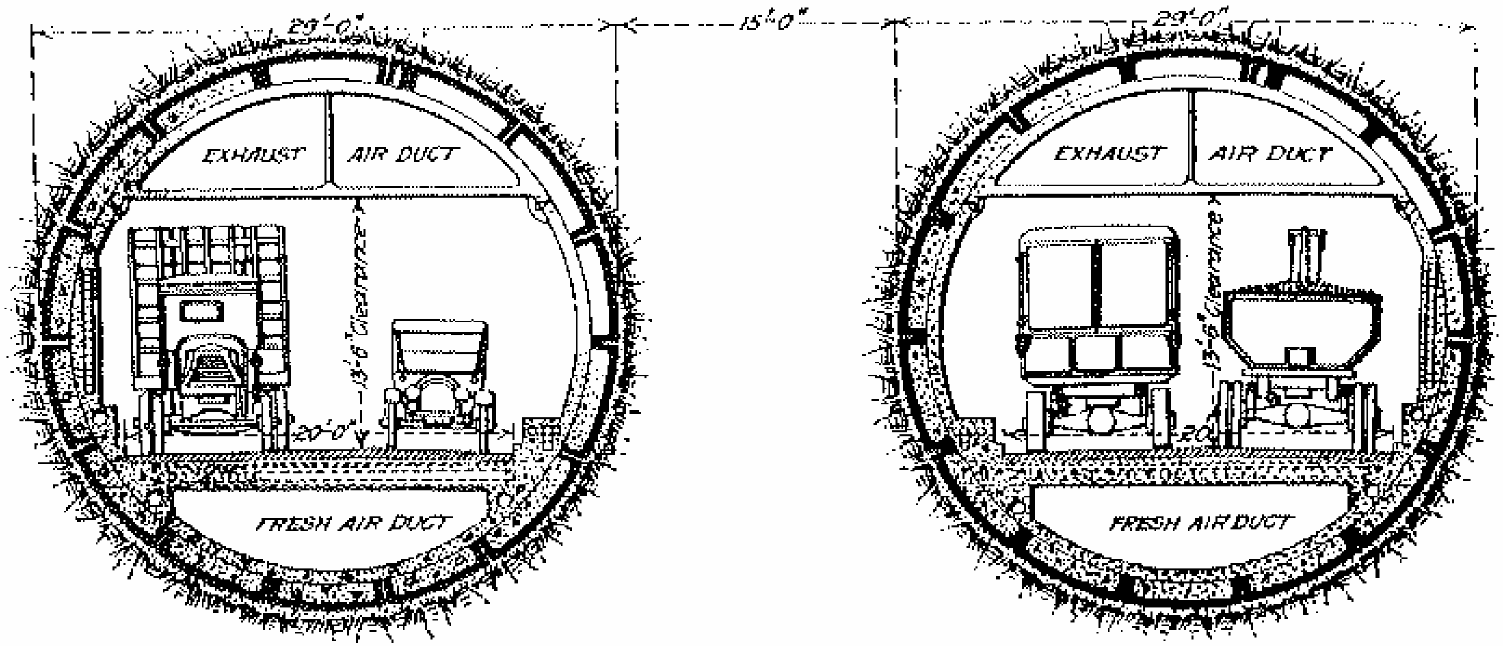
"…Those who had the project closest at heart felt that the tunnel would:

1. ***Shorten the time of transit across the Hudson River and afford a continuous means of communication between New York and New Jersey, unaffected by climatic or other interference;***
2. ***Relieve traffic congestion, already serious;***
3. ***Accelerate the movement of necessary supplies into the city of New York, and thereby relieve conditions of distress;***
4. ***Increase the tax value of real property within a considerable radius of the tunnel terminals;***
5. ***Pay its cost three times over within twenty years;***
6. ***Reduce the high cost of living by reducing the cost of trucking;***
7. ***Increase the facilities of commerce in the port of New York by removing from the surface of the harbor many lighters and other floating equipment, and;***
8. ***Furnish means for the uninterrupted movement of troops and supplies to and from the city of New York in case of need."***

RE: excerpt from *The Eighth Wonder*

<u>Above</u>: caption: “The signing of the Interstate Treaty between the New York State Bridge & Tunnel Commission, representing the State of New York, and the New Jersey Interstate Bridge & Tunnel Commission, representing the State of New Jersey, for the construction of the Hudson River Vehicular Tunnel, at the office of the Commissions in the Hall of Records, New York City, on December 30, 1919”

Chief Engineer



"When Clifford M. Holland talks tunnels, his listener is in danger of being convinced that tunnels are the only refuge for mankind; by the time he has finished his hearer sees in a tunnel all the allurement which a mole finds in a nicely constructed borrow. Because Mr. Holland does know tunnels, and he does build them safely."

***Brooklyn Daily Eagle,* February 19th 1920**

Above: caption: "Clifford Holland's design for a Hudson River vehicular tunnel made up of twin tubes." Holland's ventilated twin-tube design was selected to be built by the NY/NJ Commission/s in 1919.

"…The Commissions selected as chief engineer Mr. Clifford M. Holland, tunnel engineer of the Public Service commission, First District, State of New York, in immediate charge of the construction of all subway tunnels under the East River. He was regarded as having had a greater and more successful experience in the work of the sub-aqueous tunnel construction than any other member of his profession. A board of consulting engineers was appointed, and a contract or treaty between the two states was drawn up and approved by the Commissions and given the consent of Congress…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: *Clifford M. Holland*, Chief Engineer. Holland gathered a team of experts from the *U.S. Bureau of Mines* (USBM), *Yale University* and the *University of Illinois* to design the world's first ventilated vehicular tunnel. *Ole Singstad* (who completed the tunnel and later went on to design the *Lincoln, Queens-Midtown* and *Brooklyn-Battery Tunnel/s*) led the design team.

“…Chief Engineer Holland took office on July 1, 1919, and at once began the organization of an engineering staff. His chief assistants were selected from those who had been associated with him in the construction of the East River subway tunnels. Having had not less than ten years’ experience in sub-aqueous tunneling, they were well qualified both by technical training and by practical experience to meet the requirements of the work. Actual construction began October 12, 1920…”

RE: excerpt from *The Eighth Wonder*

The Martyr Engineer

"Things broke well for me: the choice of engineering, the good school, the right years – when work was booming, the perfect place – New York, the lucky first job – subway shafts to Brooklyn, then my life's pinnacle and purpose – the great tunnel to New Jersey, and my wife, noble, strong. She knew what the project meant to me and the city."

***Clifford M. Holland,* Chief Engineer**

RE: when 41yo Clifford Holland died of exhaustion and heart failure on October 27th 1924 – before the completion of "the great tunnel to New Jersey" – he was eulogized in the press as the "martyr engineer" for his heroics and dedication. He was also acclaimed as "the most noted tunnel builder in the world" and the engineer of the "eighth wonder of the world." Within two weeks of his death, the project was named in his honor: *Holland Tunnel*. In 1999, *Engineering News Record* (ENR) honored him as one of the ten most outstanding "Landmark Project Engineers" of the last 125 years. Born on March 13th 1883 to an old *New England* family, he told his high school classmates he was going to be a "tunnel man." To that end, he entered Harvard University's engineering program in 1902, earning his B.S. in *Civil Engineering* in 1906.

"If I had known it was tapping his strength so much, I would have urged him to be more careful, but he was so completely wrapped up in his work that I really do not know if any pleadings would have had any effect"

RE: comments made by the wife of Chief Engineer *Clifford M. Holland* upon his tragic death from nervous exhaustion at the age of 41

<u>Above</u>: caption: "Clifford Milburn Holland, 1919"

The Holland Tunnel

At Stated Meetings of the **New York State Bridge** and **Tunnel Commission** and the **New Jersey Interstate Bridge** and **Tunnel Commission** held Tuesday, November twelfth, nineteen hundred and twenty-four, the following resolution was adopted.

Whereas the untimely death on October twenty seventh, nineteen hundred twenty four of

Clifford Milburn Holland
Chief Engineer in the Construction
of the Hudson River Vehicular Tunnel

has caused a general expression of sorrow; and

Whereas, by comment in the public press as by resolutions of public bodies and societies and expressions from leading citizens and civic organizations, the opinion is general that Mr. Holland gave his life to the work of the planning and construction of this great public utility; and

Whereas, the members of the New York State Bridge and Tunnel Commission and the New Jersey Interstate Bridge and Tunnel Commission are in accord with the widespread suggestion that some fitting attribute be paid to the memory of the deceased Engineer; Therefore be it

Resolved, that the **Hudson River Vehicular Tunnel,** now being constructed between Canal and Broome Streets in the Borough of Manhattan, City of New York, and 12th and 14th Streets, Jersey City, New Jersey, be and it is hereby dedicated to the memory of Clifford Milburn Holland, and that the said Hudson River Vehicular Tunnel is hereby designated and named as

The Holland Tunnel

"…Upon the death of Mr. Holland on October 27, 1924, at Battle Creek Sanitarium, where he had gone in search of health after devoting all his strength and energy to the construction of the tunnel, the Commissions gave it his name. Under his direction all the more difficult portions had been completed and the remaining details planned, and on the very day his body was borne to his home there came a demonstration of his engineering skill and accuracy in the successful junction of the under-river headings of the north tunnel…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Contract No. 3. North Tunnel - New York and New Jersey shields - Upper cutting edges meeting. 12/28/24."

The Head Mole

Clifford Milburn Holland **devoted his life to the construction of tunnels under waterways in and around *New York City*. Holland's first engineering job was as tunnel engineer for New York City's *Public Service Commission*, which was then constructing the first New York City Subway (IRT). In 1919, at the age of 36, he was appointed chief engineer on the project to connect *New York* and *New Jersey* by way of a tunnel under the *Hudson River*. He was a natural choice for the job, having successfully overseen several tunnels under NYC's *East River*, including the *Old Slip-Clark Street Tunnel* and the *Whitehall-Montague Street Tunnel*. Holland spent so much time directly overseeing the work on the tunnel named in his honor after his death that newspaper reporters began to refer to him as "the Head Mole." Despite having had a weak heart since childhood, he endured compression and decompression several times a day as he descended into the tunnel and returned to the surface. By October 1924, he was suffering from what was termed "nervous exhaustion" and retreated to a sanitarium for a rest cure. Two weeks later, his heart failed and he died just before the two headings of the north tunnel met.**

“Another Engineer Dies on Big Tunnel Job; M.H. Freeman Is Victim of Acute Pneumonia

Milton H. Freeman, chief engineer of the New York and New Jersey Vehicular Tunnel, died at 10 o’clock on Tuesday night at his home in Valhalla, N.Y., of acute pneumonia. Mr. Freeman succeeded Clifford M. Holland as chief engineer when the latter died on Oct. 27 last.”

***New York Times*, March 26th 1925**

"…His successor, Mr. Milton H. Freeman, had been his Division Engineer. He, too, gave himself unsparingly to the work, and died on March 24, 1925. He was succeeded by Mr. Ole Singstad, who had been Engineer of Design under both Mr. Holland and Mr. Freeman. Under his direction the Holland Tunnel has been completed…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Ole Singstad, Chief Engineer. Under whose direction the Holland Tunnel was brought to successful completion."

“…Oddly enough, Ole Singstad began his career above ground - designing bridges. That was back in 1905, the year he arrived in the United States from his native Norway. He was virtually penniless but the engineering degree he had won before at the Polytechnic Institute of Trondheim landed him a job with the Central Railroad of New Jersey. He worked for several other railroads after that but in 1909 embarked on his mole-like profession as a designer for the Hudson River tunnels of the Hudson Manhattan Railroad in New York. There followed similar work on the I.R.T. subway tubes under the East River and then, in 1919, he got his first big break with the Holland Tunnel project…”

Mechanix Illustrated, **June 1941**

Location, Location, Location

"…The Holland Tunnel is located in the vicinity of Canal Street, New York City, because that street is a wide east and west thoroughfare giving direct communication across the island of Manhattan. On the east, Canal Street connects with the East River bridges and Brooklyn; on the west, with the Hudson River water front, at approximately the center of downtown traffic over the Hudson ferries…"

RE: excerpt from *The Eighth Wonder*

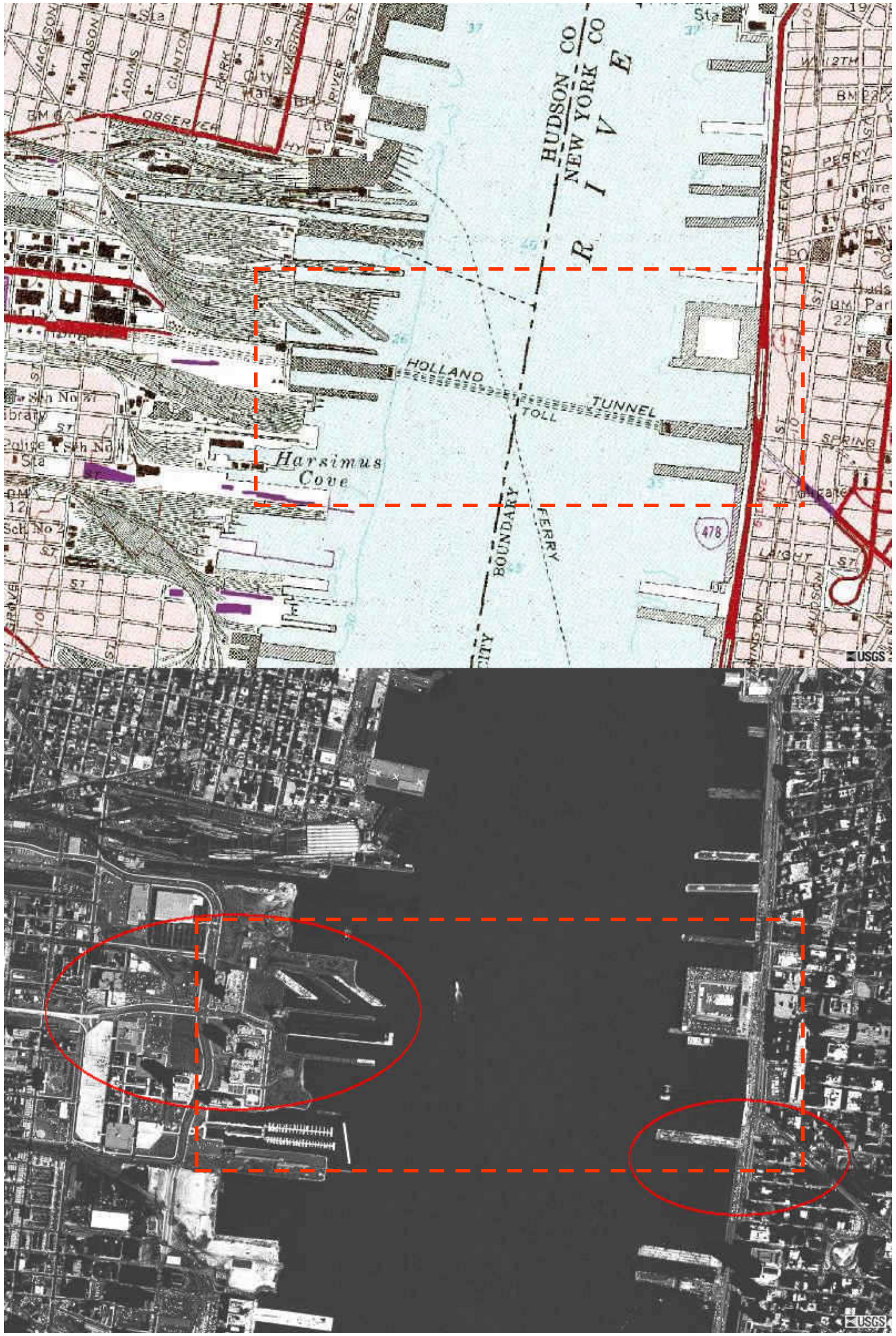
<u>Above</u>: caption: "Site of the Holland Tunnel, looking west from New York City"

"…Its location in Jersey City is at the logical point as nearly opposite Canal Street as is practicable, in order to obtain the shortest tunnel. This point is very near the center of traffic and is advantageously located. It gives direct communication to Jersey City Heights and points beyond by means of the Thirteenth Street Viaduct. The water front, with important railroad yards, is easily accessible and adequate communication is afforded with the low-lying parts of Jersey City and Hoboken through streets which parallel the river…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Aerial photograph of tunnel site, looking East from New Jersey 4/4/23"434

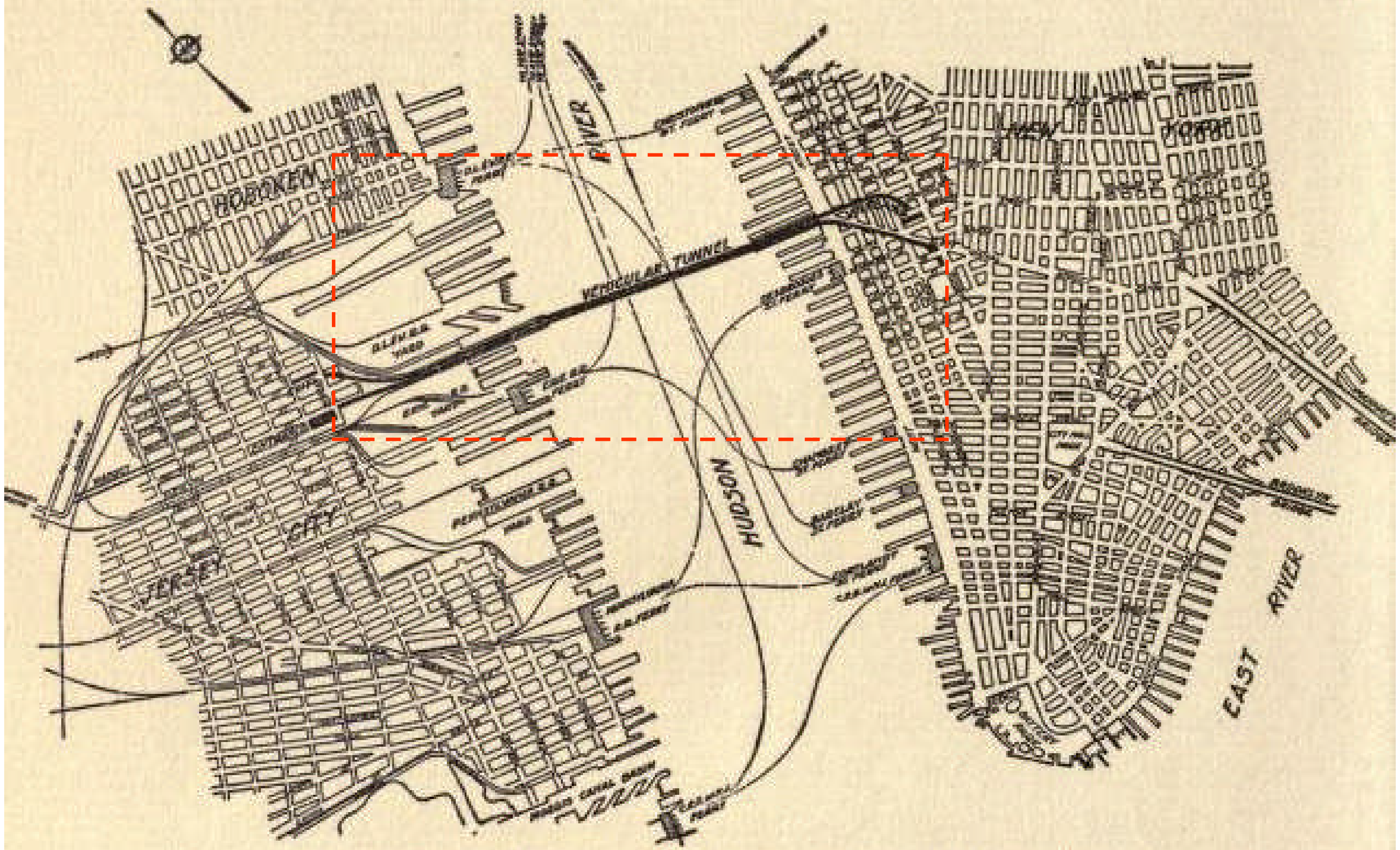
<u>Right</u>: caption: "The original two-way viaduct to the Holland Tunnel"



"…The southerly tube for east-bound traffic extends from Provost and Twelfth Streets, Jersey City, under the Erie Railroad yards, the Hudson River, and Canal Street to Varick Street, New York City. The northerly tube for westbound traffic extends from Broome Street mid-way between Varick and Hudson Streets and under Hudson Street and the Hudson River, the Erie, and the Delaware, Lackawanna and Western Railroad yards to Four-teenth Street at Provost Street, Jersey City…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Aerial Photograph and corresponding location map of Holland Tunnel Hudson River crossing between Manhattan and Hudson County, New Jersey"



LOCATION PLAN OF HOLLAND VEHICULAR TUNNEL

“…In planning a public undertaking of the magnitude of the Holland Tunnel, consideration had to be given to many features besides those of actually tunneling. The building of the structure itself was a great engineering problem, but many investigations beyond mere technical design were required…”

RE: excerpt from *The Eighth Wonder*

"…To secure the best location and arrangement of tunnel roadways, a survey of present and future traffic and the influence of the tunnel on the development of adjacent territory was called for, first of all. Traffic conditions had to be considered from many angles, such as capacity, congestion of the tunnel roadway, adequate approaches, congestion in adjoining streets, width of roadway, and the growth and development of vehicular traffic. A preliminary forecast of tunnel traffic, based chiefly on the yearly increase in traffic over the Hudson ferries, resulted in an estimate of the number of vehicles that would use the tunnel as follows:

- ***1924 (when tunnel was expected to be opened) 5,610,000***
- ***1935 . . . . 13,800,000***
- ***1937 . . . . 15,700,000***
- ***1943 . . . . 22,300,000***

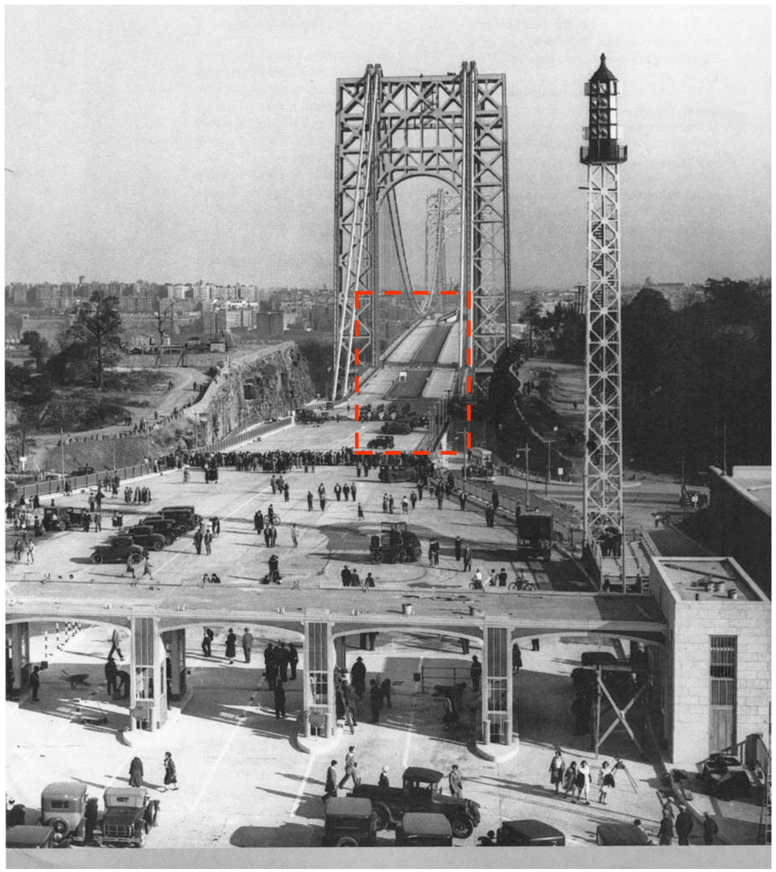
Further estimates indicated that a one-line tunnel would have a capacity about equal to the traffic demand at the opening of the tunnel. A two-line tunnel would have sufficient capacity to accommodate all traffic up to 1937, while a three-line tunnel would reach its capacity in 1943…"

RE: excerpt from *The Eighth Wonder*

Cost Effective

"…Obviously it would be unwise to construct a one-line tunnel whose capacity would be reached as soon as put in operations. As between a two-line and a three-line tunnel, it was found that the difference in cost, with interest, would be sufficient to pay for another two-line tunnel after the first two-line tunnel had outgrown its capacity. Of greater importance was the consideration that no street or section could accommodate the volume of traffic represented by a three-line tunnel. If a three-line tunnel was built, it could be operated at only two-line capacity. This would violate two of the main principles governing proper tunnel planning – the distribution of traffic so as to avoid undue congestion, and the investment of capital for construction only as facilities are needed, without the necessity of providing for the distant future. These are two of the most important features in which tunnel construction is held to be superior to bridge construction in crossing wide, navigable rivers…"

RE: excerpt from *The Eighth Wonder*



"…The cost of a long-span bridge does not vary directly with the span but increases about as the square of the span. On such a bridge no commensurate saving in the cost of construction is obtained by omitting some of its facilities. The tendency in bridge construction, therefore, is to provide facilities greatly in excess of immediate requirements, with a consequent expenditure of capital long before those facilities are needed. Then when there is sufficient traffic to utilize the bridge to full capacity, the resulting congestion in the vicinity of the bridge entrances becomes a serious matter. This is seen in the case of the East River bridges in New York City today…"

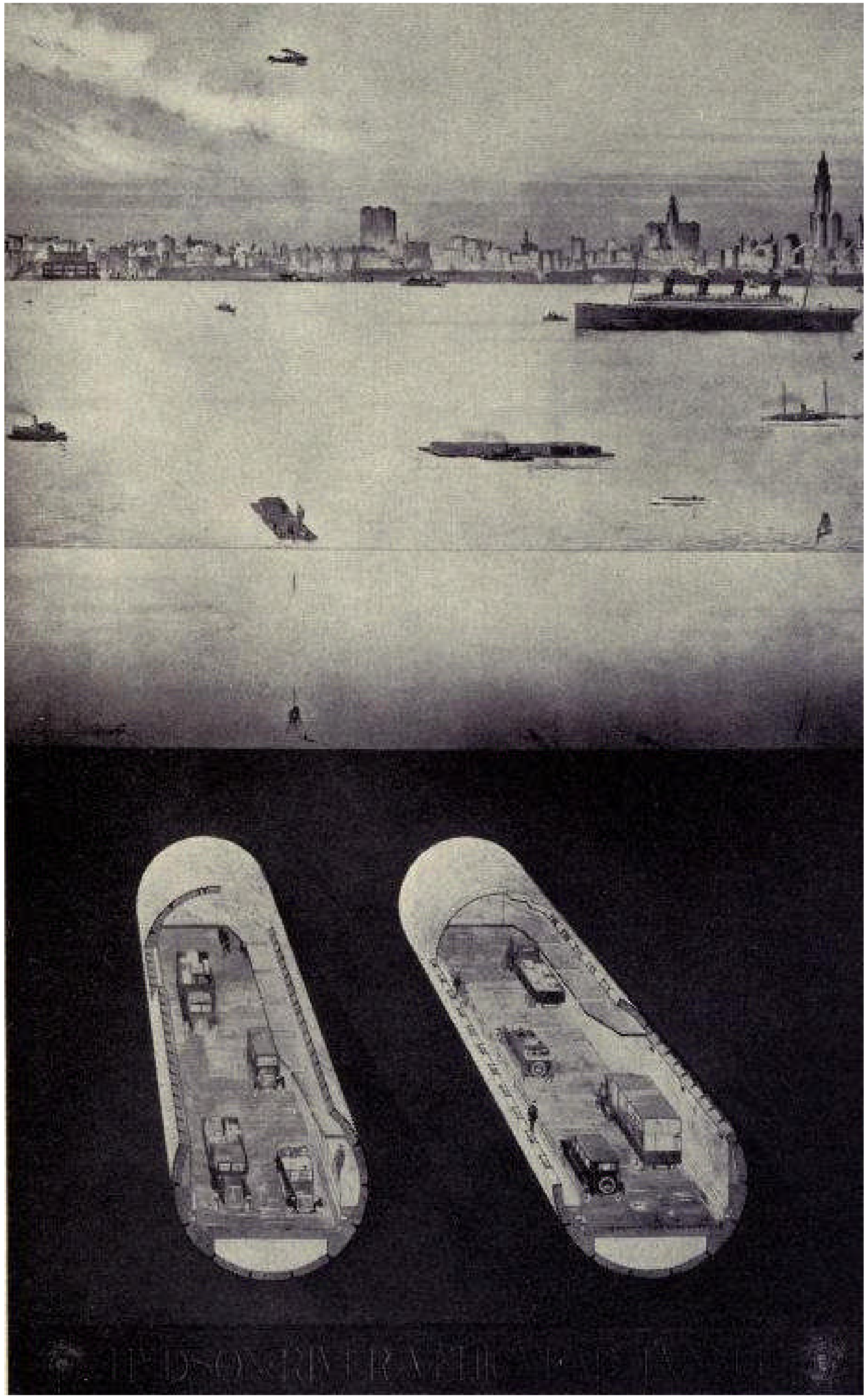
RE: excerpt from *The Eighth Wonder*

Left T&B: when the *George Washington Bridge* opened on October 25th 1931, it included only an upper deck with six traffic lanes. The center two lanes were left as open grating to be filled-in when demand increased. With the post-war boom in automobile ownership, traffic increased dramatically and these two lanes were added in 1946. From 1959 to 1962, the lower level was added, opening to traffic on August 29th 1962.

On the Other Hand…

"…Tunnel construction, on the other hand, is more flexible than bridge construction, because the cost is a direct function of its length, with the volume of excavation increasing as a square of the diameter. Since the cost of excavation represents a large part of the total cost of a tunnel, any increase in the width of the roadway can be made only at considerable expense. The proper way to plan a tunnel is to avoid the disadvantages inherent in bridge construction, build only for the present and near future, and construct other tunnels at other locations when the facilities of the first tunnel are outgrown…"

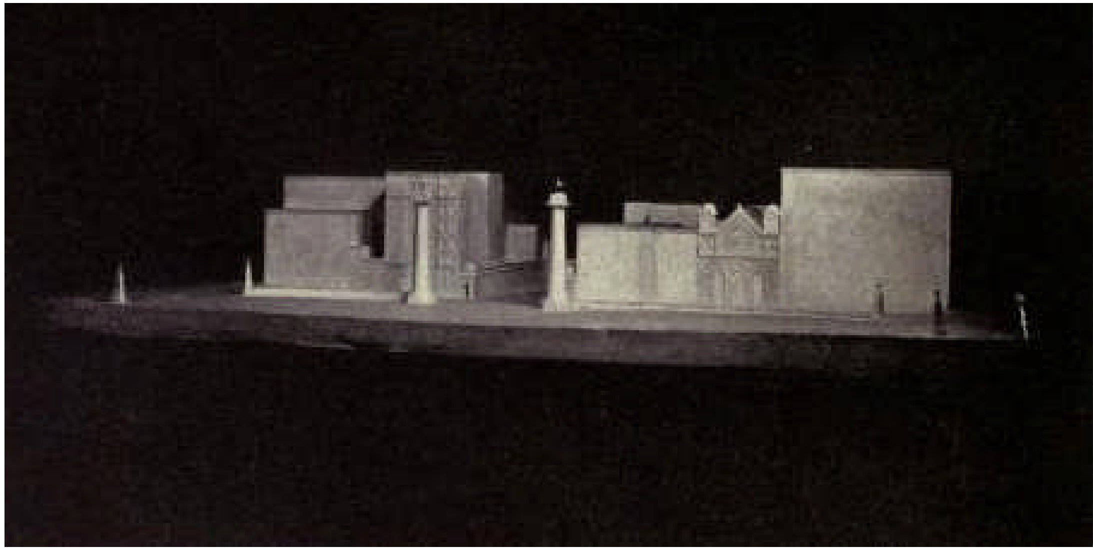
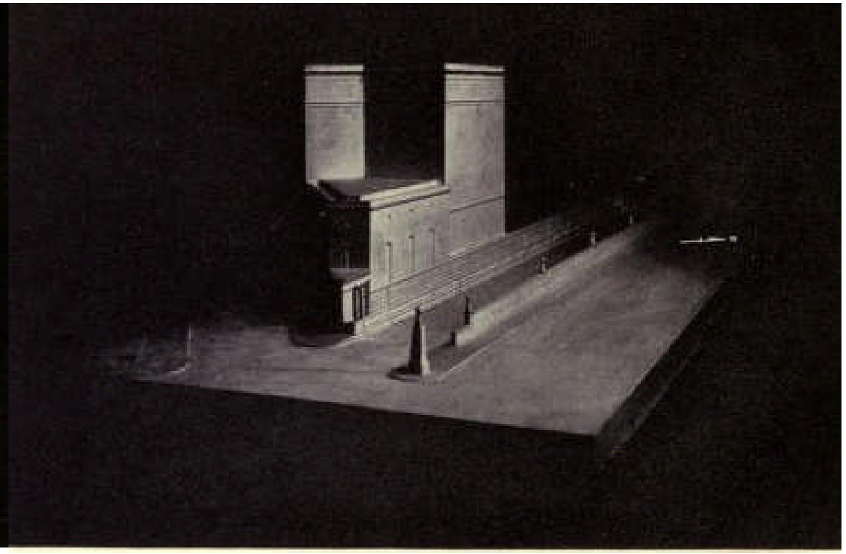
RE: excerpt from *The Eighth Wonder*



"…Since a two-line tunnel would have sufficient capacity to accommodate traffic up to 1937, and a three-line tunnel would create such traffic congestion in the vicinity of its entrances and exits as to preclude its use to capacity; also since the difference in cost between a two-line and a three-line tunnel, with interest, would pay for a new two-line tunnel when the first was outgrown, the obvious proceeding was to construct a two-line tunnel at some other location as determined by future traffic conditions. The Holland Tunnel is, therefore, a twin-tube tunnel, providing in each tube for two lines of traffic in each direction…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Sectional View of Holland Tunnel – under the Hudson River - looking toward New York City"

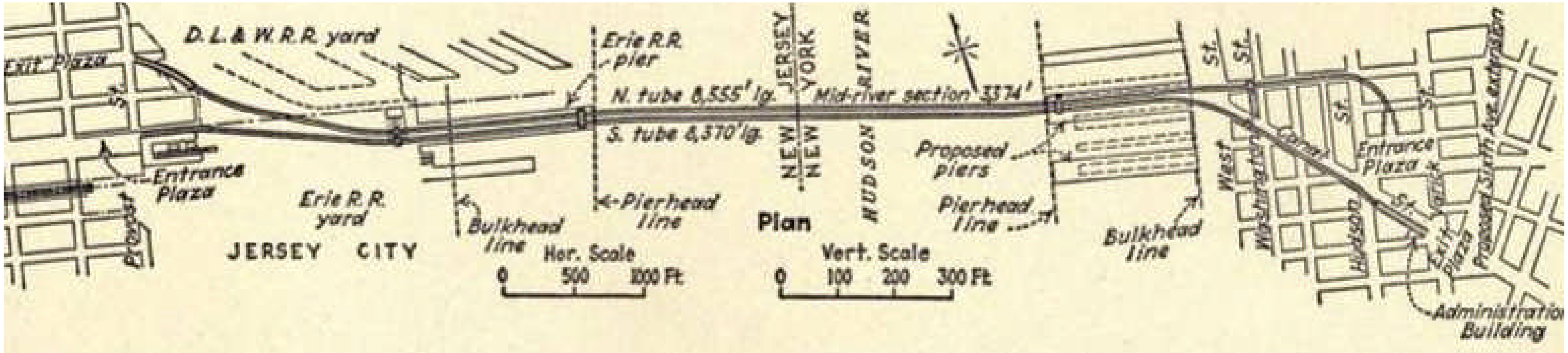
 

"…In planning the entrances and exits of the tunnel, a careful study was made of vehicular traffic, with particular reference to its movement at street intersections and through the tunnel. It was recognized that wherever traffic intersects, its continuity is broken. Instead of moving in a steady stream, it breaks into a series of waves as it is held up and released at intersections. This interruption in the stream of traffic at street intersections so limits the capacity of a street that its real capacity as determined by its width is never reached…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Model of Entrance to Tunnel, New York City. Looking north-northwest across entrance plaza which comprises north half of block between Broome and Watts Streets"

<u>Right</u>: caption: "Model of Exit from Tunnel, New York City. Looking north-west along canal Street"



"…A tunnel differs from a street in that the only interruptions by cross traffic are at the entrances and exits. Consequently these points are of vital importance, affecting as they do the ultimate capacity of the tunnel. Unless the entrances and exits insure continuity of traffic during the period of maximum demand, the capacity of the tunnel roadway can never be reached. Accordingly, the entrances and exits of the Holland Tunnel are widely separated. In New York City, one is to the north and the other to the south of Canal Street through traffic; in addition they are located so as to be served by two main north and south avenues. Tunnel traffic is thus given the best possible facility for free movement while at the same time the greatest separation is secured at a reasonable cost. In accord with this same principle the entrance and exit at the Jersey City end are located in separate streets adjacent to the railroad yards east of the north and south traffic streets connecting Jersey City with Hoboken…"

RE: excerpt from *The Eighth Wonder*

Above: caption: "Plan of the Holland Tunnel"

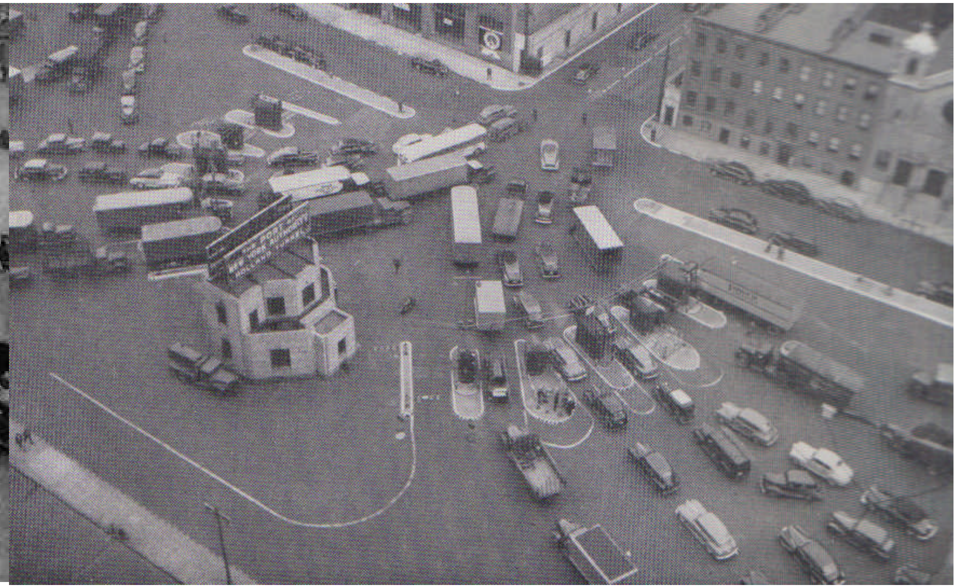
<u>Top Left</u>: caption: “Canal Street near future Holland Tunnel, 1920”
<u>Top Right</u>: “NYC Holland Tunnel Entrance, 1933”
<u>Left</u>: caption: “New York Tunnel Entrance”

<u>Top Left</u>: caption: “New Jersey entrance of the Lincoln Tunnel, 1927”

<u>Top Right</u>: caption: “New Jersey Tunnel Entrance”

<u>Left</u>: caption: “New Jersey Tunnel Exit”

<u>Above</u>: caption: "Holland Tunnel entrance from New Jersey at night"
<u>Left</u>: caption: "New Jersey approach to the Holland Tunnel"



"…This separation of the tunnel entrance and exit traffic is considered to be a factor of the greatest importance in relieving congestion in the vicinity of the tunnel. This was particularly necessary in New York City, with its large and rapidly increasing volume of traffic. It was also called for in Jersey City, where there were no wide thoroughfares in the vicinity of the tunnel. In addition, property was taken to provide broad plazas at entrances and exits. The entrance plazas serve to accommodate the waves of traffic as they approach the tunnel and converge in the portal roadway into continuous lines of vehicles through the tunnel. Similarly wide exit plazas insure the free and uninterrupted movement of traffic away from the tunnel. Through the separation of entrance from exit, and the use of adequate plazas, the tunnel traffic can be distributed over a large number of streets…"

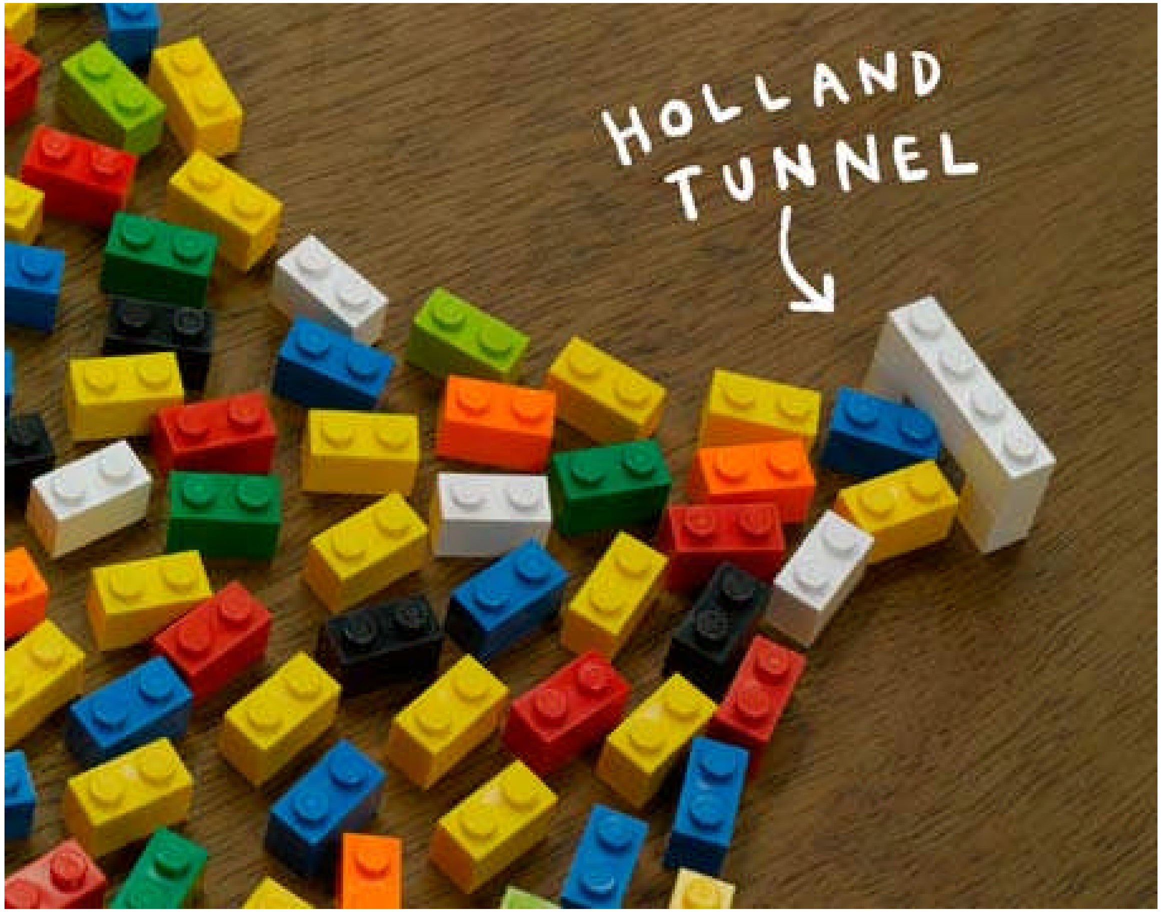
RE: excerpt from *The Eighth Wonder*

Left: caption: "Manhattan entrance to the Holland Tunnel, opening day November 13, 1927"

Right: caption: "Holland Tunnel entrance (Manhattan) ca. 1931"

<u>Top Left</u>: caption:: “Aerial photograph of tunnel site in New York, looking West. 5/4/23”
<u>Top Right</u>: caption: “Far view of New Jersey approach. 7/28/23”
<u>Left</u>: caption: “Nos. 248-250 Erie Street being removed from exit plaza, Jersey City, NJ, 5/24/26”[452]

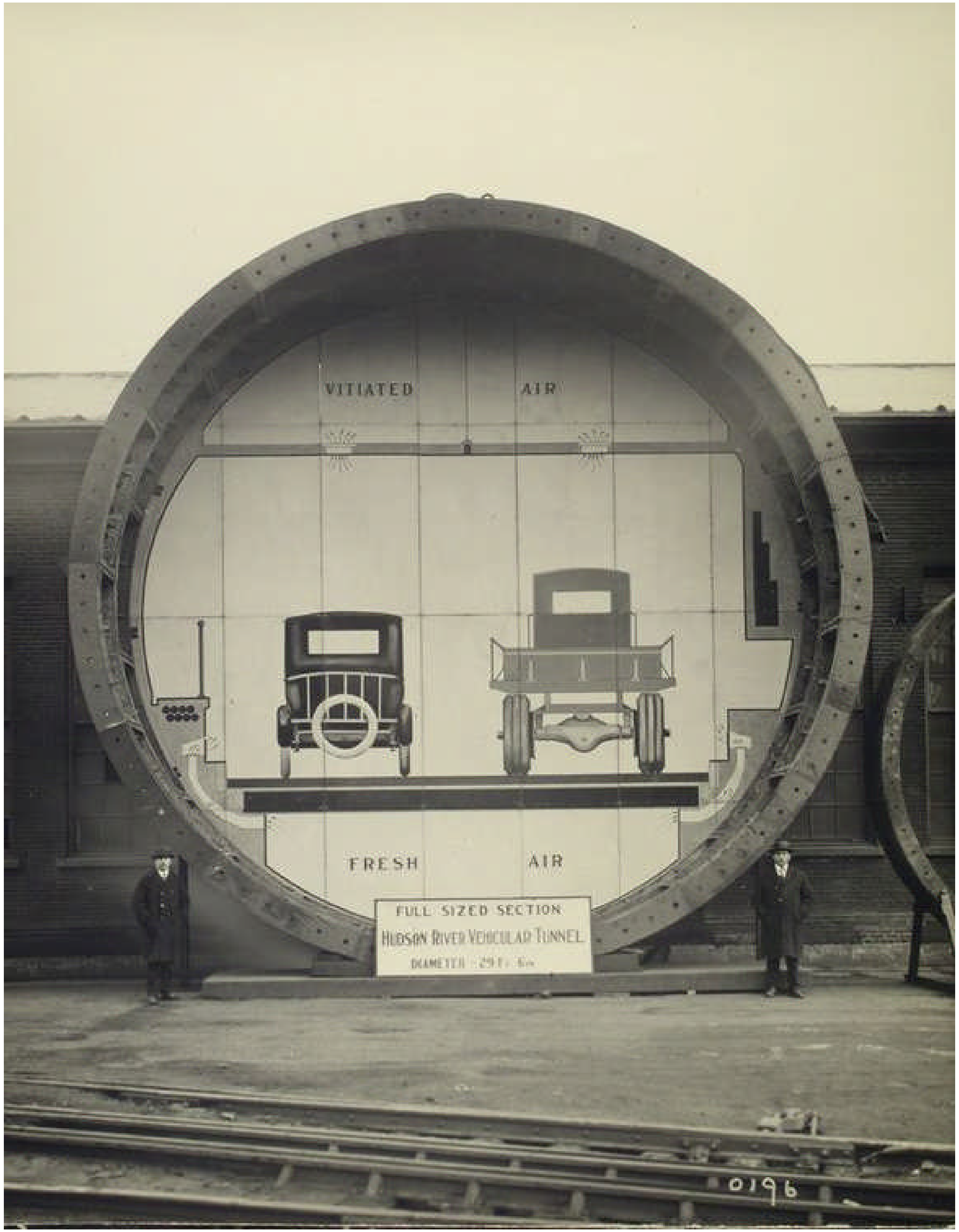
<u>Top</u>: caption: "Holland Tunnel entrances in New York City, 1929"
<u>Bottom</u>: caption: "Aerial view of Holland Tunnel traffic during the weekday, 1935"


HOLLAND
TUNNEL

The Right Fit

"…In considering the requirements for the width of the roadways and the clear headroom needed, measurements were taken of vehicles crossing the Hudson on ferries between New York and New Jersey. It was found that their height varied from 6 feet 6 inches for passenger cars to a maximum of 13 feet for large loaded trucks, but that the number exceeding 12 feet in height was only 1%. The width of motor vehicles varied from 6 feet for passenger cars and light trucks to a maximum of 10 feet 6 inches for army transport trucks. In the case of three-horse teams, the outside dimension of the three horses abreast was 9 feet, but the number of vehicles exceeding 8 feet in width was only 3½%…"

RE: excerpt from *The Eighth Wonder*



"…In determining the amount of clear headroom required, it was necessary to consider the matter of providing sufficient area in the tunnel roadway. Any increase in clear headroom, without increasing the size of the tunnel, could be made only at the expense of the available ventilating duct area. Any reduction in this area would increase the power required for ventilation and add to the cost of operating the tunnel. Given a maximum height of 12 feet 2 inches and a maximum width of 8 feet, a clear headroom of 13 feet 6 inches seemed adequate to allow even for jacking up vehicles in case of breakdown, and this was decided upon…"

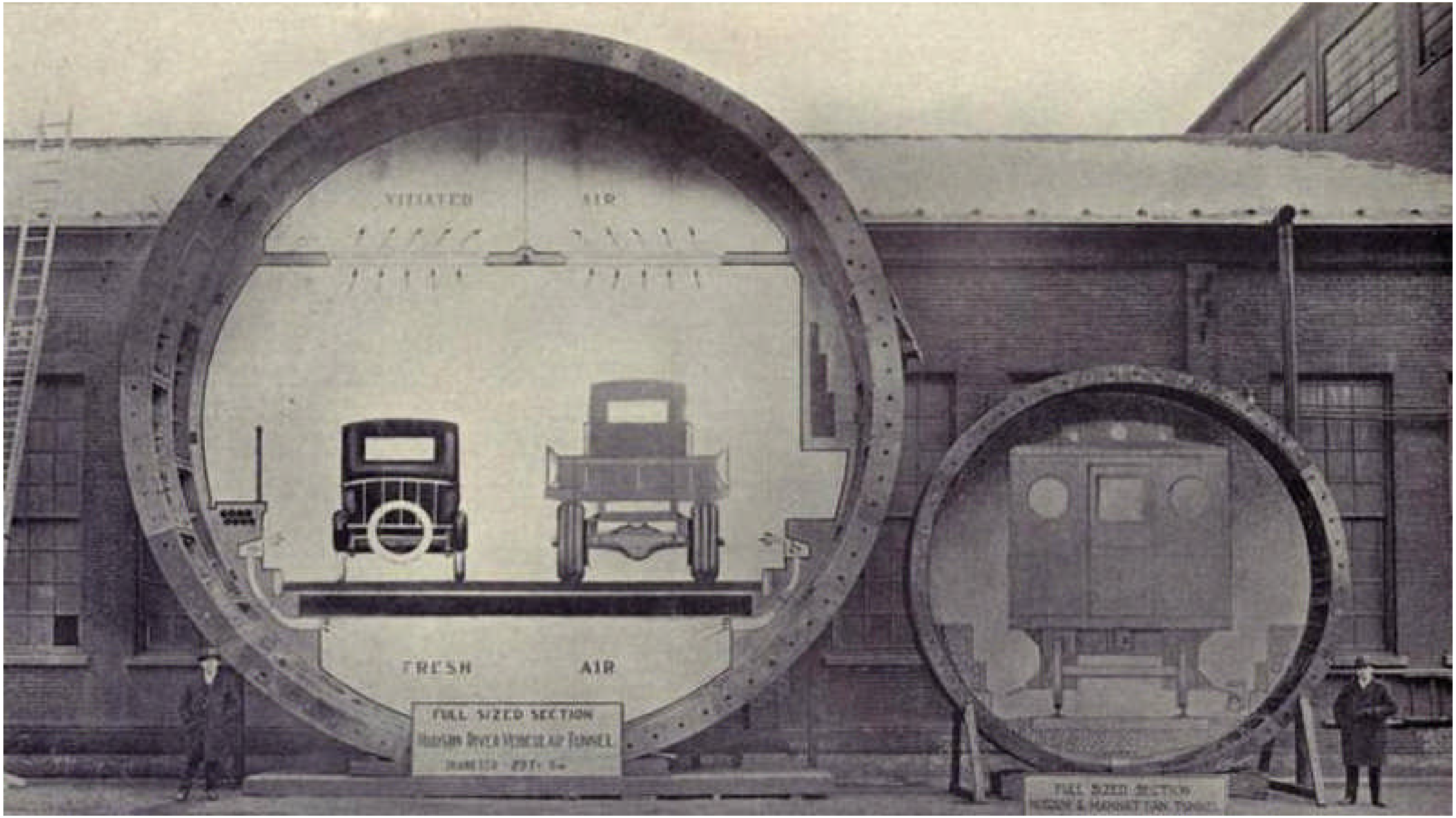
RE: excerpt from *The Eighth Wonder*

Left: caption: "Full sized section Hudson River vehicular tunnel 29 foot 6 inches diameter"


KEEP 75 FT. APART.
SPEED LIMITS
MAX. 35 – MIN. 20

“…Normal operating conditions in a tunnel accommodating two lines of vehicles in the same direction on one roadway obtain when there is a slow line of heavy trucks and passenger cars 6 feet wide. It is, however, necessary to provide for such a contingency as when a vehicle of maximum width has to pass another of the same width that has stalled. The roadway has to be sufficiently wide to permit the passage abreast of two vehicles of maximum width…”

RE: excerpt from *The Eighth Wonder*



<u>Above</u>: caption: “Holland Tunnel and Hudson and Manhattan RR Tunnel – Full-sized section of Holland Tunnel (diameter 29’-6”) and full-sized section of Hudson and Manhattan R.R. Tunnel (diameter 16’7”). Rings weigh 16,630 pounds and 5.670 pounds per lin. foot, respectively” [460]

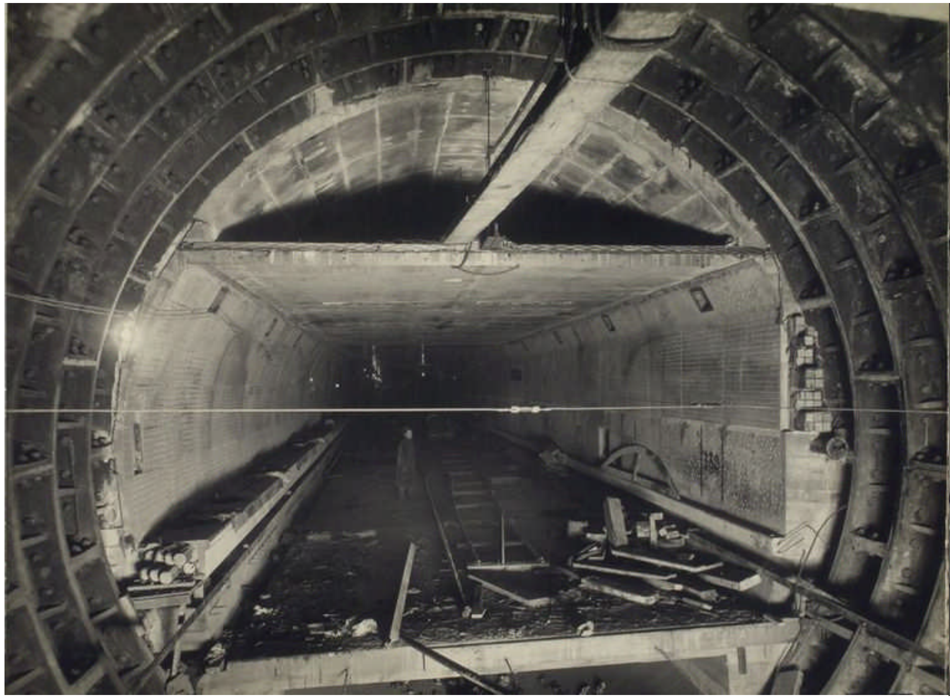
"…It was believed that in the slow line, operating at a speed varying from 3 to 6 miles per hour, a clearance of not less than 6 feet between the outside of the tire and the curb should be provided. In the fast line, due to the greater speed, this clearance should not be less than 1 foot. It was also considered for safe and convenient operation a clearance between moving vehicles of 2 feet 9 inches should be allowed. These considerations led to the adoption of a width of roadway of 20 feet, with, in addition, a sidewalk is set back from the curb line a distance of 6 inches and is located at an elevation of 26 inches above the roadway…"

RE: excerpt from *The Eighth Wonder*


STAY

"…This roadway is paved with granite blocks laid in the usual sand cement cushion layer, about one inch thick, with the joints filled with hot asphalt mixed with heated sand. By means of squeegees, a thin coating, sprinkled with sand, is left upon the surface, resulting in a smooth, resilient, and long wearing surface that will help to deaden the sounds due to traffic, and be more quickly repaired than concrete…"

RE: excerpt from *The Eighth Wonder*

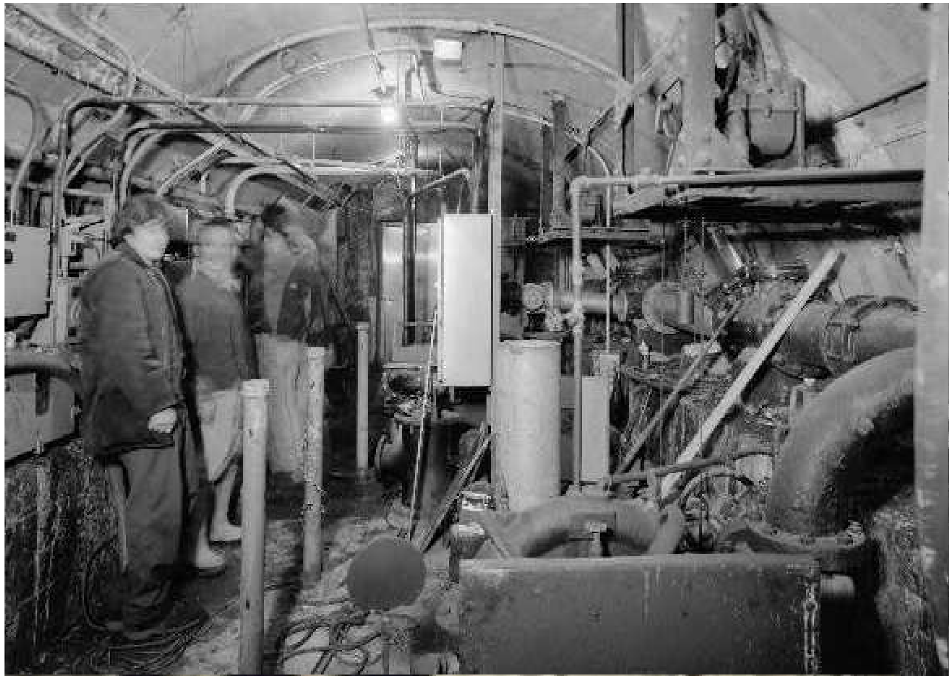


"…Each side of the roadway is lined with a granite curb, the roadway having a transverse slope from one side to the other, with a depressed concrete gutter behind the curbstone on the low side inlet openings at frequent intervals. The drain connects with a sump at the low point of the tunnel, from which a discharge pipe is carried under the roadway of each tunnel to the New York river shaft. Intercepting sumps with pumping equipment are provided in all the river and land shafts…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Concrete construction. South Tunnel West, New Jersey, 5/6/25"

<u>Right</u>: caption: "First truck to enter the Holland Tunnel, North tunnel, East of Land Shaft, N.Y. 7/20/25"



<u>Top Left</u>: caption: “North Tunnel, Middle Pump Room, located at center (lowest point) of Tunnel”

<u>Top Right</u>: caption: “North Tunnel, Pump Room located under New York side Hudson River Ventilation Building”

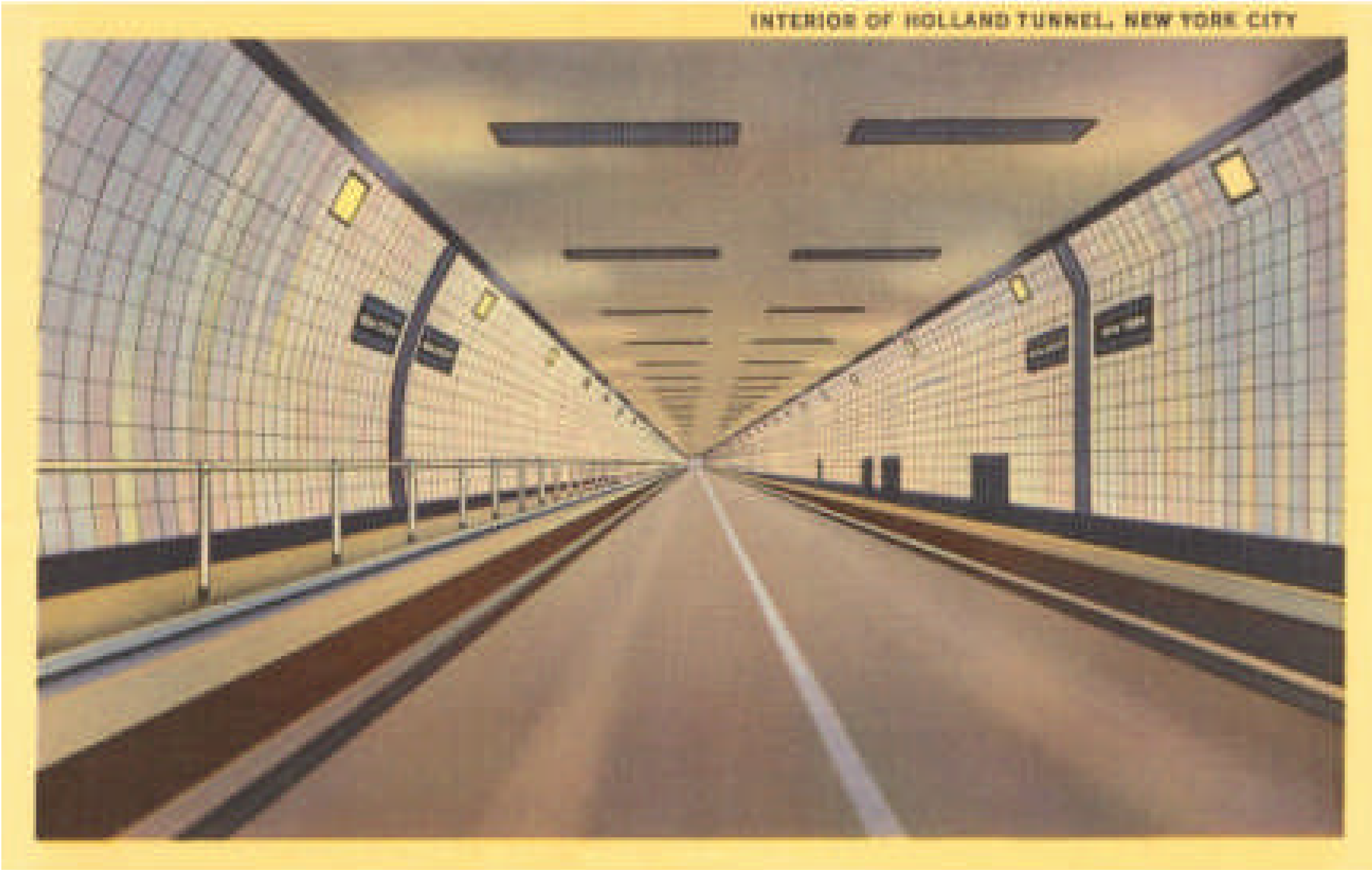
<u>Left</u>: caption: “Flooded South Tunnel. 4/3/24”

"…The tunnel is lighted by electric lamps located in the side walls of the tunnel immediately below the ceiling slabs. A continuous water main is provided throughout the entire length of each tube, with hose connections for fire protection and flushing at frequent intervals. The walls are lined with white tile, care being taken to eliminate all tile containing blue, green, or red tints, upon advice of a 'color psychologist,' on account of its 'depressing effects.' The color of the borders is a light orange. The ceiling is painted white…"

RE: excerpt from *The Eighth Wonder*

<u>Top</u>: caption: "North Tunnel, west of Spring Street shaft. Sample tiling, hand railing and lighting system. 2/10/25"

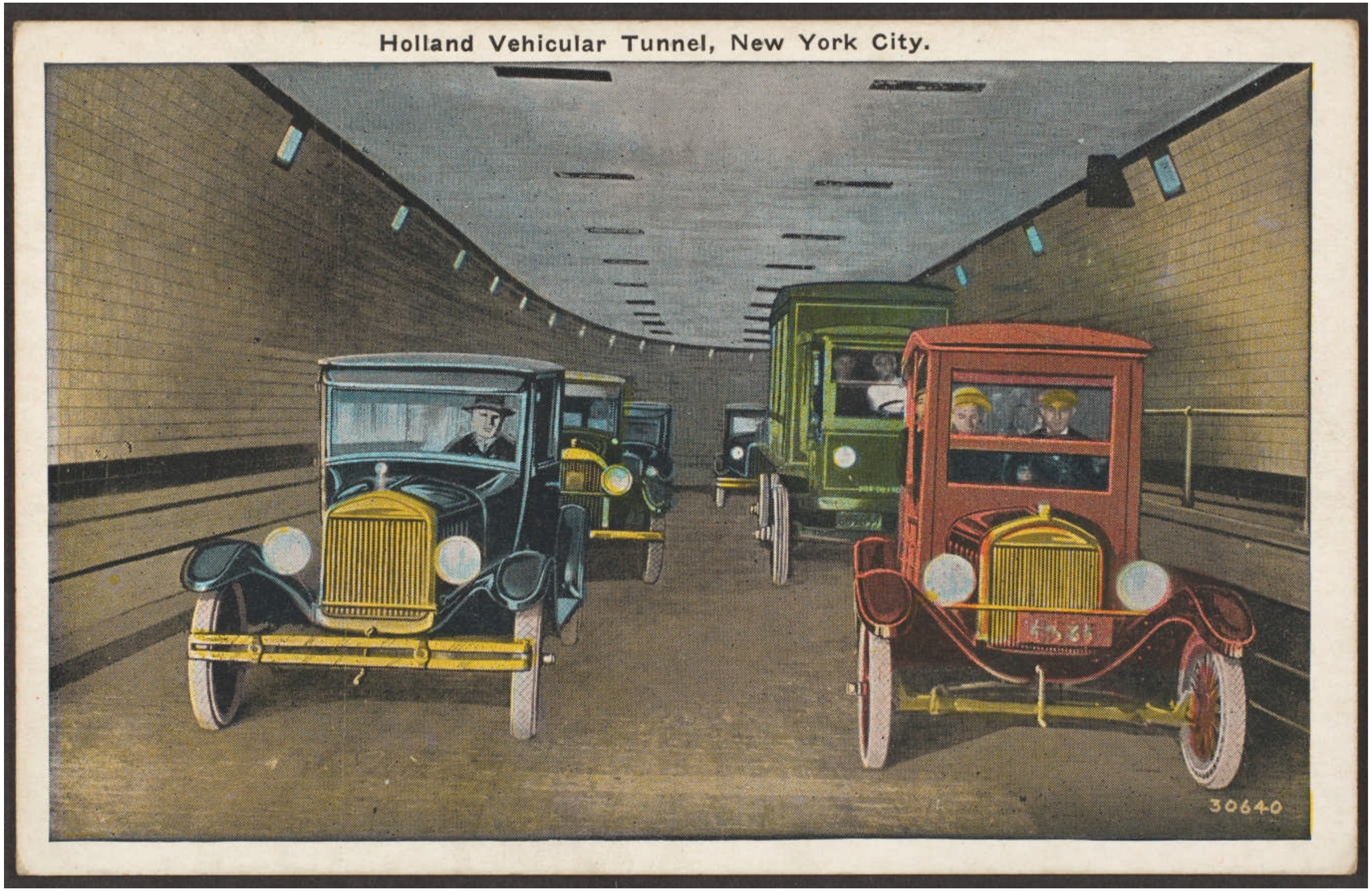
<u>Bottom</u>: caption: "Holland Tunnel State Line Markers, 7/1/26"


INTERIOR OF HOLLAND TUNNEL, NEW YORK CITY

"The tunnel, with its twin tubes, 29 feet 6 inches in diameter, is the largest sub-aqueous tunnel in America, exceeding by 6 feet 6 inches the Pennsylvania Railroad tubes. On the New Jersey side, the diameter of one of the tubes is increased to 30 feet 4 inches to meet ventilation requirements. This exceeds by 4 inches the diameter of Rotherhithe Tunnel under the river Thames, London, England. Which has been the largest sub-aqueous tunnel in the world…"

RE: excerpt from *The Eighth Wonder*

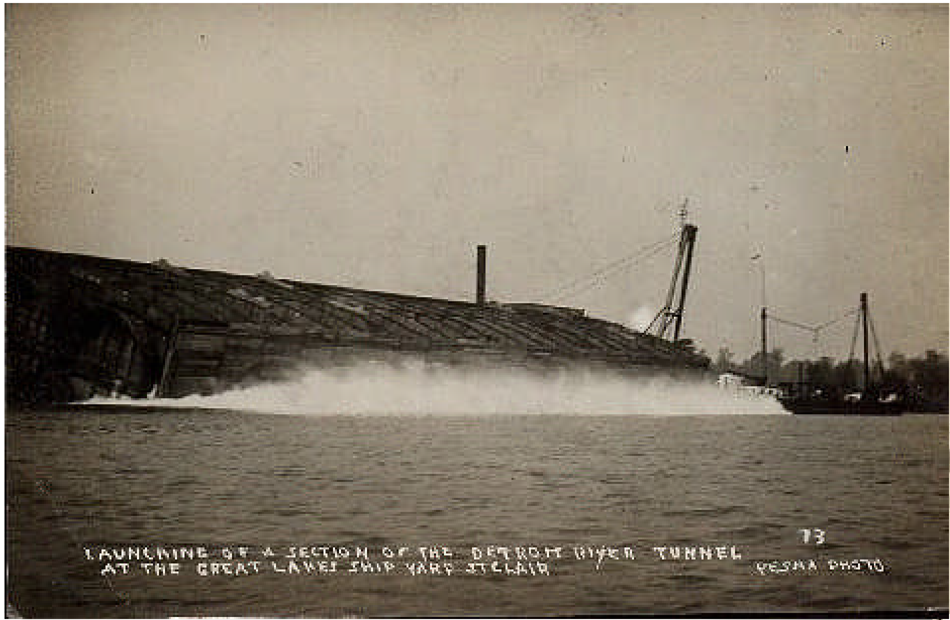
<u>Left</u>: caption: "North tunnel - State line markers, New York - New Jersey. 5-1-26"

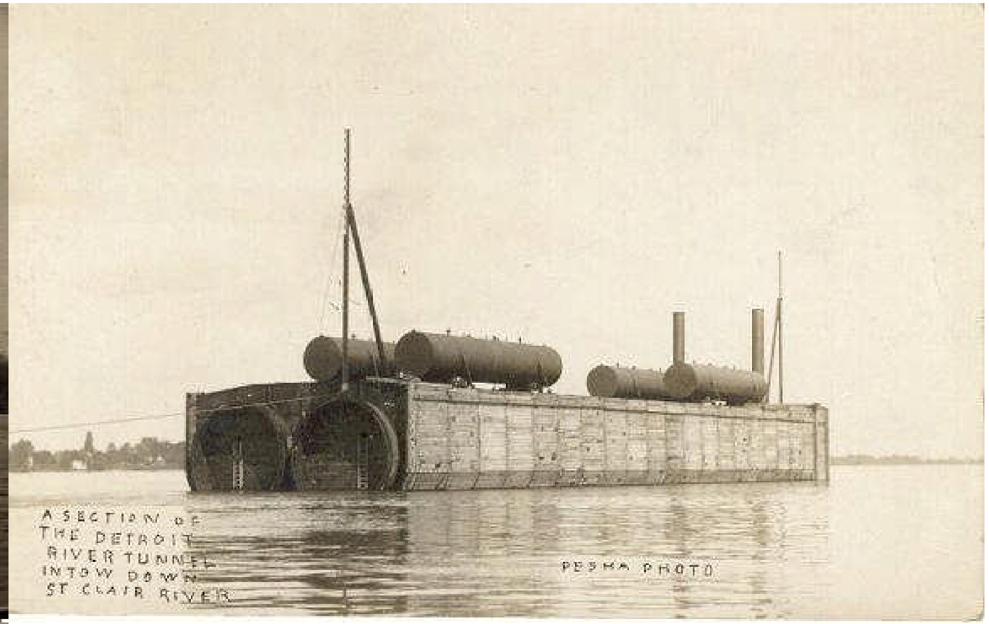

Holland Vehicular Tunnel, New York City.
30640

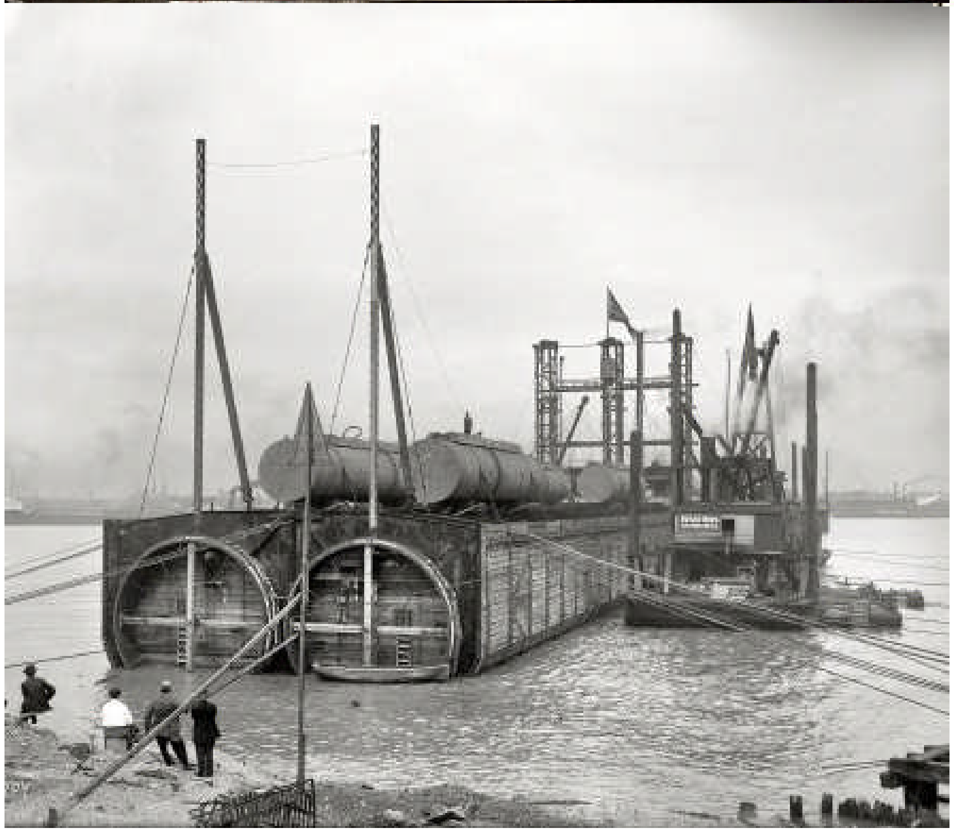
The Trench Method

“…The shield method of construction was adapted for the Holland Tunnel after careful consideration of other schemes, notably the trench method. By the trench method, the work is conducted from a plant floating in the river, and the tunnel is constructed either under a protecting roof or floated into position and sunk in sections in a dredged trench. The longest sub-aqueous tunnel built by this method is the Detroit River tunnel of the Michigan Central Railroad…”

RE: excerpt from *The Eighth Wonder*







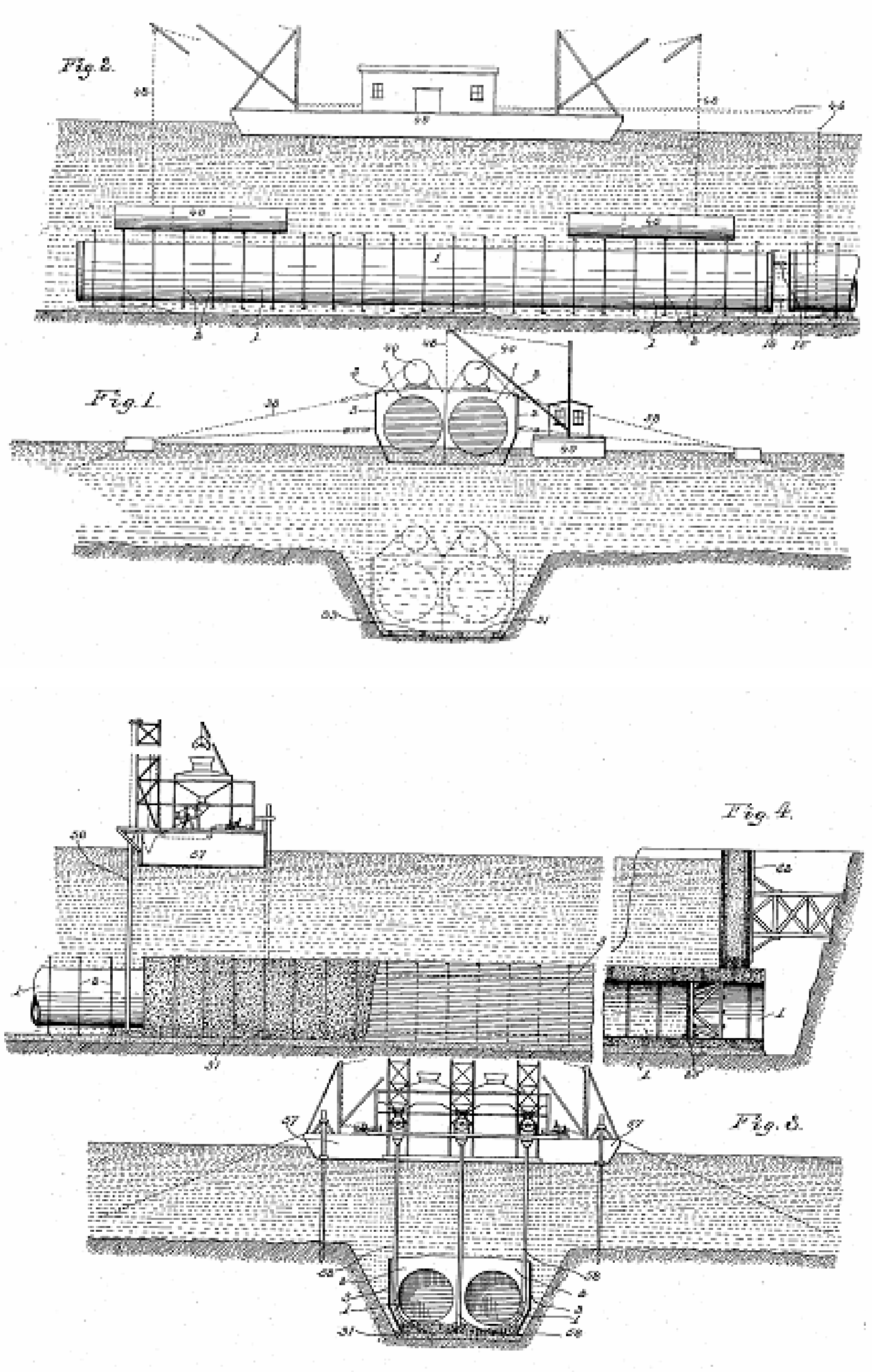
<u>Top Left</u>: caption: "Launching of a section of the Detroit River Tunnel at the Great Lakes Ship Yard St. Clair"

<u>Top Right</u>: caption: "A section of the Detroit River Tunnel in tow down St. Clair River"

<u>Left</u>: caption: "Sinking cast section of Michigan Central RR Company tunnel"

"Be it known that I, OLAF HOFF, a citizen of the United States of America, residing at New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Sub-aqueous Tunnels…This invention relates to the construction of that class of sub-aqueous tunnels, which are formed by a series of pre-constructed tunnel tube sections built on shore, launched and floated to the tunnel site and then sunk to position one after another, in a trench prepared to receive them. My invention embodies certain improvements in the structural features of the tunnel and in the method of carrying out the construction which is especially devised for the building of tunnels across navigable waters where it is important to carry on the work expeditiously and by such a method as will offer the least possible temporary surface obstruction to navigation, and will also make it possible to carry the tunnel to no greater depth than suffices to avoid interference with vessels passing thereover. My construction provides a tunnel built wholly of steel and concrete and resting upon a foundation also preferably built of steel and concrete and forming part of the completed tunnel itself. Each steel tunnel tube section may be several hundred feet in length, and each tube is provided with temporary bulkheads to enable it when launched, to be floated to the tunnel site. In sinking each section to its prepared water bed, water is gradually let into the tube and the sinking is controlled by air cylinders attached to the top of the section and adapted to support the weight of the tube, or nearly so, in sinking. After the section is sunk and joined to the previously laid section, it is embedded in concrete and one of the novel features of my invention consists in so constructing the tunnel tube section that it serves as a form for the concrete, and in providing a continuous foundation of concrete upon the water bed, all as more fully described hereinafter and shown in the accompanying drawings showing my invention as applied to a tunnel constructed of tunnel tube sections of the double or twin tube type…"

RE: excerpt from *U.S. Patent No. US 907356 A* (December 22, 1908)



"…Figure 1 represents an end elevation of a tunnel tube section in position for sinking: Fig. 2 is a longitudinal vertical section of Fig. 1, showing the tunnel tube section as having been sunk to the water bed and illustrating the manner of connecting it to a previously laid section: Fig. 3 is a cross-section of a tunnel tube section in position upon the water bed and illustrating the method of embedding it in concrete: Fig. 4 is a sectional side elevation of Fig. 3, and showing the shore end of the tunnel section…"

RE: excerpt from *U.S. Patent No. US 907356 A* (December 22, 1908)

"…It was recognized that in the excavation of a trench under the Hudson River, there would be an unavoidable interference with a great volume of river traffic. Fifteen hundred boats cross the line of the tunnel daily. Such congested river conditions would make every dredge or other machine working in the tunnel an obstruction to traffic. Collisions would be frequent, increasing the time and cost of the work, with danger both to shipping and to equipment of construction. Storms, fog, and ice would cause a discontinuance of surface work for at least two months of each year. At the New York end, a large mass of ledge work, involving blasting and removal at great depth, would be a serious obstacle to open trench excavation under water…"

RE: excerpt from *The Eighth Wonder*

"…Since there was a real hazard involved in carrying on operations from a plant anchored in mid-stream, the shield method was clearly called for. In addition, silt conditions in the Hudson River were regarded as extremely favorable to this method. In a trench tunnel, soft material greatly increases the volume of excavation, while in the case of a shield tunnel this material is most easily excavated. If the silt is not shoved aside by the shields, it is easily disposed of through the tunnel. The shield may be closed with the exception of certain openings through which the material is squeezed into the tunnel as the shield advances…"

RE: excerpt from *The Eighth Wonder*

NY Land Shafts

"…The first contract provided for the sinking of two land shafts, one at Washington and Canal Streets and the other at Washington and Spring Streets, New York City. They were sunk by the compressed-air method. The double steel walls of the caissons were filled with concrete as the caissons were sunk. This added to their weight when sinking weight was needed, and at the same time completed the structure of the walls. In addition to this concrete, weight for sinking was obtained by storing the excavated material from the working chamber on the roof of the chamber as the caisson went down. This necessitated handling the material a second time, but gave the desired weight and permitted the lowering of the caisson without greatly reducing the air pressure in the working chamber, thereby preventing loss of ground…"

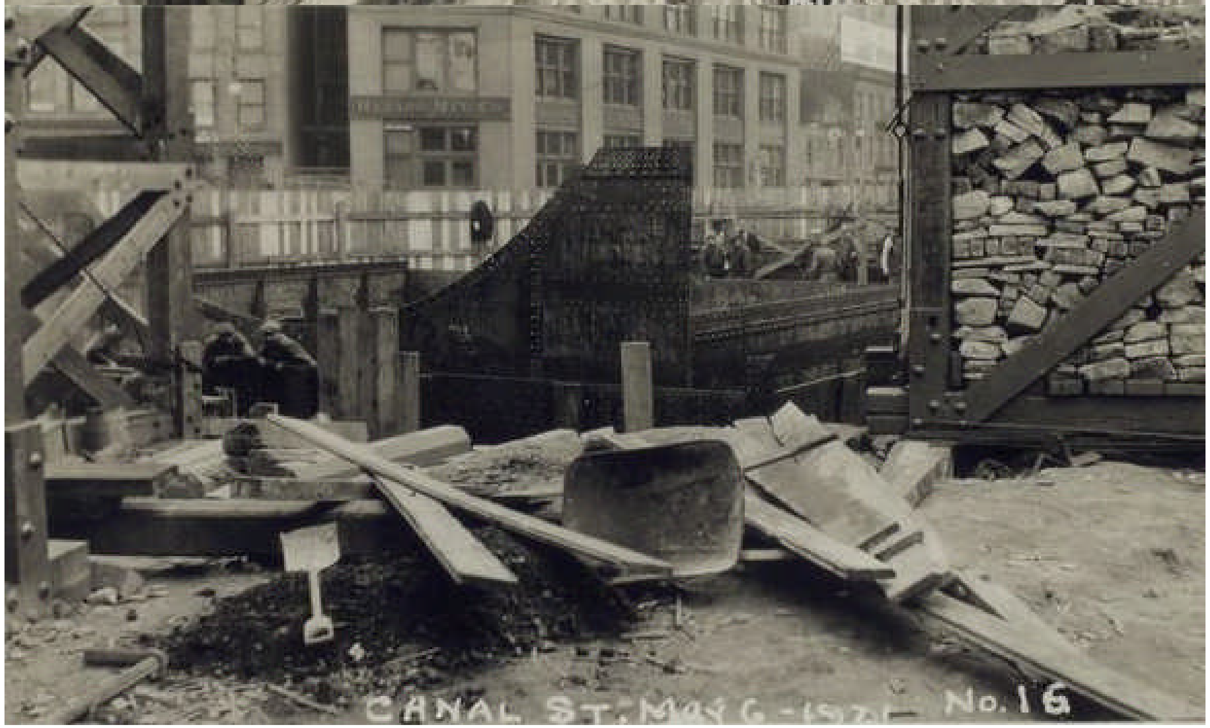
RE: excerpt from *The Eighth Wonder*

Canal St. Shaft

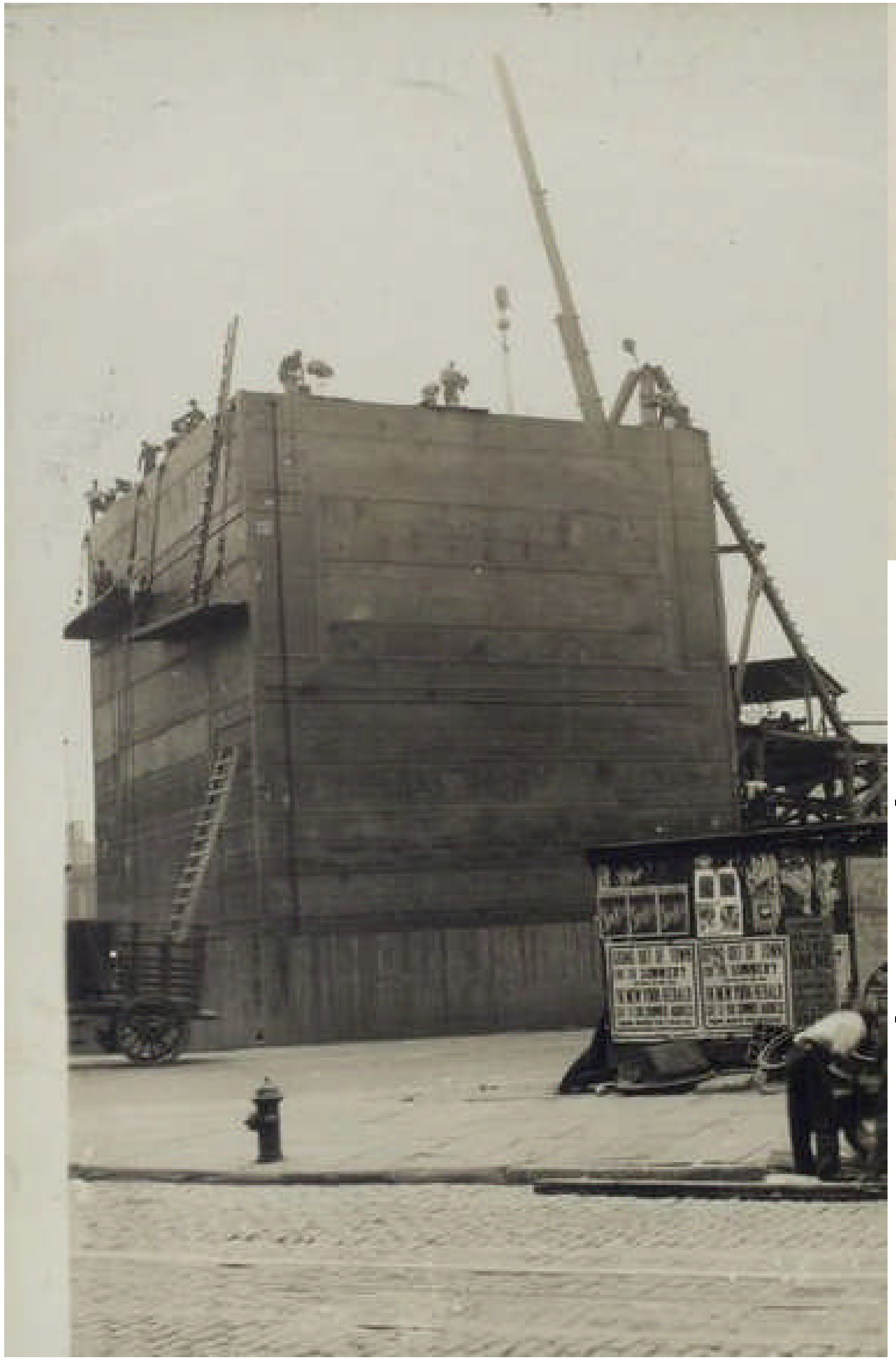
Excavation started Mar. 28, 1921.
First caisson steel arrived April 25, 1921
Steel erection started April 27, 1921
Concrete started July 11, 1921
Steel erection completed July 19, 1921
Steel Riveting completed July 20, 1921
Changed to blocking for sinking July 21, 1921
Air turned on July 28, 1921 - 9:30 A.M.
Excavation completed August 9, 1921
Waterproofing and brick placed August 10-11, 1921
Invert placed August 11-14, 1921.
Caisson watered and air removed   August 14, 1921
Caisson unwatered August 24, 1921
Air pressure 4 lbs to 29 lbs.
Average quantity of free air ran from 500 cu. ft. on July 28 to about 30ft. below M.H.W. when quantity increased to 1200 cu. ft. and then to 1800 cu. ft. at 45 ft. depth Then a decline to 700 cu. ft. at about 53 ft. depth below M.H.W. Increase due to approach and passing through coarse sand.

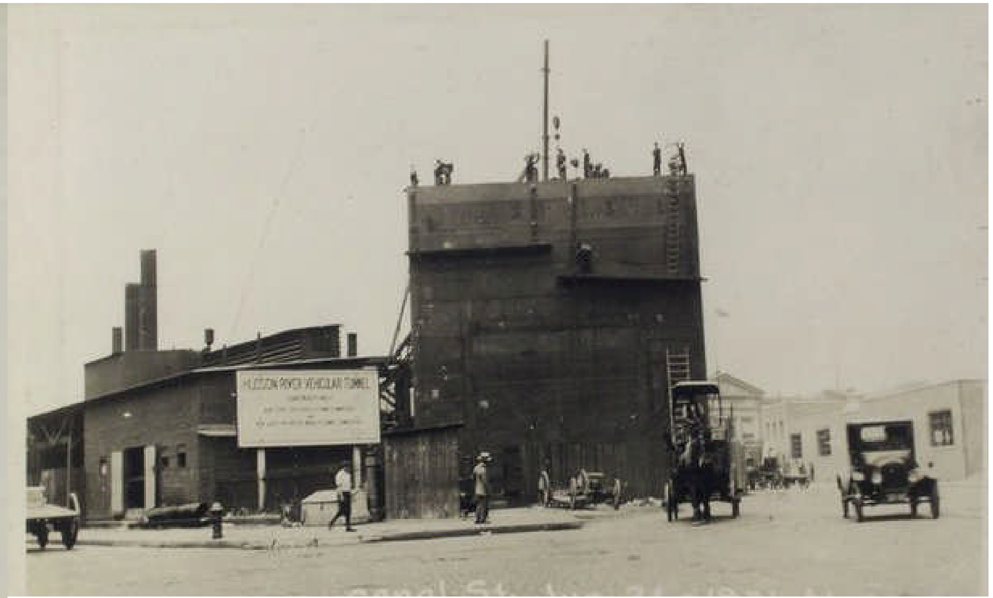
<u>Above</u>: caption: "Canal Street Shaft (Work Schedule). Material practically all red-sand fine and course and a streak of blue clay at 10 ft. below M.H.W."

Above: caption: "General view of site. Canal Street shaft, April 13, 1921"
Left: caption: "Cutting edge - Cut through old sewer. Canal Street, May 6, 1921"



<u>Top</u>: caption: "Working chamber, Cutting edge, Blocking. Canal Street, May 6, 1921"
<u>Bottom</u>: caption: "West side, inner and outer skin plates. Canal Street, May 6, 1921"

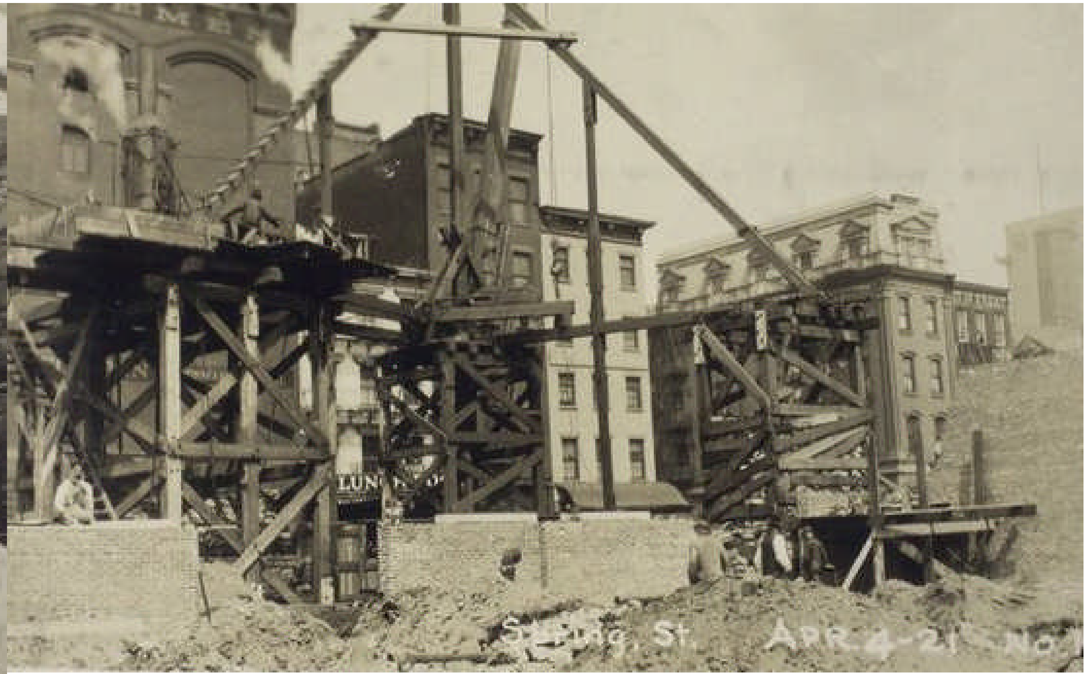




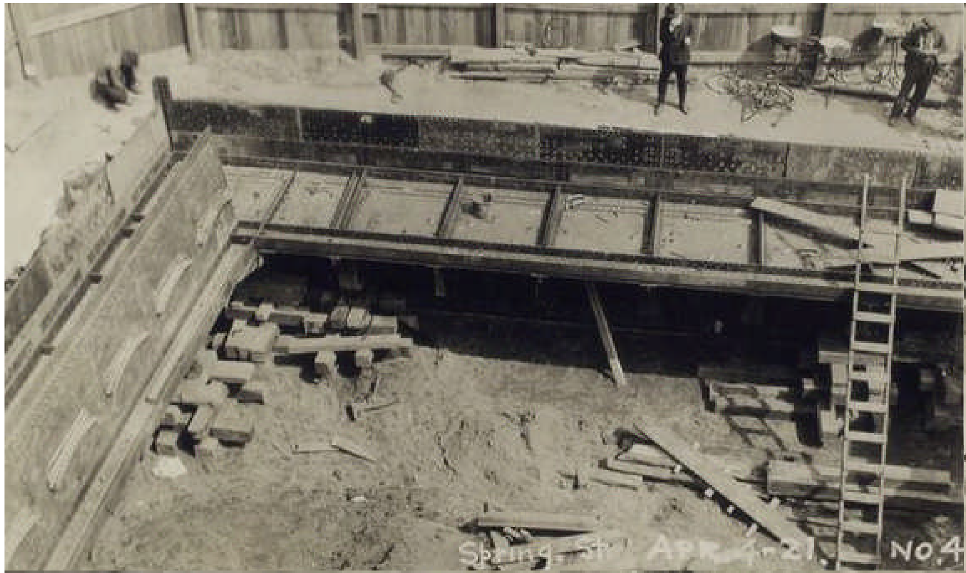
<u>Above</u>: caption: “North side, riveting. Canal Street, June 24, 1921”
<u>Left</u>: caption: “East side, riveting. Canal Street, June 24, 1921”

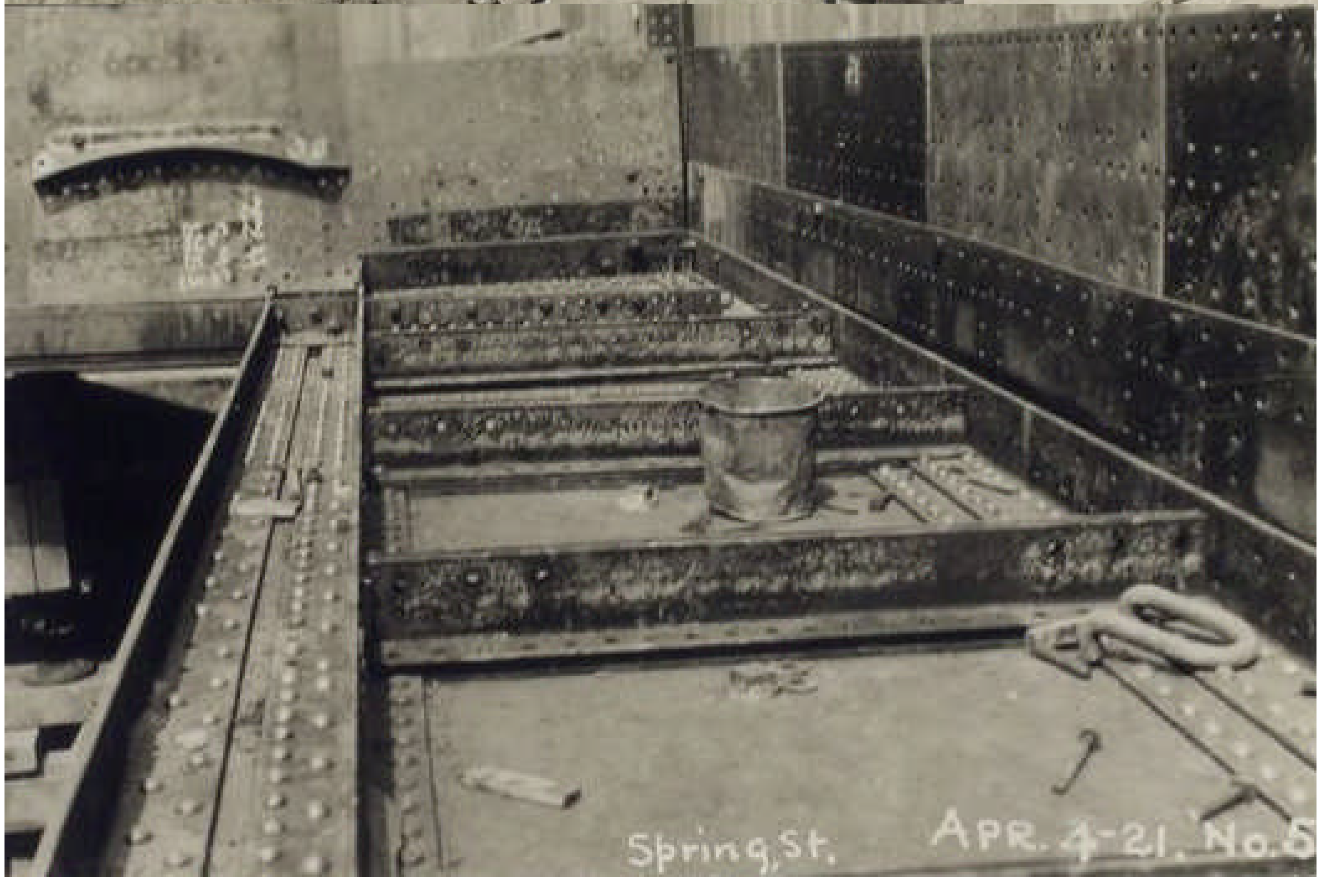
Top: caption: "Concreting, mixing plant. Canal Street, July 14, 1921"

Bottom: caption: "Painting. Canal Street Shaft, July 14, 1921"



<u>Above</u>: caption: “General view of Plant. Spring Street, April 4-21”
<u>Left</u>: caption: “Cutting edge. Spring Street, April 4-21”





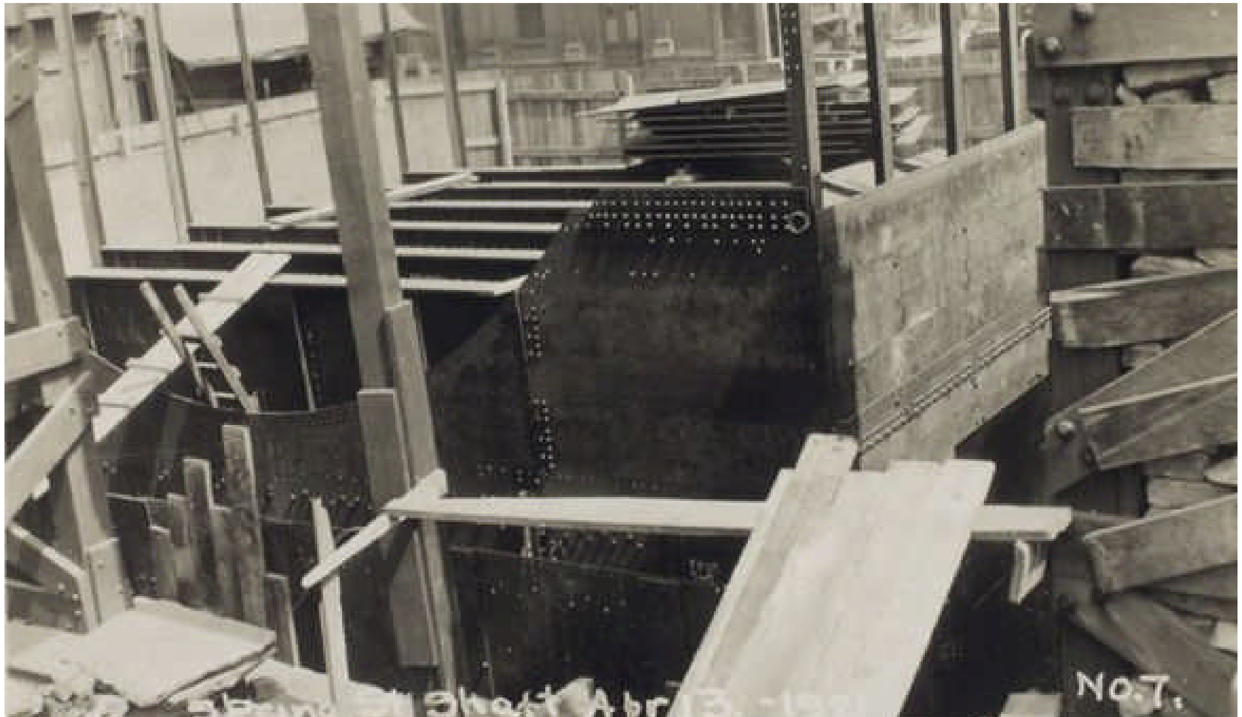
Top Left: caption: "Plate girder, bottom of inner skin plates, carrying brackets from cutting edge. Spring Street, April 4-21"

Top Right: caption: "Inner skin plates West wall - Tube opening. Spring Street, April 4-21."

Left: caption: "Detail of plate girder. Spring Street, April 4-21"

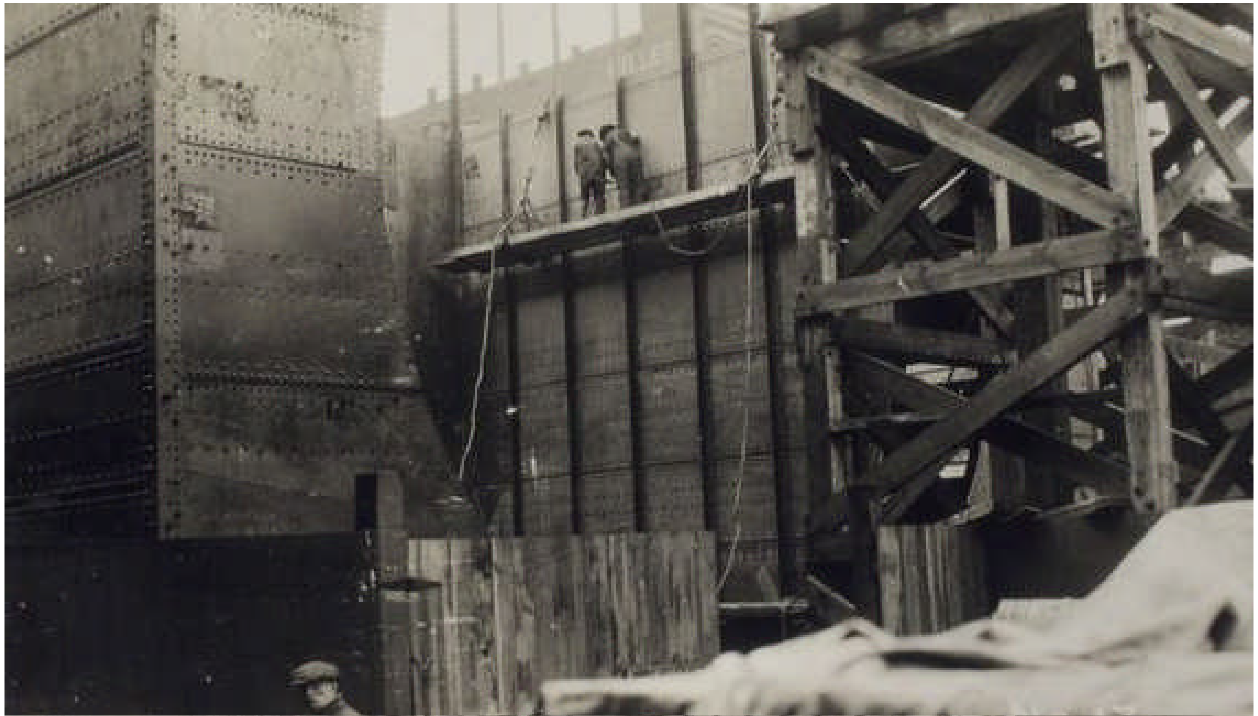
<u>Above</u>: caption: "First truss - North-West corner. Spring Street, April 13, 1921"
<u>Left</u>: caption: "Looking between skin plates. First truss at corner. Spring Street, April 13, 1921, West wall"

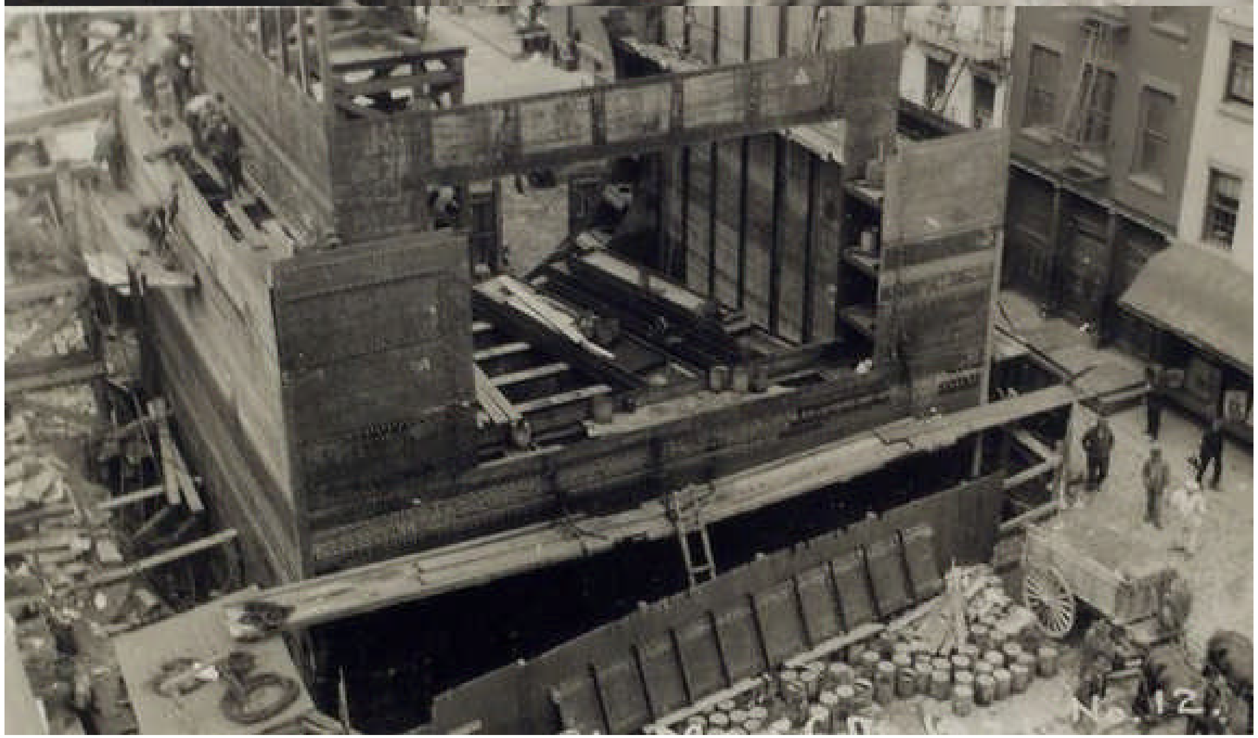
<u>Top</u>: caption: “Working chamber, roof girders bolted. Spring Street, April 13, 1921”
<u>Bottom</u>: caption: “Working Chamber, blocking up for bolting, April 13, 1921”



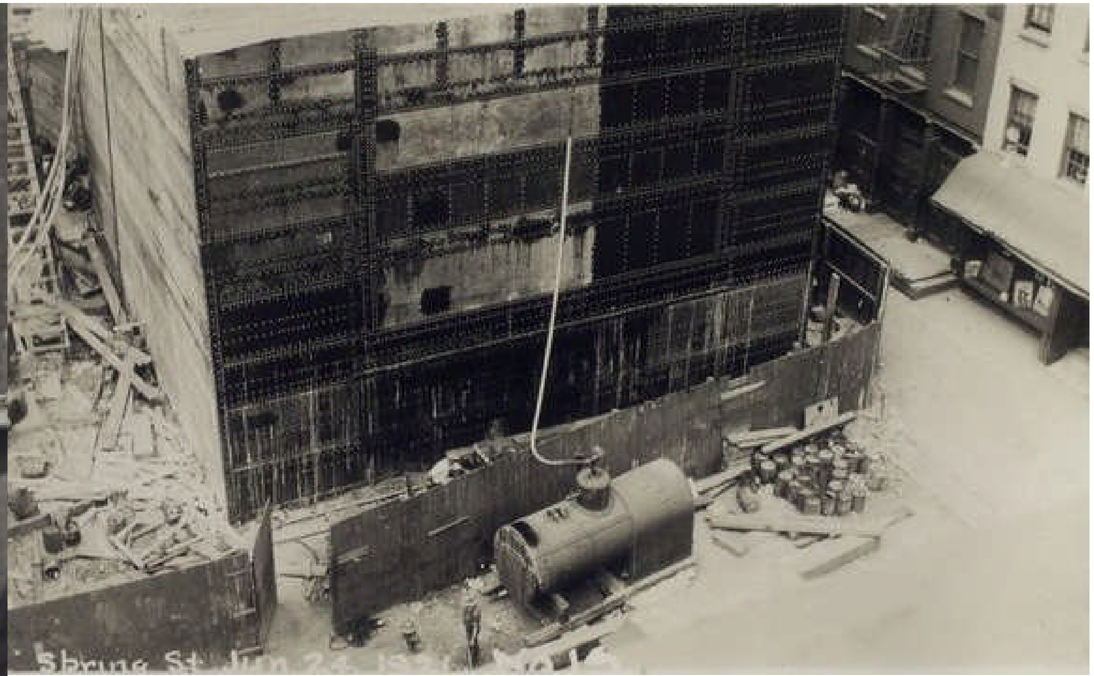
<u>Top</u>: caption: "Roof girders of working chamber in place. Spring Street shaft, April 13, 1921"

<u>Bottom</u>: caption: "Roof girders and sided angles, roof plates on blocking. Spring Street, April 13, 1921"



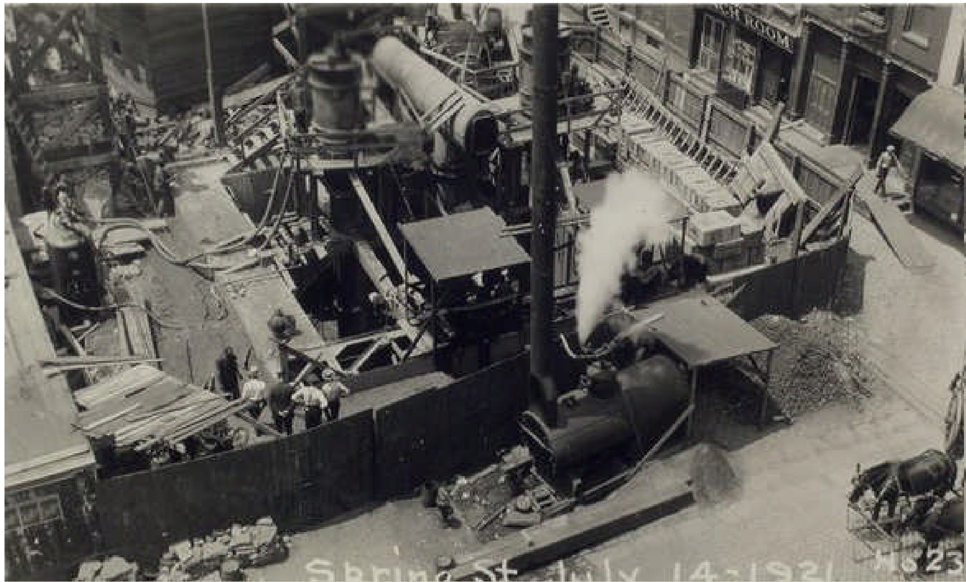


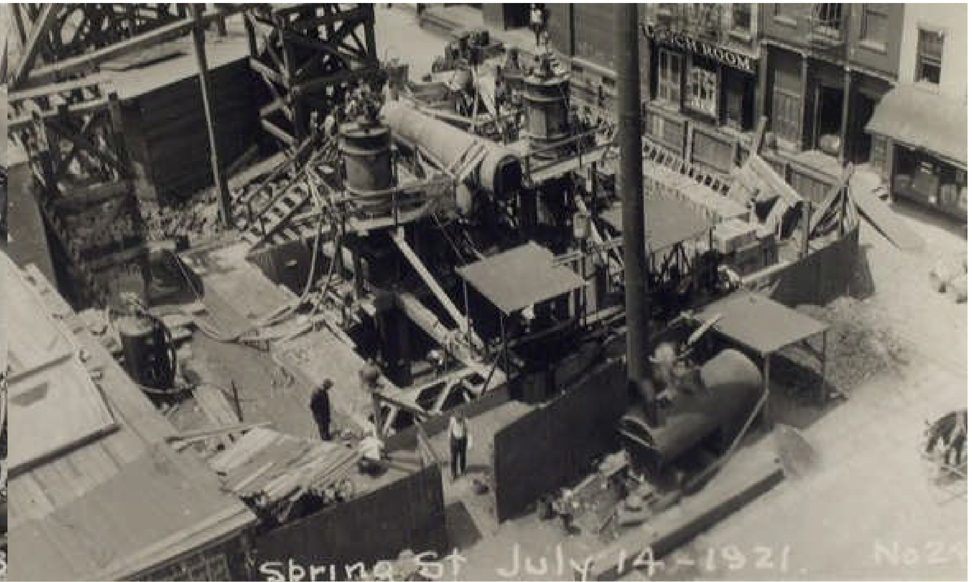
Top: caption: "General view, West side, tube opening. Showing riveters at work, lines of air hose. Spring Street, May 6, 1921"
Bottom: caption: "General view, East side. Subway opening. Spring Street, May 6, 1921"

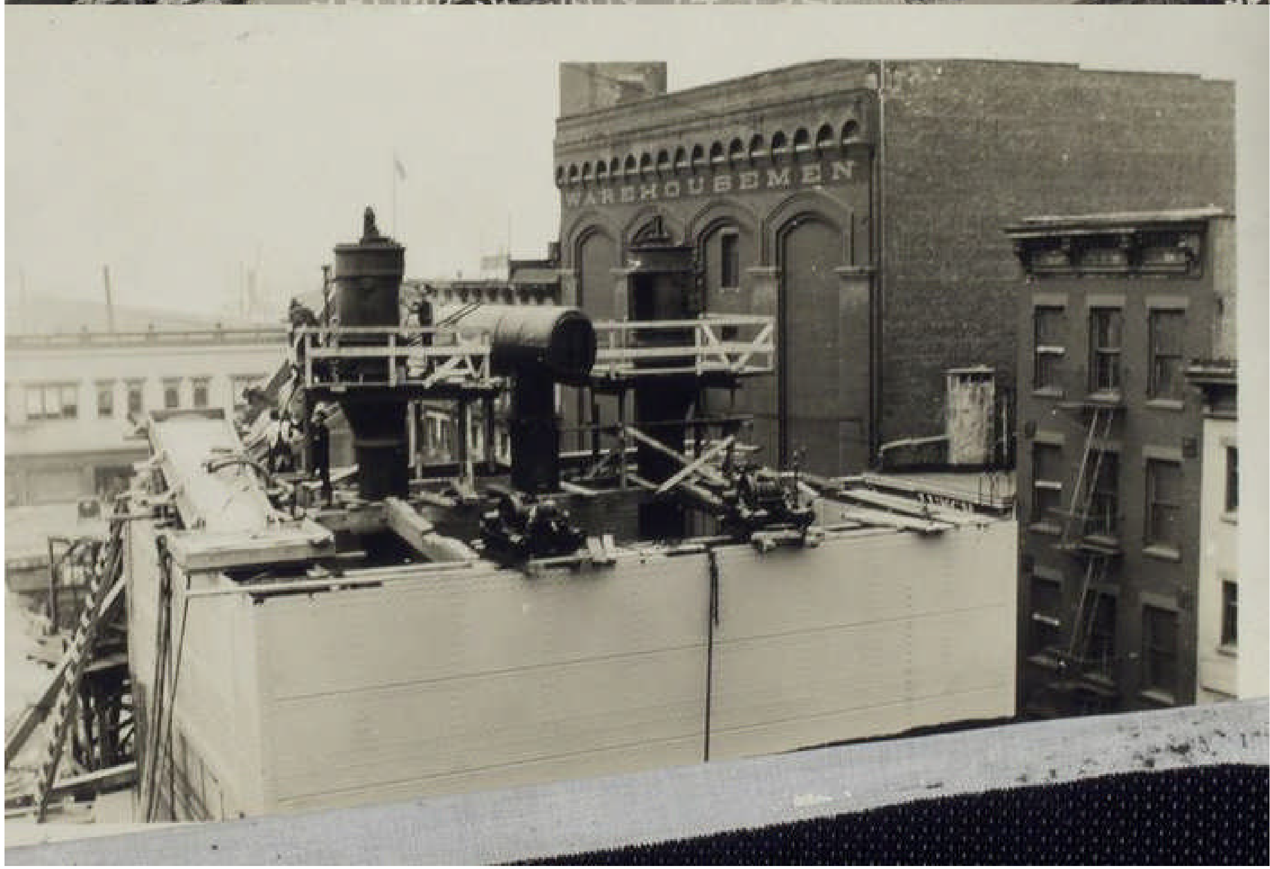


<u>Above</u>: caption: "General view. Caisson about ready to start sinking. Concrete chute at left, hoisting engines in front, air lines at side. Spring Street, June 24, 1921"

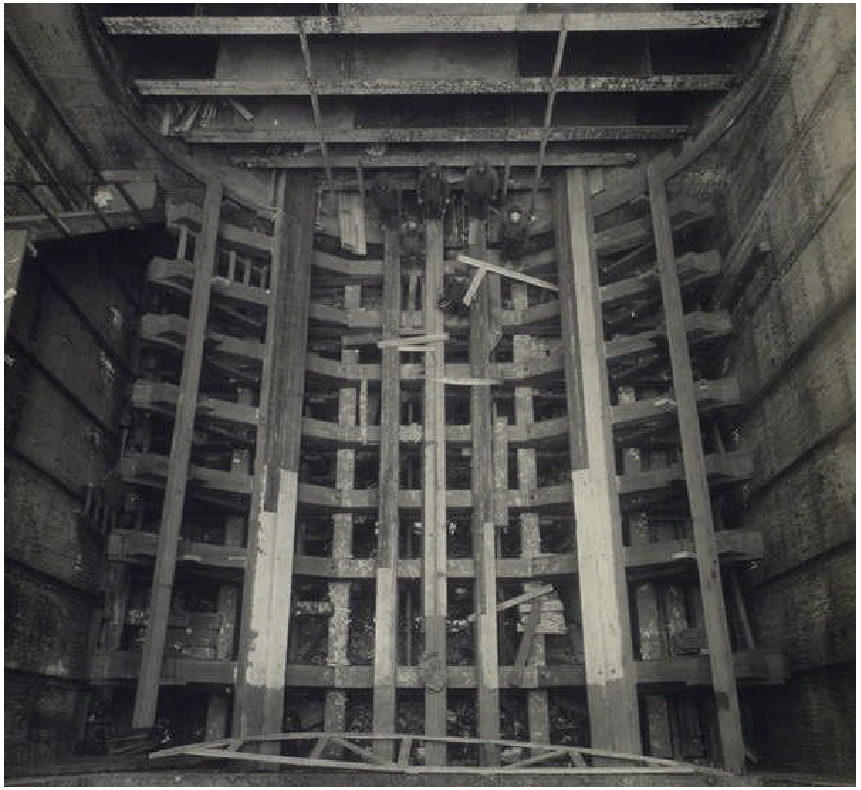
<u>Left</u>: caption: "Looking down between Muck Lock and Man Lock showing bulkhead girders. Spring Street, June 24, 1921"







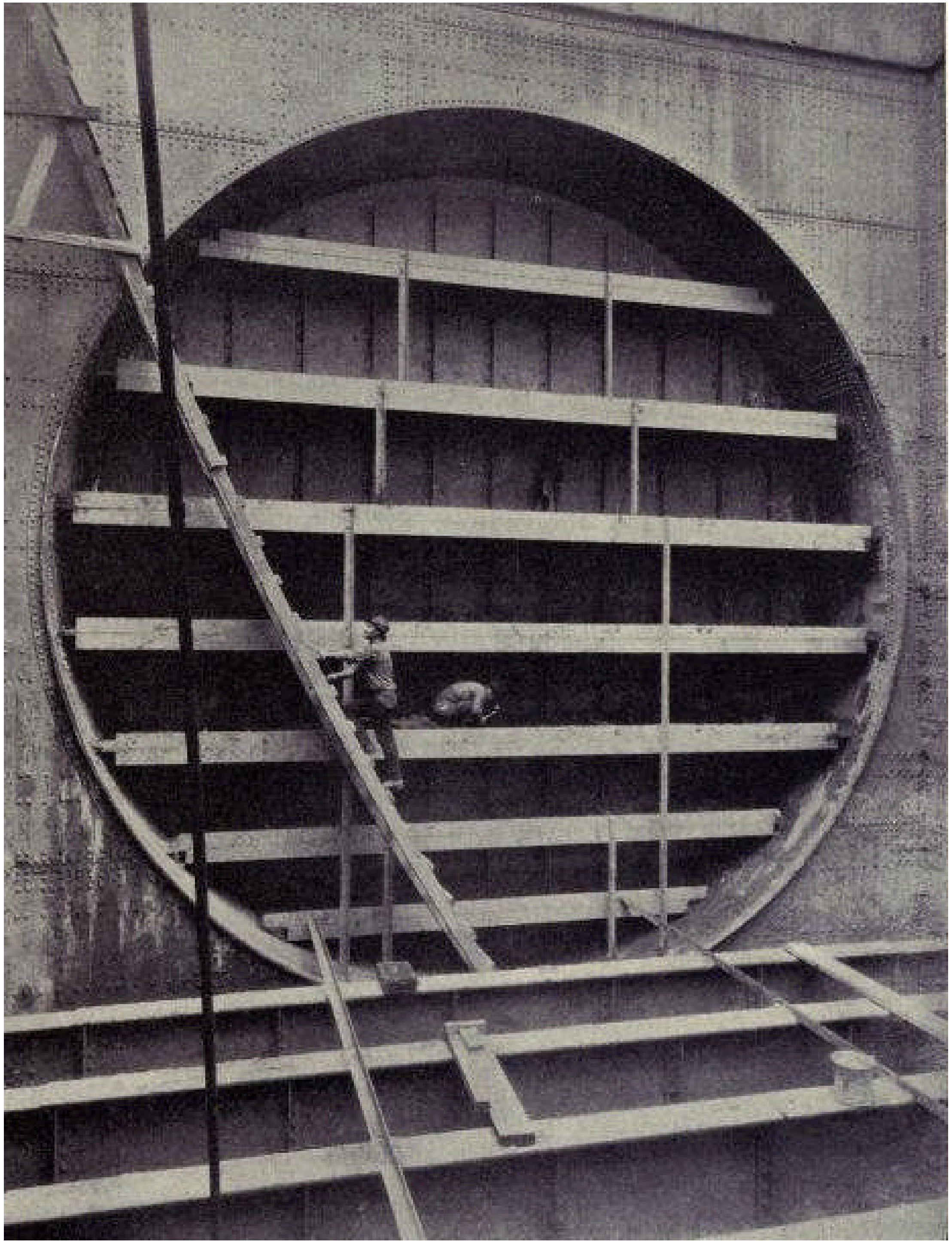
<u>Top Left</u>: caption: "Caisson top about 16 inches above surface. Cast iron weights N.E. corner. Slight fissures showing at left side. Spring Street, July 14, 1921."
<u>Top Right</u>: caption: "Shift entering lock. Spring Street, July 14, 1921"
<u>Left</u>: caption: "View of Plant. Spring Street, warehouse to the right"



"…Upon the removal of the compressed air, the bottom seals of the caissons proved to be water-tight. The shafts were now ready for the building of the shields preparatory to the beginning of shield tunneling…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Spring Street shield cradle, Spring Street shaft, New York, 11/18/23"



"…Temporary bulkheads were provided in the west side walls to connect with the approach section which was to be constructed by excavation from the surface…"

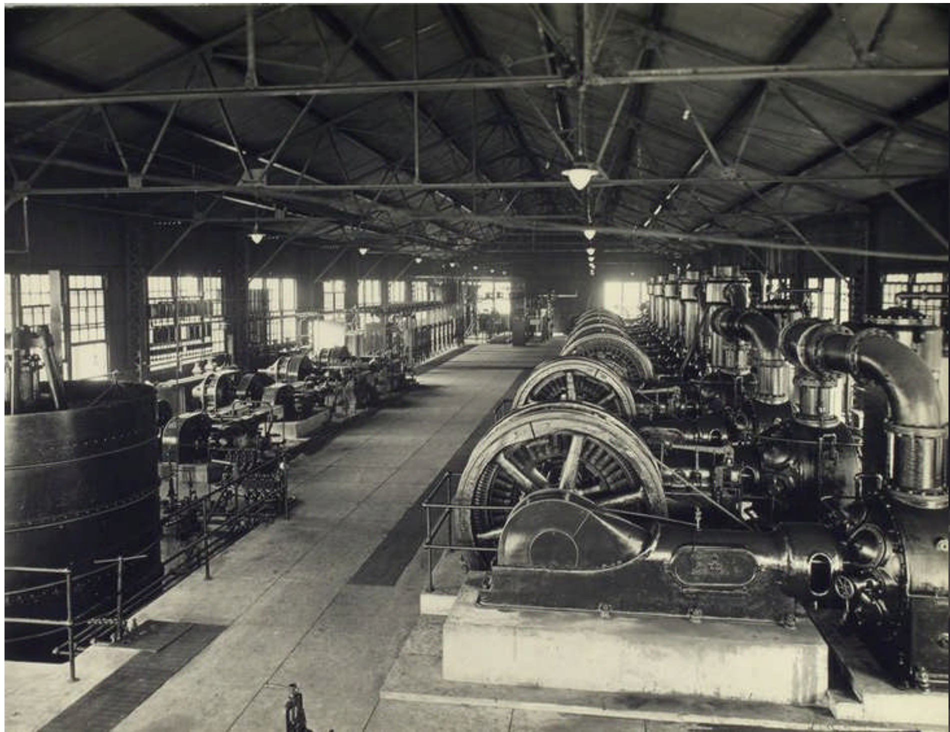
RE: excerpt from *The Eighth Wonder*

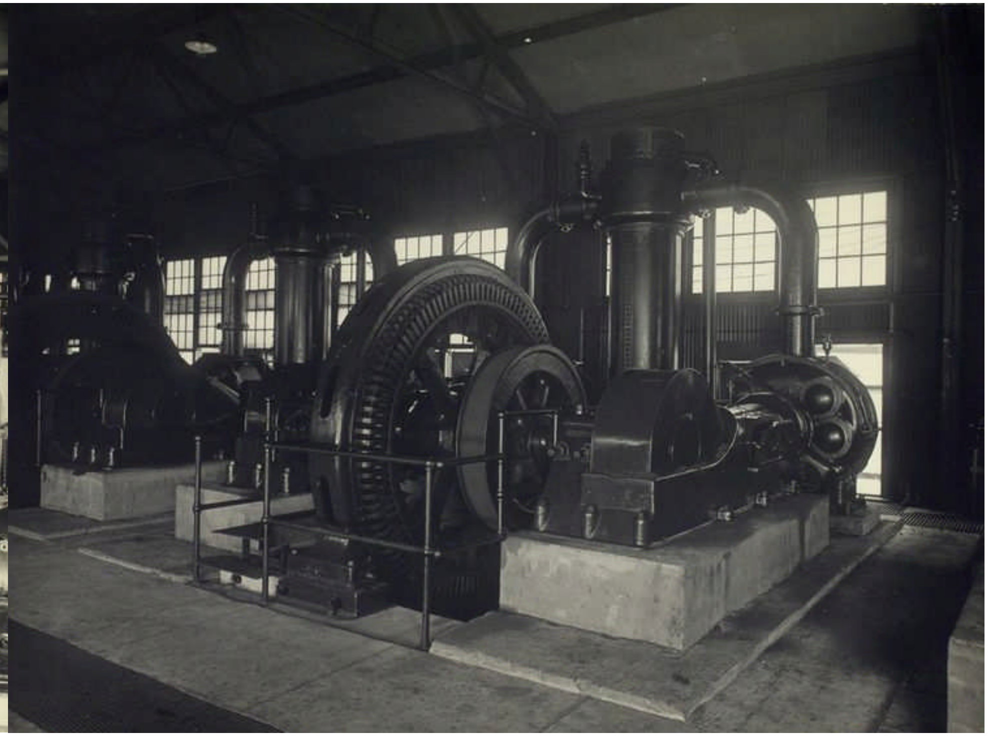
<u>Left</u>: caption: "Land Shaft Caisson ay Spring Street, New York City. Showing steel bulkhead in west side wall through which shield advanced after erection."

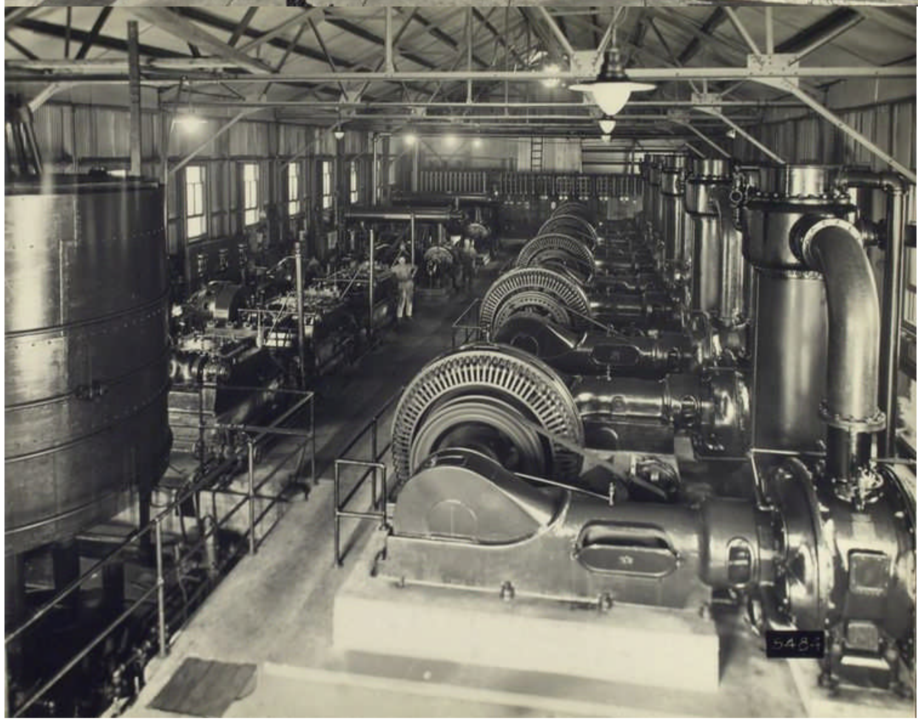
Mobilization

“…This work followed by placing under contract the entire under-river portion of the tunnel. Power plants had to be constructed to produce low-pressure air for caissons and tunnel, high-pressure air for the operation of grouting machines, air drills, and hoisting engines used below the surface, and hydraulic pressure for operating the jacks used in driving the shield and for operating the erector arm for building the tunnel lining. Overhead gantries and dumping platforms for the receipt and disposal of materials and buildings for housing the workmen had to be provided. Pipes, through which compressed air would be supplied to the tunnel headings, had to be laid to the shafts. On the New Jersey side this involved laying low-pressure lines as large as 16 inches in diameter, high-pressure lines, hydraulic lines, water lines, electric cables, and telephone cables. Every facility had to be provided, even an independent telephone system connecting all parts of the work with the public telephone system…”

RE: excerpt from *The Eighth Wonder*







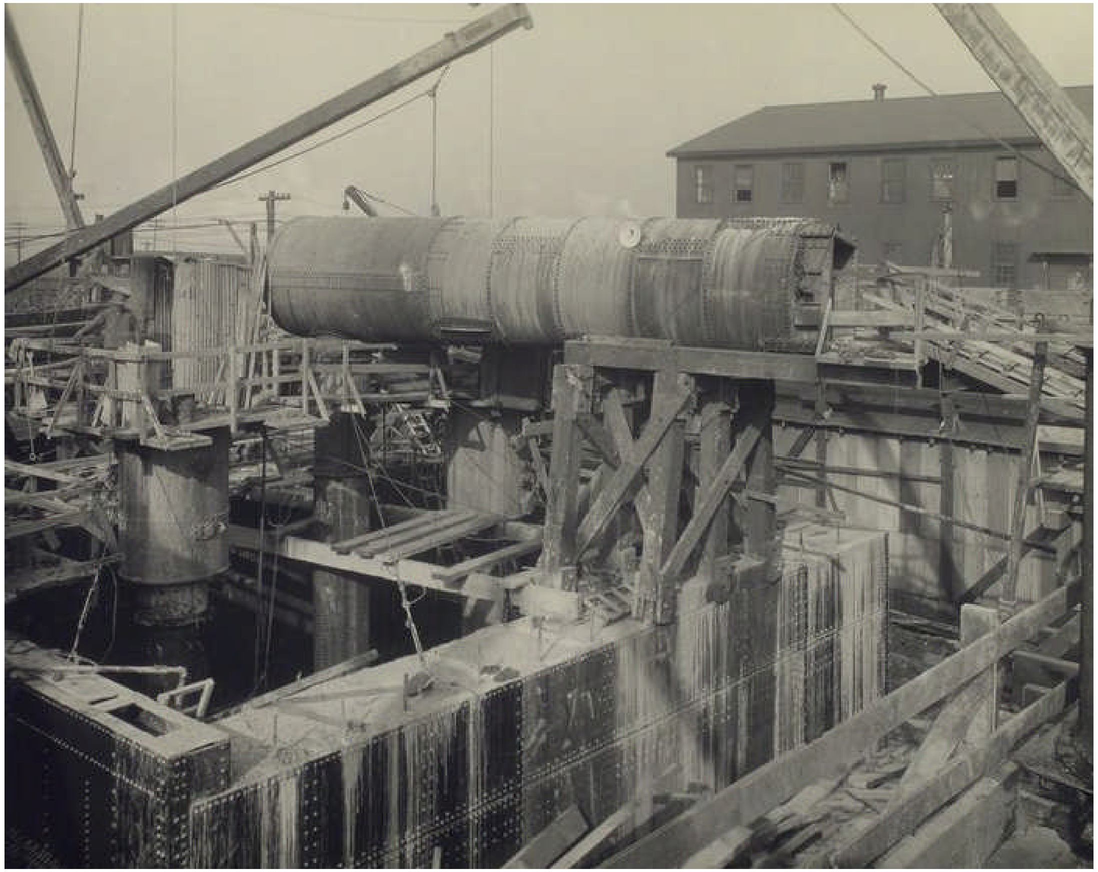
Top Left: caption: “Power House (General interior) Henderson & 12th Strs, Jersey City. 8/4/ 23.”
Top Right: caption: “Low air compressor No. 5, Power House, 12th & Henderson Sts., J.C. 6/1/23.”
Left: caption: “Power House (General interior view), Canal & West Street, New York. 7/23/23.”

<u>Above</u>: caption: "N.Y. Telephone Co. cables at Canal & Hudson Streets, New York. 12/2/24."

"…Canal Street Park was made available as a site for the air-compressing plant and engineers' field office. Pier 35 and adjacent slips were used for the storage of materials and for the disposal of excavated matter from the tunnel heading. Overhead gantries connecting the shafts with the pier permitted traffic to the water front in connection with the tunnel to pass above the city streets…"

RE: excerpt from *The Eighth Wonder*

Air-Locks



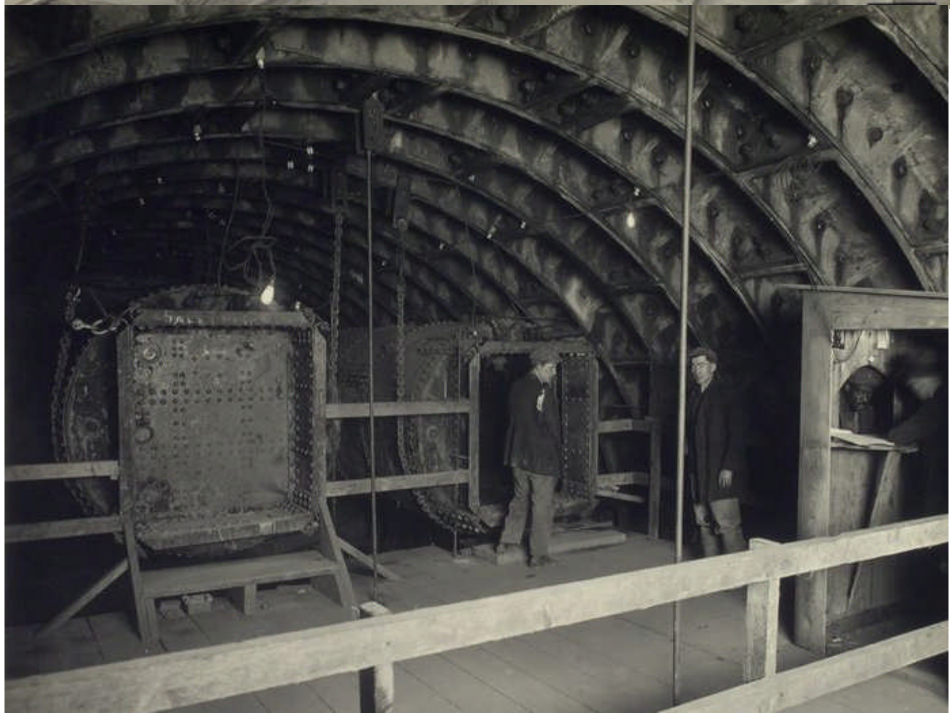
"…Every precaution was taken to provide for the safety of the workmen in the compressed-air chambers. A high emergency gangway in the upper part of the tunnel led from the shield to the locks, for escape in case of a blowout. Safety screens were installed in the compressed-air chambers. Fire is a real danger in compressed-air work on account of the increased amount of oxygen present. As an indication of the fire hazard, a candle, if still glowing when extinguished, will again burst into flame…"

RE: excerpt from *The Eighth Wonder*

<u>Above</u>: caption: "Locks of North Land Shaft, New Jersey. 1/27/23."

"…We entered one of these (only one was used normally, the other reserved for emergencies) and saw the iron door clanged to and fastened. Then followed lessons in equalizing the pressure inside and outside the head by holding the nose and 'snorting' – very much as one does when trying to expel water from the nose after diving. The danger of the 'caving in' of one's eardrums was stressed, and we were warned to hold up our hand the moment the pressure became too severe. This was the only way to attract the attention of the man who turned on the compressed air as the noise made even shouting inaudible. We sat wild-eyed – expecting the hideous monster to leap upon us any minute. The bark was worse than the bite. Twice we raised our hands and the pressure was turned off until the pressure in our ears was relieved. When the twenty-nine pound mark was reached the door leading into the high-pressure section was opened, and there we were in the very midst of the digging. Once accustomed to the pressure, it was not noticeable…"

RE: excerpt from *The Eighth Wonder*



Top Left: caption: "Gang about to go down shaft on cage. Canal Street shaft, New York. 4/24/23."

Top Right: caption: "Gang of 'Sand Hogs' Waiting In Line. Canal Street shaft and air locks, South tunnel. 4/24/23."

Left: caption: "Man lock. South tunnel, New York. 4/24/23."

"…We stood watching the big burly men as they shoveled the debris into the cars that carried it out through the lower air chambers. Not particularly envious of them at such hard labor, we listened only half-heartedly to our guide until he remarked that the automobiles we had seen parked at the entrance belonged to these very 'sand-hogs'; that they made high wages and worked short hours. There are laws forbidding their working in compressed air for more than two hours at a time, for health reasons. Law likewise requires the company employing the men to furnish hot showers and hot coffee for them when they come out…"

RE: excerpt from *The Eighth Wonder*

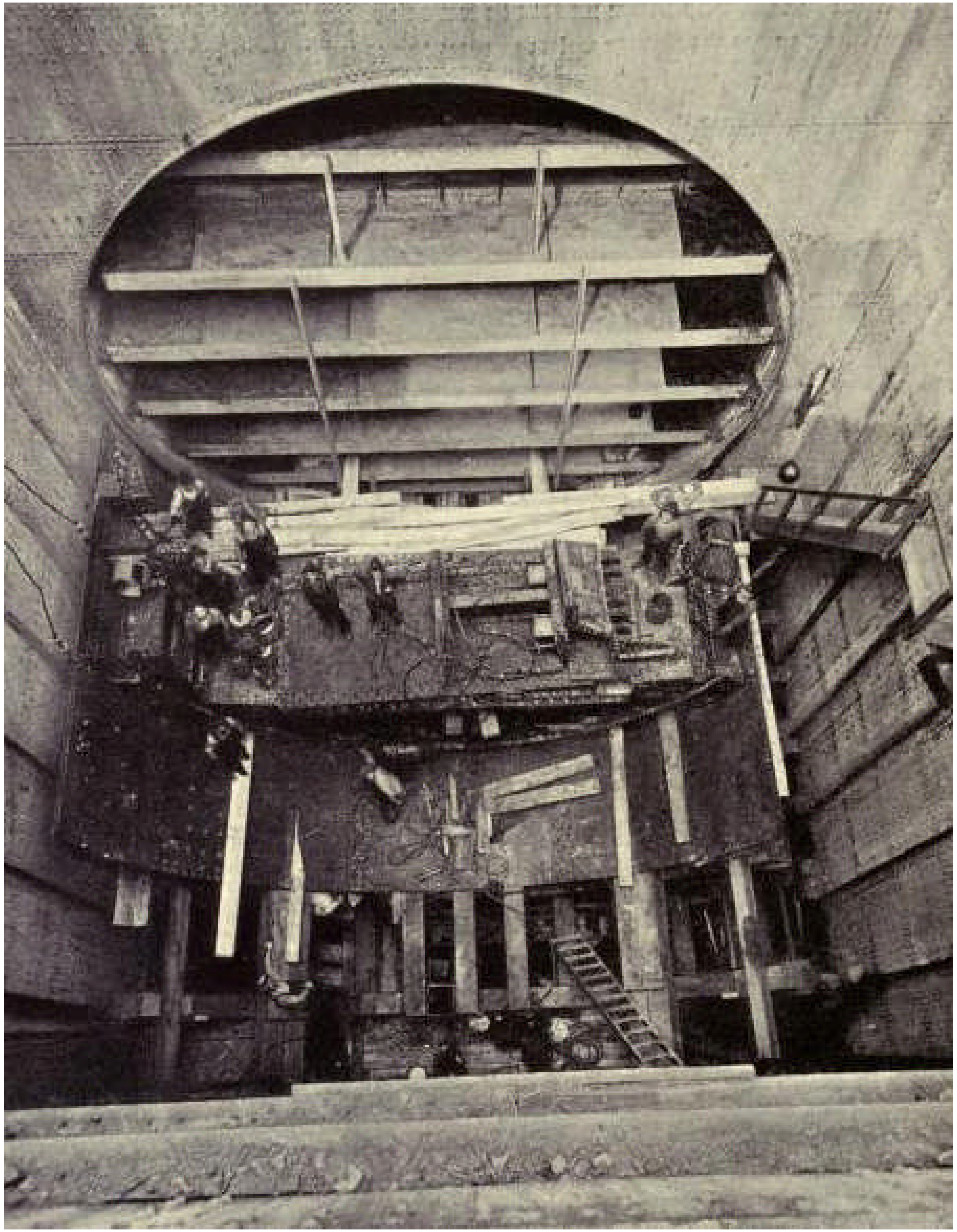
"…We picked up bits of rock for souvenirs and continued gasping when one of our hosts turned questioner. He asked if we could whistle. Assuring him that whistling did not stump the modern girl, we inquired his preference as to a tune. He consulted the other men, and after much deliberation proposed to give us a big party on the condition that we whistle 'Yankee Doodle' – all five verses. With one accord lips were puckered and cheeks distended. Our chagrin was only equaled by the laughter of our tormenters as we puffed and blew in vain. The party was given for the effort and not for the results obtained against twenty-nine pounds of pressure…"

RE: excerpt from *The Eighth Wonder*

“…In quitting the compressed air it was necessary to put on fleece-lined coats to prevent catching cold. We retraced our steps through the man-lock, where the pressure was reduced gradually back through the tube, and insisted on the law requirement of hot coffee on signing off…”

RE: excerpt from *The Eighth Wonder*

The End of the Beginning



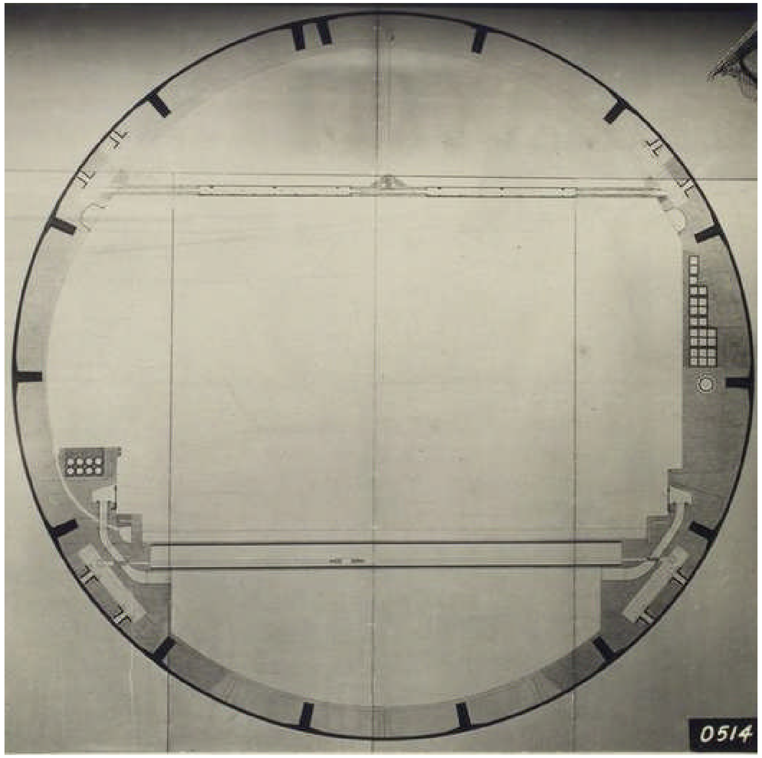
"…The first shield was erected in the Canal Street shaft. On October 26, 1922, compressed air was introduced into the shield chamber, and tunneling was begun…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Assembling Shield in Canal Street Shaft. View looking down into shaft, showing bulkhead in west side wall."

"…Each shield was 30 feet 2 inches in outside diameter, 16 feet 4 inches long, and the upper half was equipped with a hood projecting 2 feet 6 inches ahead of the shield proper. Five vertical and three horizontal walls divided the shield in to 13 compartments, through which the ground in front was excavated. It was equipped with thirty 10-inch jacks, having a combined thrust of 6,000 tons. A hydraulic erector was used to build the tunnel segments into a complete ring. The weight of the shield, with all equipment, was about 400 tons…"

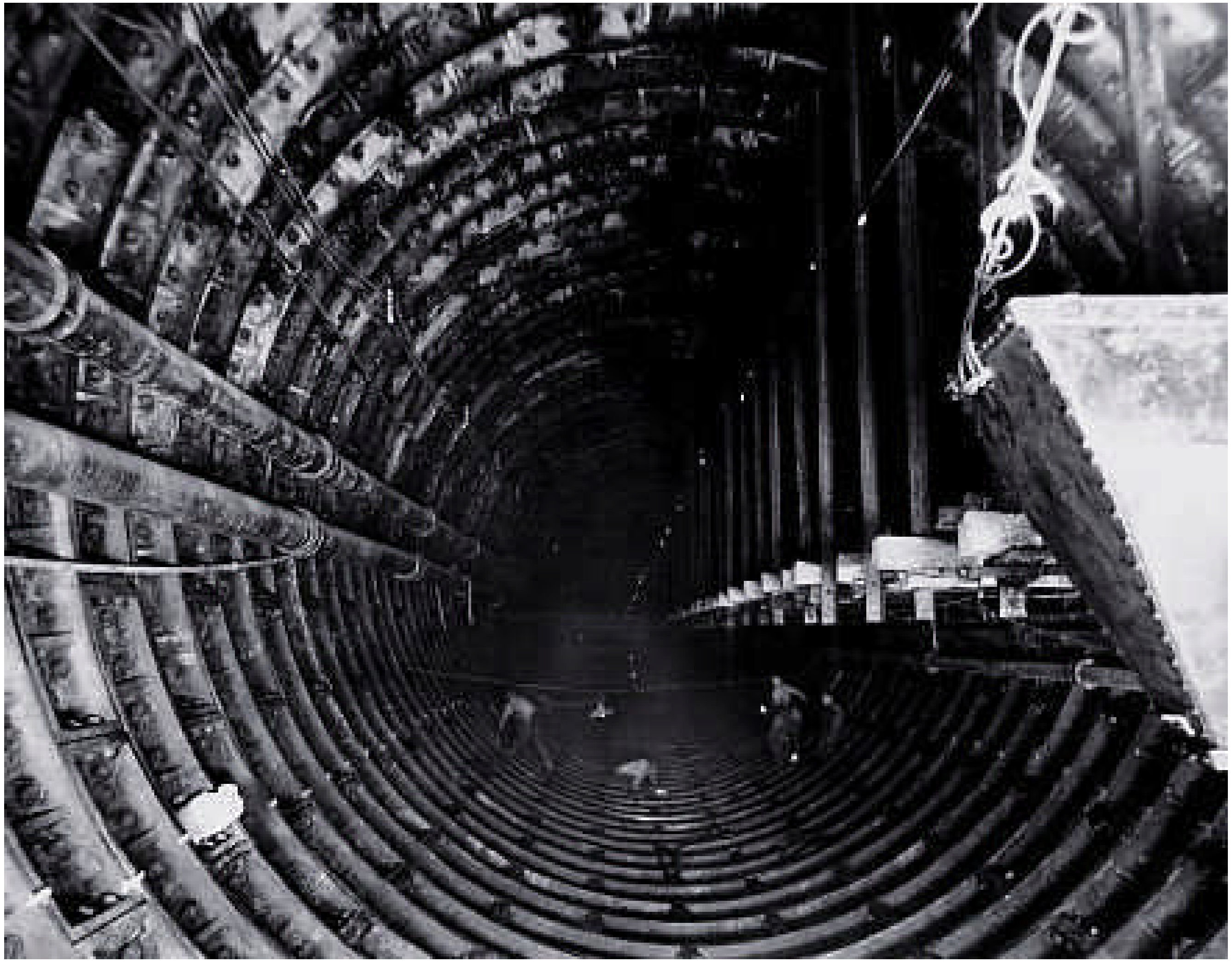
RE: excerpt from *The Eighth Wonder*

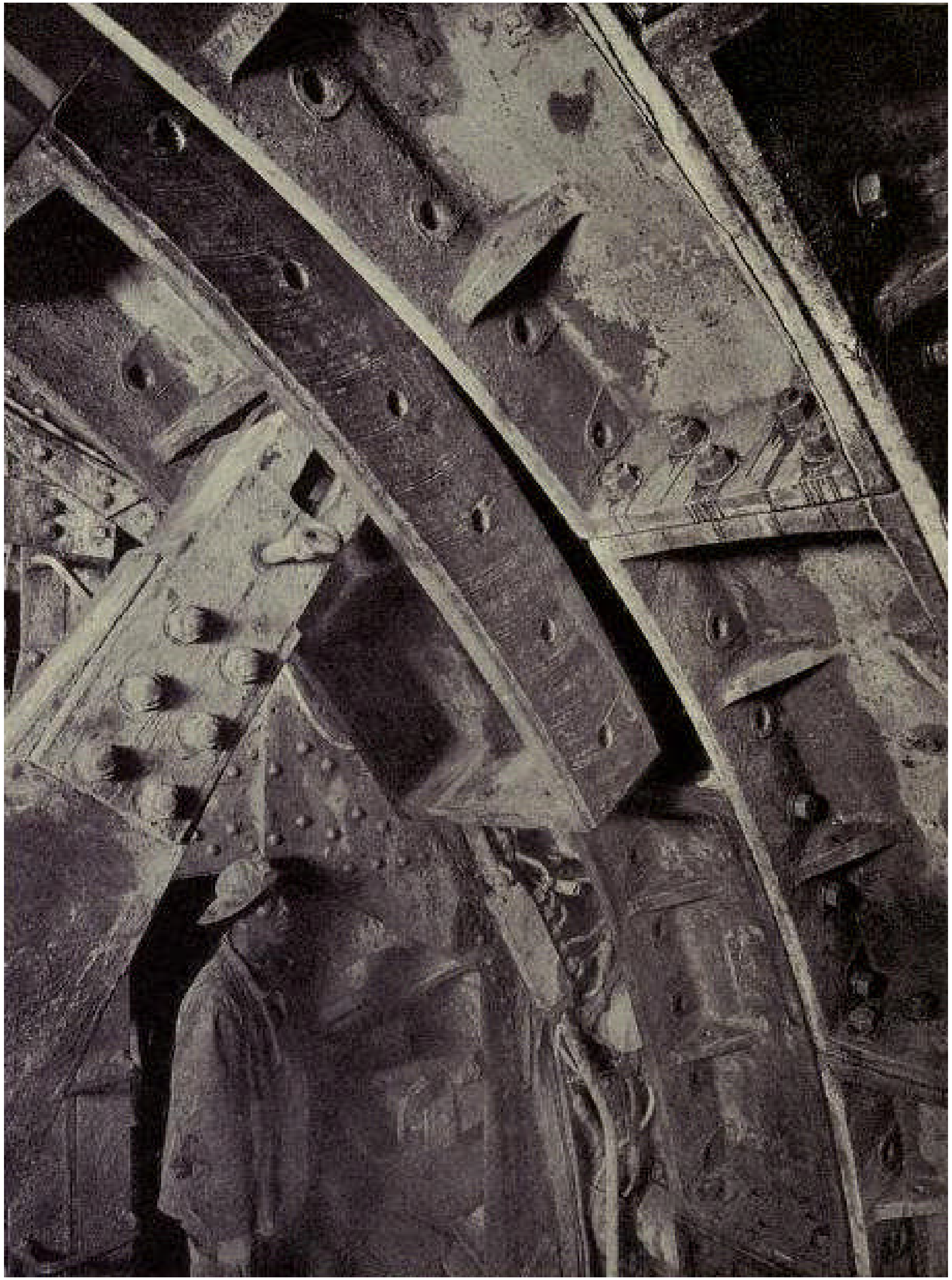


"…The tunnel lining is composed of rings 2 feet 6 inches wide, consisting of 14 segments, each approximately 6 feet long, with a key one foot long, bolted together. Inside the lining is an inner lining of concrete 19 inches thick…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Concrete lining of the tunnel showing different steps in placing"





"This work was done under a shield, or movable head, slightly larger than the external diameter of the tunnel. The shield was forced forward two and a half feet at a time, the width of a section, by means of thirty hydraulic jacks supported against the end of the tunnel already built. Several of the jacks were then removed and a segment was hoisted into place by a tremendous erector arm till a complete ring had been added, and then the shield was forced ahead again. Doors in the lower part of the shield allowed about thirty per cent of the displaced compressed silt to enter the tunnel on each shove…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Erector Arm. Swinging iron segment into place in tunnel lining, South Tunnel"

<u>Above Top</u>: caption: "Steel pile segments and forms for setting concrete invert. 4/30/25."
<u>Above Bottom</u>: caption: "Concrete invert, North Tunnel East, New Jersey"
<u>Left</u>: caption: "Iron men bolting plate in place, South tunnel, New York, 4/5/23"

<u>Above</u>: caption: "Proposed test - Cast Iron section. Canal Street, July 14, 1921."

<u>Above & Left</u>: caption: "Broken plate. Cast-iron lining South tunnel. 11/22/22."


HUDSON RIVER VEHICULAR TUNNEL
MODEL OF METAL LINING 1/15 ACTUAL SIZE
EACH RING IS 29 FT. 6 IN.
IN DIAMETER.
TUBES ARE 65 FT. FROM
CENTRE TO CENTRE.
110,000 TONS OF
CAST IRON & STEEL
SEGMENTS & KEYS ARE REQUIRED.
BETHLEHEM STEEL COMPANY, INC.
WILL FURNISH 60,000 TONS OF IRON & 10,000 TONS STEEL CASTINGS.

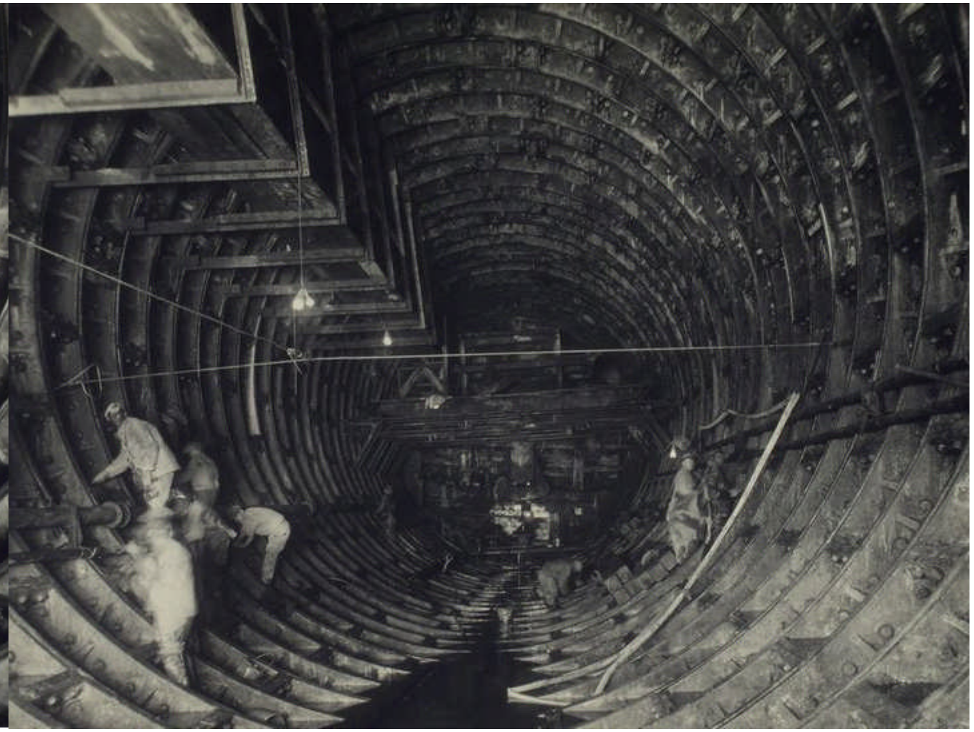
Into the Void

"…As the shield advanced and the lining was erected behind it, the space due to the difference in the diameter of the shield and the rings forming the lining was filled by forcing a grout of cement and sand in equal parts into the void under high air pressure. For this purpose each segment was provided with a grout hole fitted with a screw plug. The lining was made water-tight by placing hemp grommets soaked in red lead around the bolts, and by caulking lead wire into grooves between the segments…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Cast-iron tunnel segment with grout plug temporarily removed"

Above: caption: "Grouting in South tunnel, New York. 4/10/23."
Left: caption: "Grout nose and nipple in plate with man on wrench, South tunnel, New York. 4/9/23."



Top Left: caption: “Cleaning, caulking, pointing and making iron watertight invert, South Tunnel east, N.J. 12/5/24.”
Top Right: caption: “North Tunnel West shield at Ring No. 312 and cleaning and caulking, N.J. 4/1/25.”
Left: caption: “Ring No. 266, South tunnel, New York, showing clay and mud coming through grout hole. 6/13/23.”

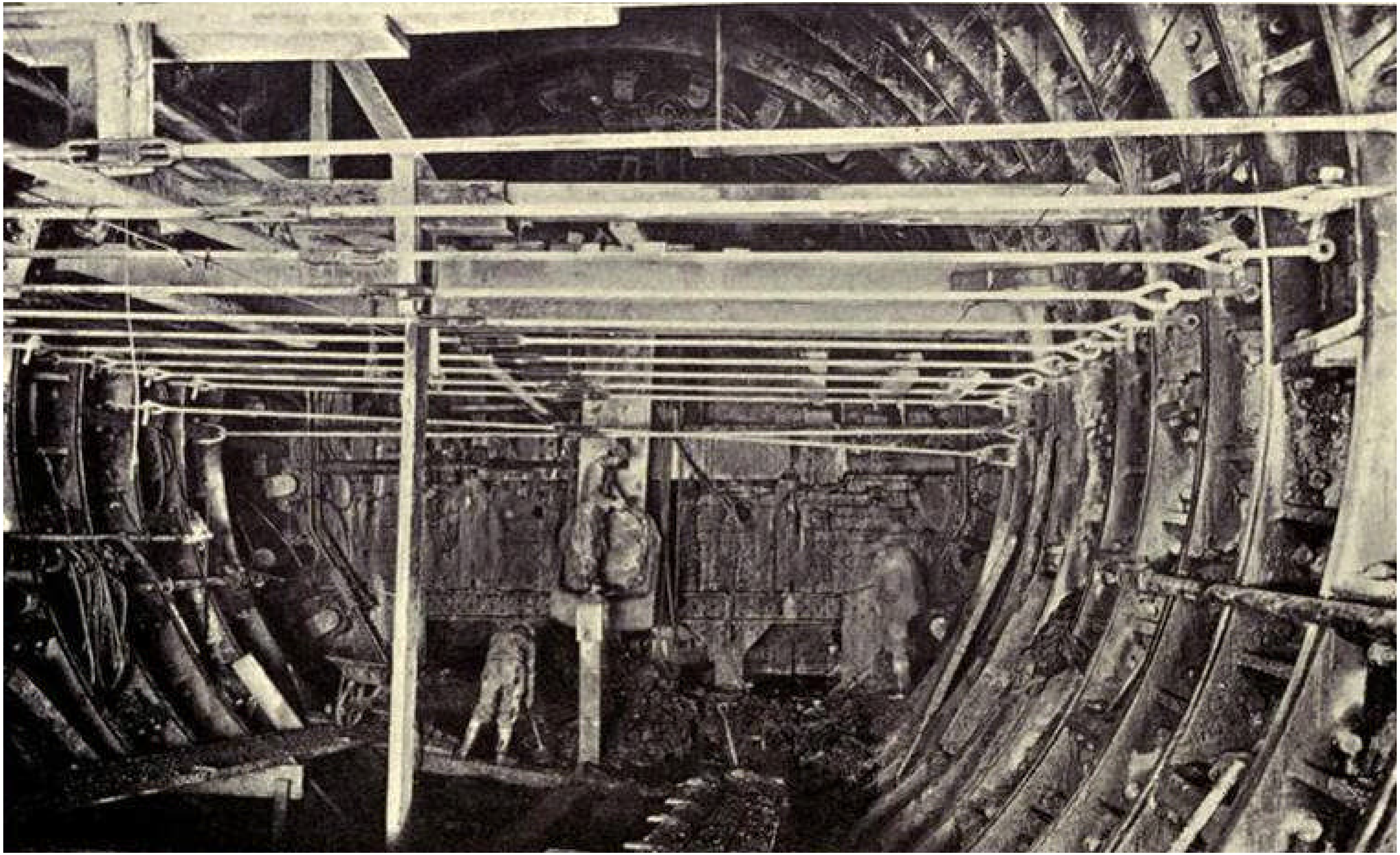
NY Shield Driving

"…Shield driving requires extreme care and exactitude to keep to line and grade. The position of the shield fixes the location of the tunnel, and no correction can be made afterward. It is absolutely essential that the slightest deviation of the shield from its theoretically correct position be known at once, so that measures may be taken to remedy the error during the next shove. The shield is guided by the operation of the jacks distributed around its circumference, omitting the use of those jacks in the direction toward which the shield is to move…"

RE: excerpt from *The Eighth Wonder*

“…The starting of the shields out of the caissons at the New York land shafts was difficult because of the large diameter of the shields and the shallow cover overhead. The material at this point was granular, consisting largely of fine sand, which if undisturbed, held air fairly well. As the shields were under the city streets, it was impossible to increase the cover overhead. To avoid blow-outs at the face with the consequent inrush of water, it was necessary to regulate the air pressure carefully and to protect the face during each successive step in excavating. As a preliminary step to shoving the shields out of the caissons, the circular steel bulkheads in the caissons were burned out in front of the shields. The work was done by removing the steel in horizontal layers, each layer carefully protected as the steel was removed to avoid exposing a great area of the face to air leakage, especially when the air pressure sufficient to dry out the bottom would be heavy enough to cause a blow-out at the top…”

RE: excerpt from *The Eighth Wonder*



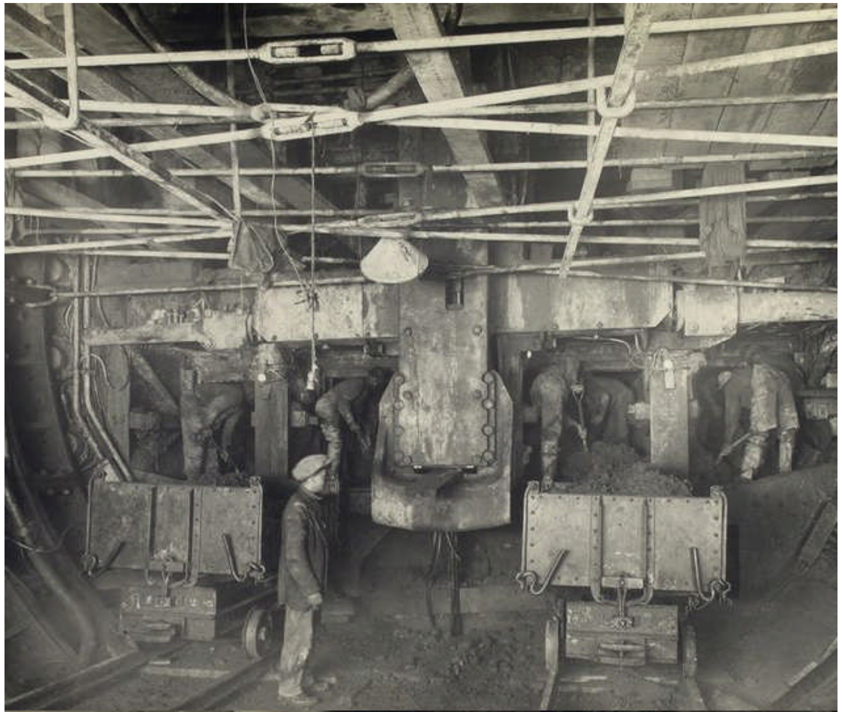
<u>Above</u>: caption: "Shield, South Tunnel, Canal Street at West Street, New York City. View of rear end of shield in place and temporary bulkhead. Tunneling operations temporarily suspended and air pressure removed in order to remove shaft deck and place cages in shaft and air locks in tunnel."

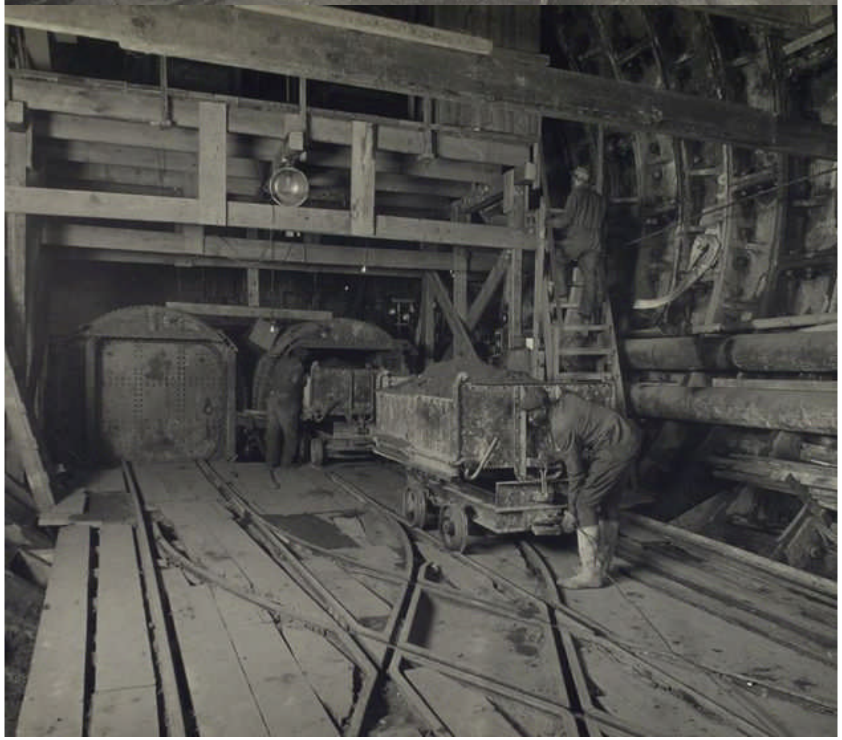
“…Removal of the steel bulkhead was started, with the steel above intact and with air pressure sufficient to dry out the bottom. After the lower third of the steel bulkhead had been removed, a wooden bulkhead was built in front of the shield, and the space between this bulkhead and the ground ahead was packed with clay. The air pressure was then reduced until it balanced the water pressure at the top of the shield, and work was begun at the top, removing the top plates and proceeding downward. As these plates were removed, breast boards packed front and back with clay were inserted to cover the exposed excavation. This work proceeded down to the point where the bottom plates had previously been removed, while at the same time the air pressure was raised step by step to balance the water pressure. The shield was then advanced against the wooden bulkhead at the bottom, compressing the clay which was removed as the shield advanced, with the jacks reacting against the cast-iron tunnel lining temporarily erected in the shaft…”

RE: excerpt from *The Eighth Wonder*

"…In order to prevent the leakage of air around the hood of the shield, an annular pocket was excavated ahead of the hood the full length of a shove, and the pocket was packed with clay. This served a double purpose: first, the hood, as the shield advanced, cut into this clay and made a thorough seal in front against air leakage; and second, by exploring the full length of the shove, assurance was had that the shield would not pick up and drag timbers in front of it, leaving open channels behind them through which air could readily escape. The necessity of taking this precaution is evident when it is considered that at this point there were but 14 feet of cover above the shield to the street surface, and only 8 feet from the top of the shield to the under side of an old brick sewer, which would readily allow the air to escape from the tunnel heading…"

RE: excerpt from *The Eighth Wonder*



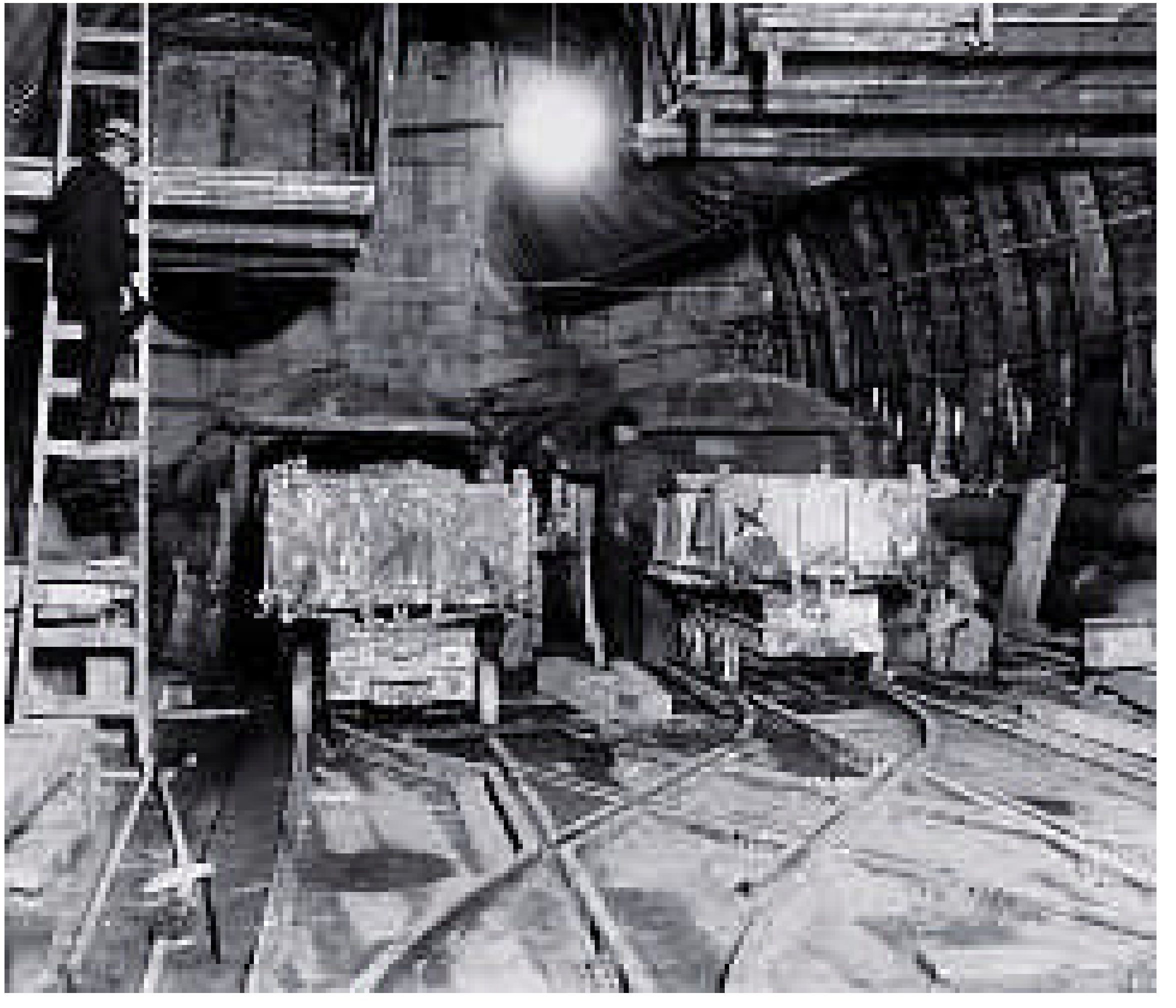


"…As the tail of the shield left the caisson, grouting was at once started to fill the annular space which the shield left outside the tunnel lining. Every effort was made to keep this space fully grouted, even to the extent of stopping the shield in the middle of a shove to keep the grout up with the shield. The method just described was later modified so that in the bottom quarter of the shield, instead of packing ahead with clay, a fixed wooden bulkhead was built in the shield, and the shield was advanced into the fine wet sand with this bulkhead in place. This compressed the earth, driving out the water, so that the material was firm and could be excavated during the shove over the top pf the bulkhead, or through small openings in the bulkhead itself. This prevented a free run a wet material into the bottom which is the ordinary method of tunneling under a river…"

RE: excerpt from *The Eighth Wonder*

<u>Top</u>: caption: "Miners in shield, shoveling out, South tunnel, New York. 4/5/23."

<u>Bottom</u>: caption: "Muck cars coming out of muck lock, South tunnel. 4/25/23."



"…The grouting previously described was continued, and not only prevented an abnormal escape of air at the tail of the shield, but also prevented settlement of the streets and adjacent buildings. The buildings at the corner of West and Spring Streets settled slightly, but at no time were they in need of shoring, nor were the occupants disturbed at any period of the tunnel work. This was the situation also with the New York Central tracks under which the Canal Street tunnel was driven. The grouting was carried on so effectively that it filled some of the old sewers in the vicinity which later had to be cleaned out…"

RE: excerpt from *The Eighth Wonder*

Too Close for Comfort

“…The Canal Street shield passed very close to a cofferdam around an excavation for a sewage treatment plant, and it was evident from the first that great care must be exercised in driving the tunnel past this location. At the nearest point the shield was within 5 feet of the steel sheeting of the cofferdam, with the bottom of the sheeting at about the springing line of tunnel. On November 30th, when the shield was about 40 feet away, it was noticed that sand and water were being forced through the sheeting into the cofferdam by the air pressure from the tunnel heading. In about two hours approximately 159 cubic yards of earth had been blown into the excavation from behind the sheeting, and it was plain that not only was the cofferdam in danger, but the continuation of tunneling operations would be hazardous because the cavities left in the ground provided open channels for the leakage of air, which might have resulted in a tunnel blow-out. It was decided that tunneling operations should be temporarily suspended, that the steel sheeting of the cofferdam should be left in place permanently, and the concrete walls of the permanent structure be placed immediately, being increased in thickness to enable them to withstand the pressure from tunneling operations…”

RE: excerpt from *The Eighth Wonder*

NY River Bulkheads

"…Preparatory to tunneling under the river bulkhead, clay and other material to prevent the escape of the compressed air from the tunnel were deposited in the slip between the piers and on the landward side of the river bulkhead construction. Not only were the voids around the piles filled, but the soft mud in the slip was displaced by the heavier clay, a firmer material and better adapted to resist air leakage…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Marginal Street in front of Lehigh Valley Pier No. 34 - view of clay bagging placed on the surface of the ground to prevent air escaping from South tunnel, New York. 4/24/23."

"…In this section great care was taken in excavating ahead of the hood to be sure that all piles within the area of the tunnel section were cut off before coming in contact with the shields. This was done to avoid pushing the piles through the ground and leaving back of them an open channel for air to escape. These piles extended down to the springing line of the tunnel excavation, and as many as thirty had to be cut off at one time in advancing the shield the length of one ring. In this manner both shields passed under the river bulkhead without accident…"

RE: excerpt from *The Eighth Wonder*

<u>Above</u>: caption: "Piles encountered in breasting down for ring No. 144, South tunnel, N.Y. 4/25/23."

Hudson River Silt

"…The tunnels then entered the Hudson River silt. The front of the shield was completely bulkheaded. Some of the lower pockets in the shield were opened to allow a part of the material to enter the tunnel as the shield was advanced. The balance of the material in excavation was displaced bodily…"

RE: excerpt from *The Eighth Wonder*

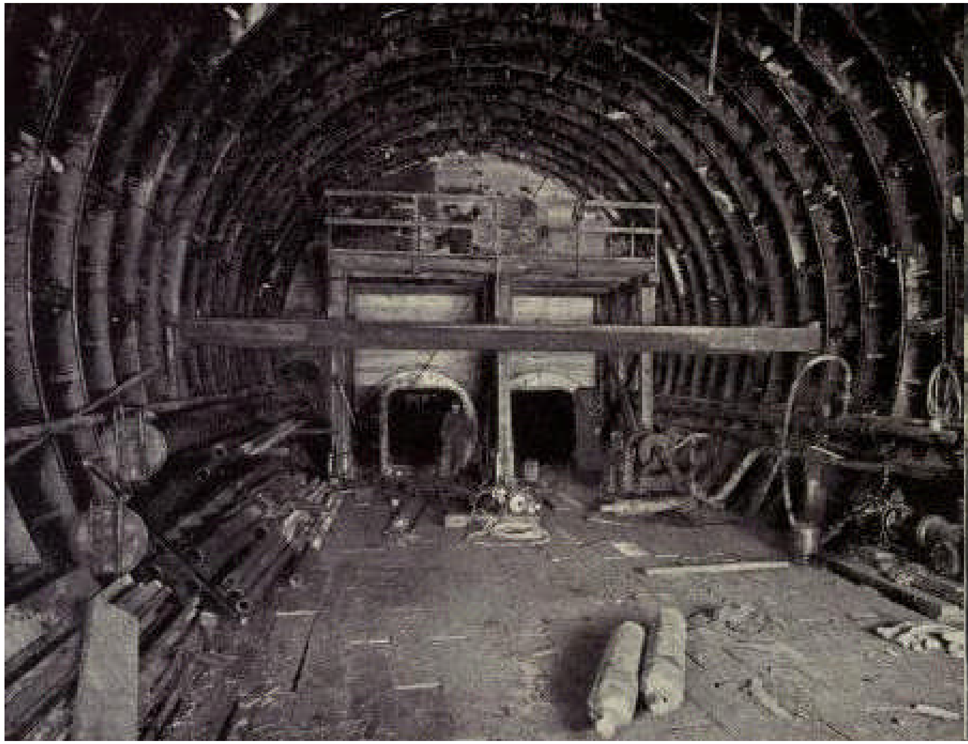
"…At once it was noticed that there was a tendency for the tunnel lining to rise behind the shield. This rising always accompanied movement of the shield; whenever the shield was stopped the rising ceased. The difficult feature at this point was that the shield was so heavy that it settled while the cast-iron tunnel lining behind the shield rose, so that the shield at all times was below grade while the tunnel lining a short distance back was above grade…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Tightening bolts in New Jersey North Tunnel East. 05/09/24."

"…The bulkhead contained four air chambers or locks. Two large compartments at the bottom of the bulkhead were equipped with tracks for bringing supplies to the workers and for removing excavated material. Two smaller chambers were provided in the upper section for the workmen who on entering or leaving the tunnel must be gradually brought from one pressure to another…"

RE: excerpt from *The Eighth Wonder*




"…The bulkheads in the shield were moved forward to reduce weight by lessening the amount of muck in the shield. This aided somewhat in keeping the shield from settling and then more material could be taken in through the shield. This procedure lessened the pressure on the tunnel behind and reduced its tendency to rise. As the contract required that a second tunnel bulkhead should be constructed in this vicinity, the south shield was stopped after passing through 218 feet of silt and the bulkhead was built. This bulkhead, which is typical of all the bulkheads, is a concrete wall 10 feet thick, equipped with the usual muck, man and emergency locks, and adds temporarily considerable weight to the tunnel…"

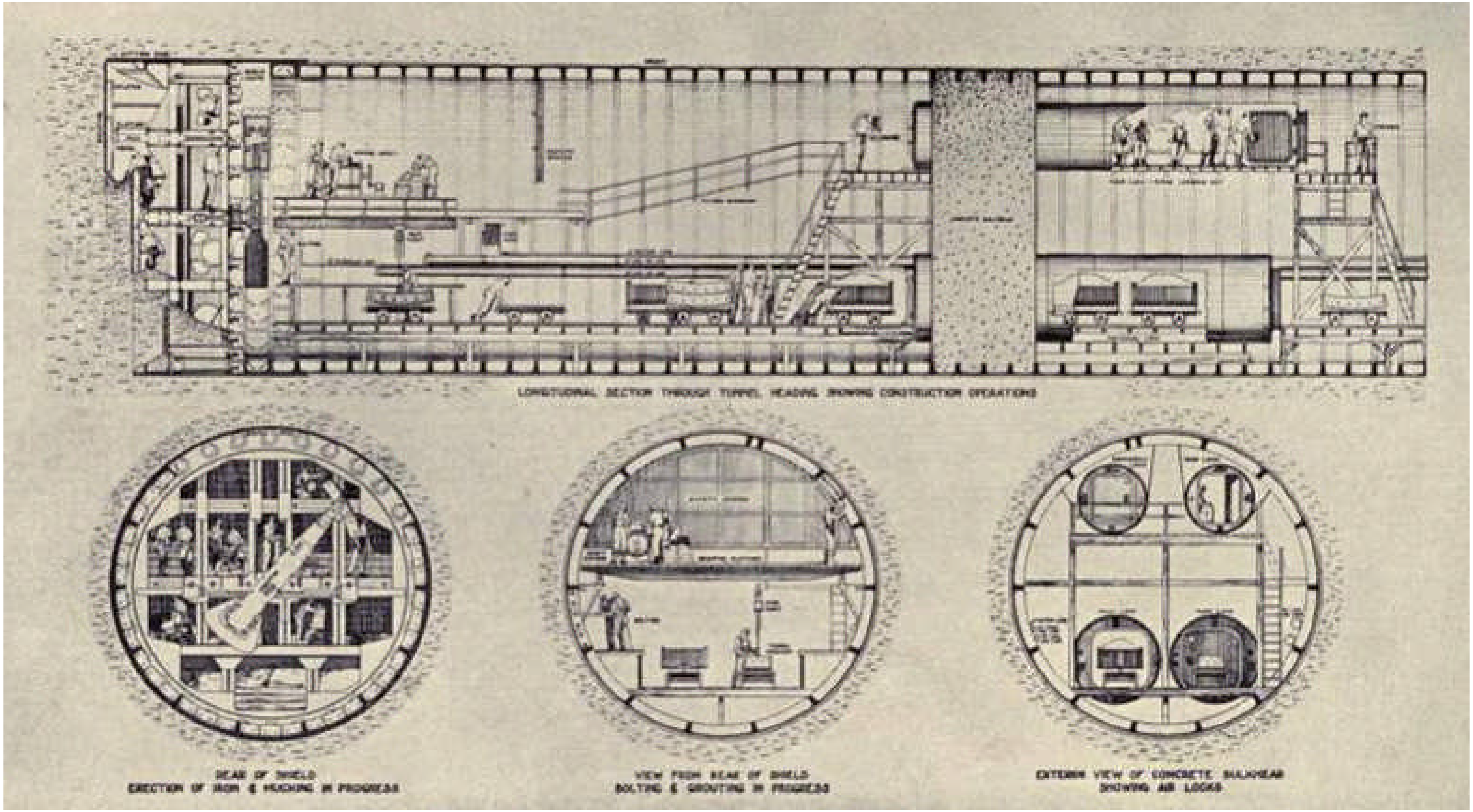
RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Concrete Bulkhead and Locks. South Tunnel, Canal Street, NYC"

<u>Right</u>: caption: "Bulkhead from inside. South tunnel. New York, 4/7/23."

"…With this additional weight, the rising of the tunnel was somewhat checked and after tunneling a distance of 121 feet farther in the silt the shield entered at the bottom of the sand layer which overlies the rock, and thereupon all rising of the completed tunnel during shield driving ceased. In the north tunnel, which was driven through the same material after the south tunnel was built, a larger amount of material was taken in through the shield at the start, and while there was some rising of this tunnel behind the shield, it was very much less than in the south tunnel. In neither tunnel was the movement sufficient to endanger the structure…"

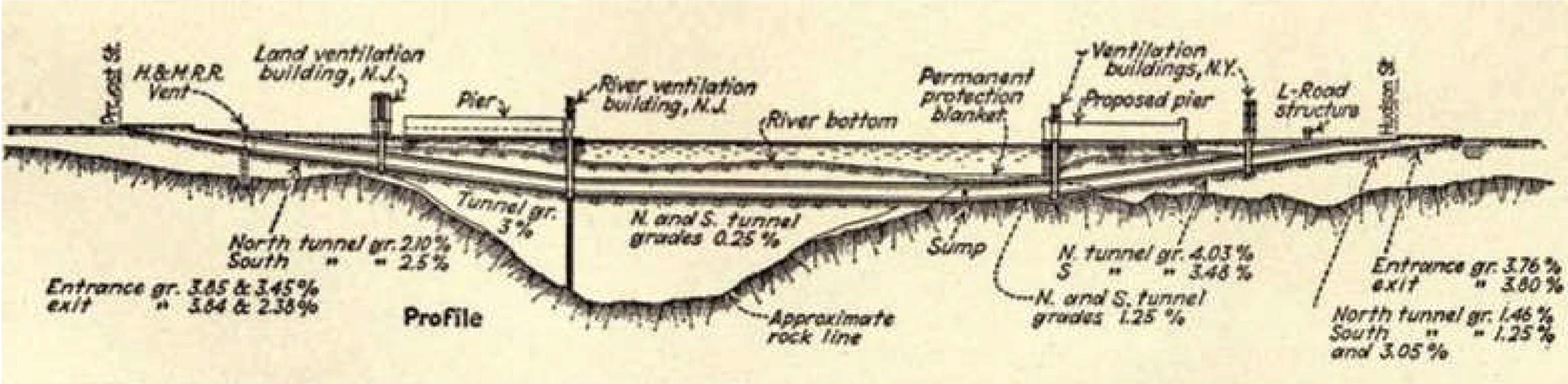
RE: excerpt from *The Eighth Wonder*



<u>Above</u>: caption: “Longitudinal Section Through Tunnel Heading, Showing Construction Operation. Below, rear of shield showing erection of iron and mucking in process; view from rear of shield with bolting and grouting in process; exterior view of concrete bulkhead showing air locks”

"…The excavation in the part-earth and part-rock section just east of the New York river shaft caisson was carried on by driving a short bottom heading in advance of the shield, in which was placed a concrete cradle with steel rails embedded in it upon which the shield slid. After placing the cradle the rock was blasted out for one or two advances of the shield and then the soft material on top was carefully excavated and supported by poling and breast boards…"

RE: excerpt from *The Eighth Wonder*



"…Ever ride through the Holland Tunnel in your car? An easy, effortless and safe trip, wasn't it? Well, don't be alarmed when you learn that certain sections of this sturdy old tube - the granddaddy of all sub-aqueous vehicular tunnels - rise and fall with the Hudson River tides. The reason is simply that part of the tunnel rests on river silt and another section, near the New York pierhead line, on a ledge of rock. Upon the rock the tunnel resists the tides but where it leaves the rock and enters silt, immobility leaves off and mobility sets in…lined the mobile section with cast steel instead of the cast iron used elsewhere. The greater tensile strength of steel absorbs the strain, making the so-called 'bending' perfectly harmless…"

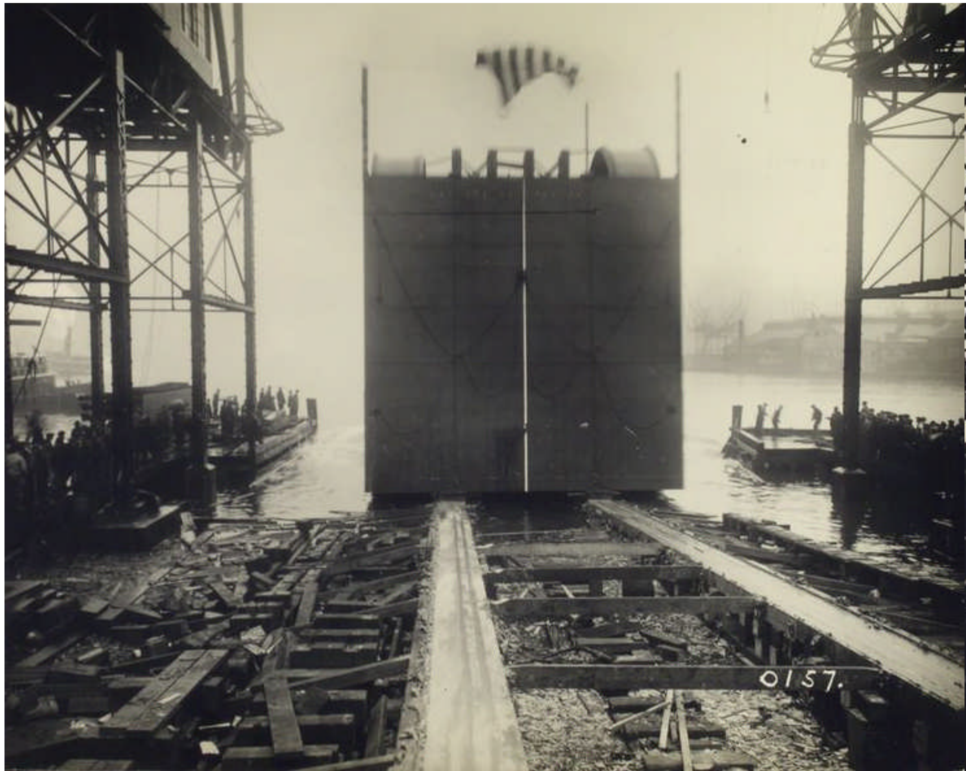
***Mechanix Illustrated,* June 1941**

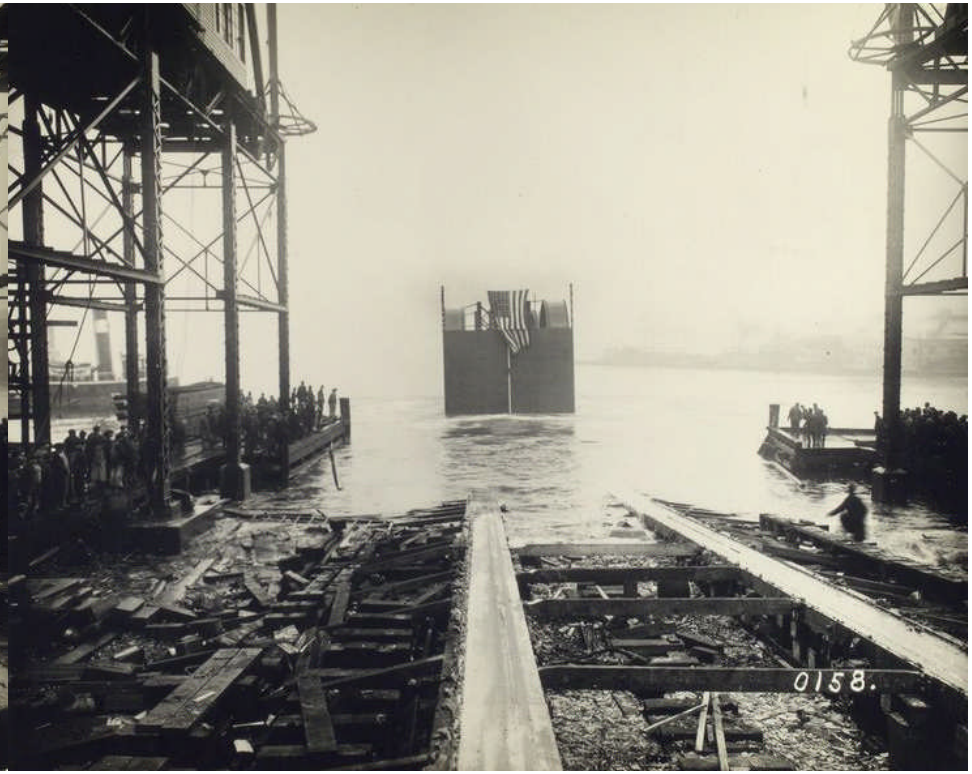
<u>Above</u>: caption: "Profile of the Holland Tunnel"

NY River Caisson

"…The New York river ventilating shaft caisson was sunk by the compressed air method in the river near the New York overhead line. It was built on launching ways, then launched and drydocked. After concrete had been placed in the pockets surrounding the working chamber, additional steel was erected, carrying it to a height of 55 feet…"

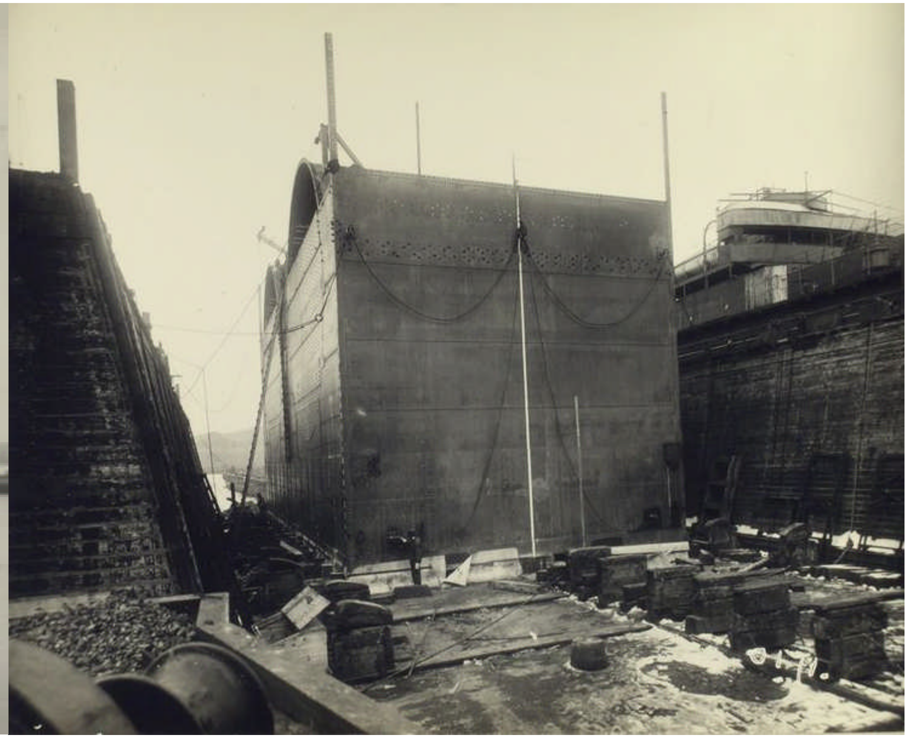
RE: excerpt from *The Eighth Wonder*





Above L&R: caption: "View of launching of New York River Shaft Caisson, Staten Island Shipbuilding Co.'s Plant, Mariner's Harbor, S.I. 12/5/22."

Left: caption: "Launching party, launching of New York River Shaft Caisson, Staten Island Shipbuilding Co.'s Plant, Mariner's Harbor, S.I. 12/5/22."



<u>Top Left</u>: caption: "View of launching of New York River Shaft Caisson, Staten Island Shipbuilding Co.'s Plant, Mariner's Harbor, S.I. 12/5/22."

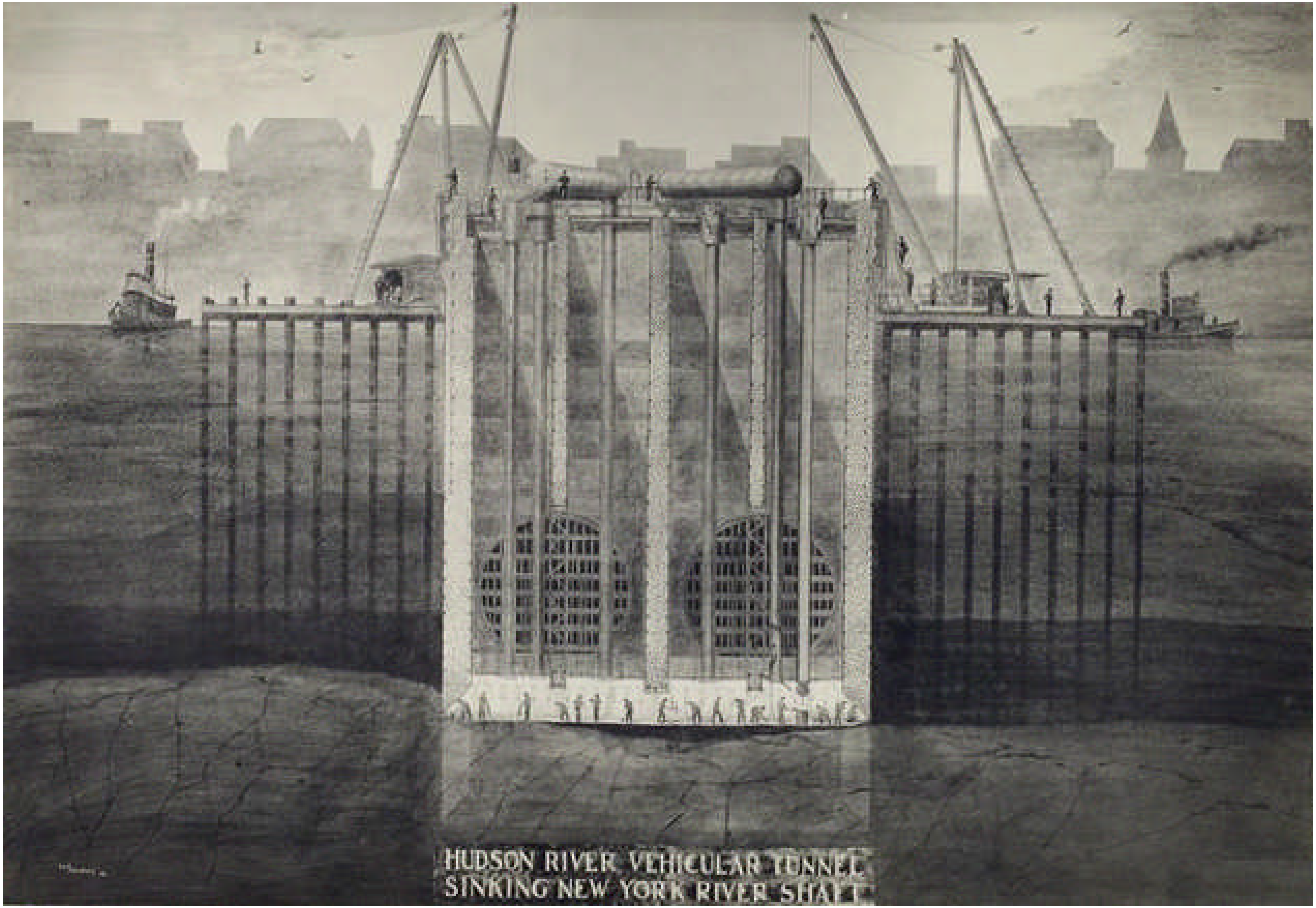
<u>Top Right</u>: caption: "General view New York River Shaft Caisson in dry dock after launching, Staten Island Shipbuilding Co.'s Plant, Mariner's Harbor, S.I. 12/5/22."

<u>Left</u>: caption: "General view New York River Shaft Caisson. Staten Island Shipbuilding Co.'s Plant. Mariner's Harbor, S.I. 1/2/23."

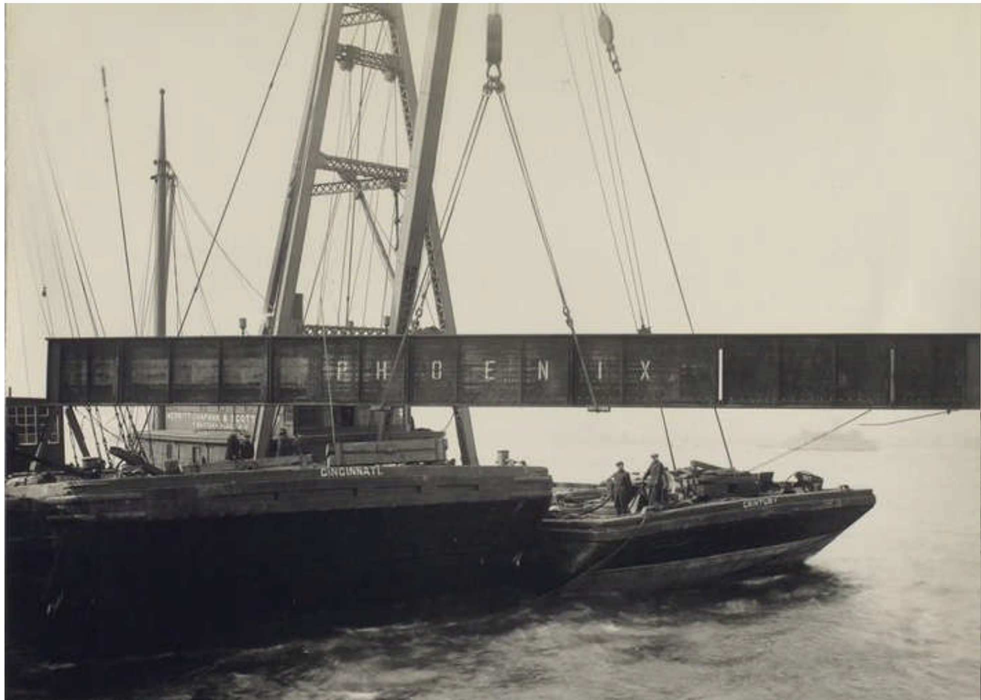
<u>Above</u>: caption: "General view New York River Shaft Caisson. Upper New York Bay North of St. George, S.I. 1/20/23."

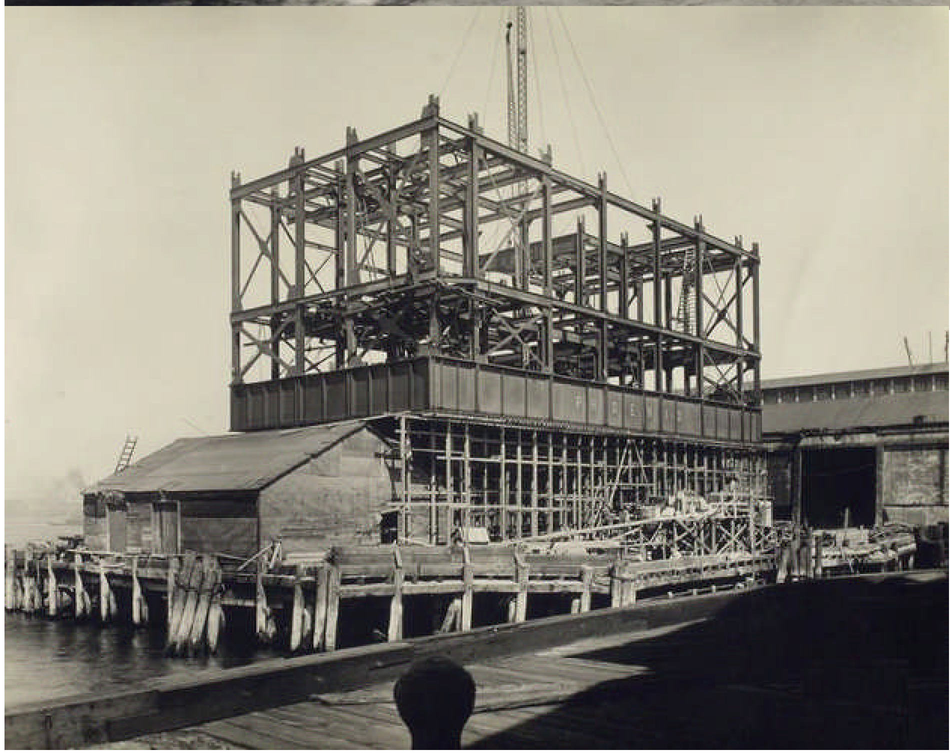
"…A platform supported on piles had been built on three sides of the site (the south side being open ready to receive the caisson), and the caisson was towed to its position on the work. The caisson at that time weighed approximately 1,650 tons. Upon arrival, additional steel was erected and concrete was placed in the walls, the caisson sinking as the additional weight was placed. Care was taken to keep the entire center of gravity as low as possible to maintain the necessary stability. When it had reached a depth of 35 feet, the cutting edge encountered the river bottom, into which it settled at each low tide, and weight was added with sufficient rapidity to overcome the tendency to float on the subsequent rising tide…"

RE: excerpt from *The Eighth Wonder*



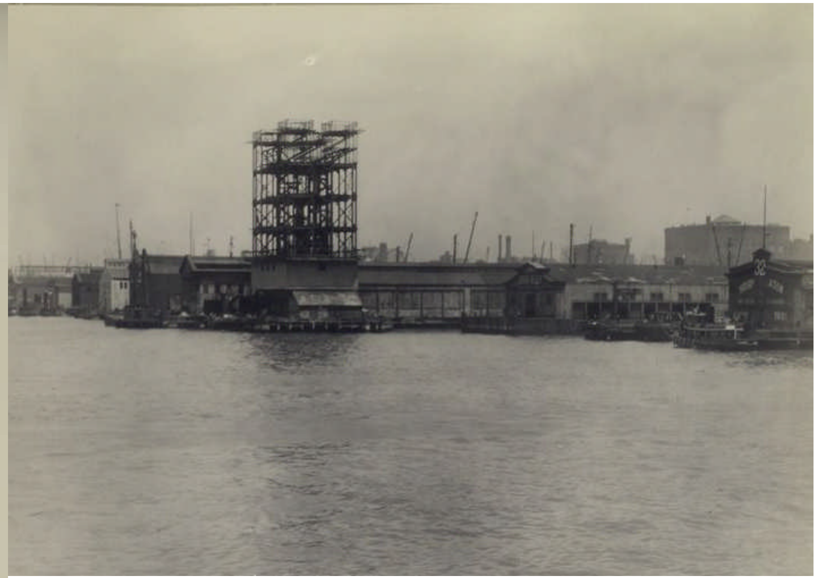
<u>Above</u>: rendering showing operations of sinking New York River Shaft Caisson



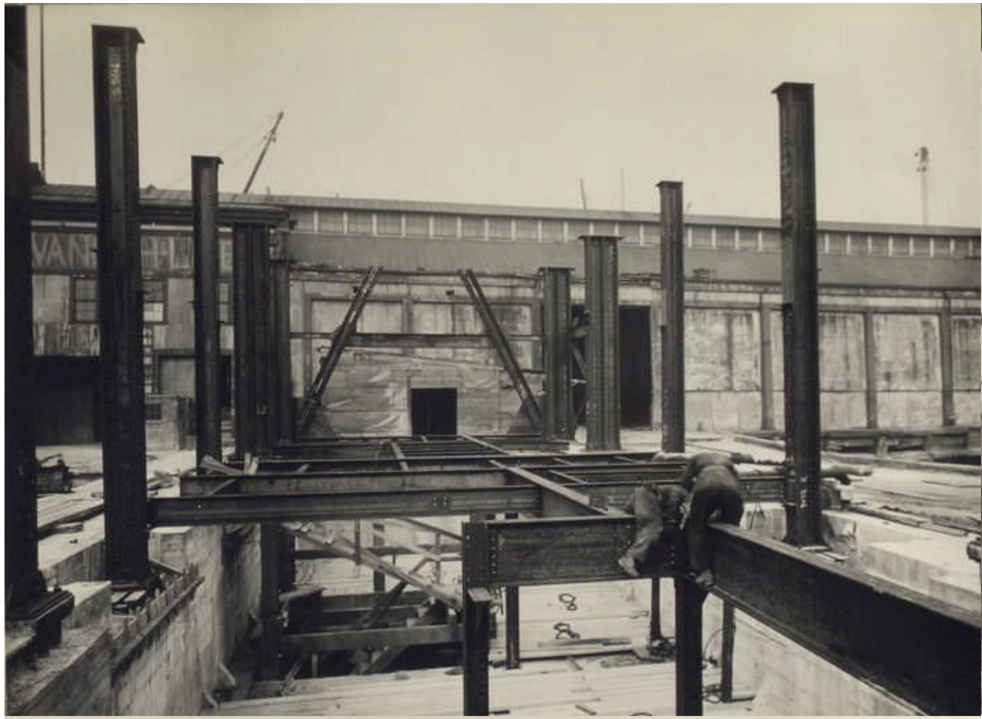



<u>Above L&R</u>: caption: “River Ventilation Building, New York. Erection of steel girders. 3/12/26.”

<u>Left</u>: caption: “River Ventilation Building, New York. Erection of steel to third floor level. 4/20/26.”



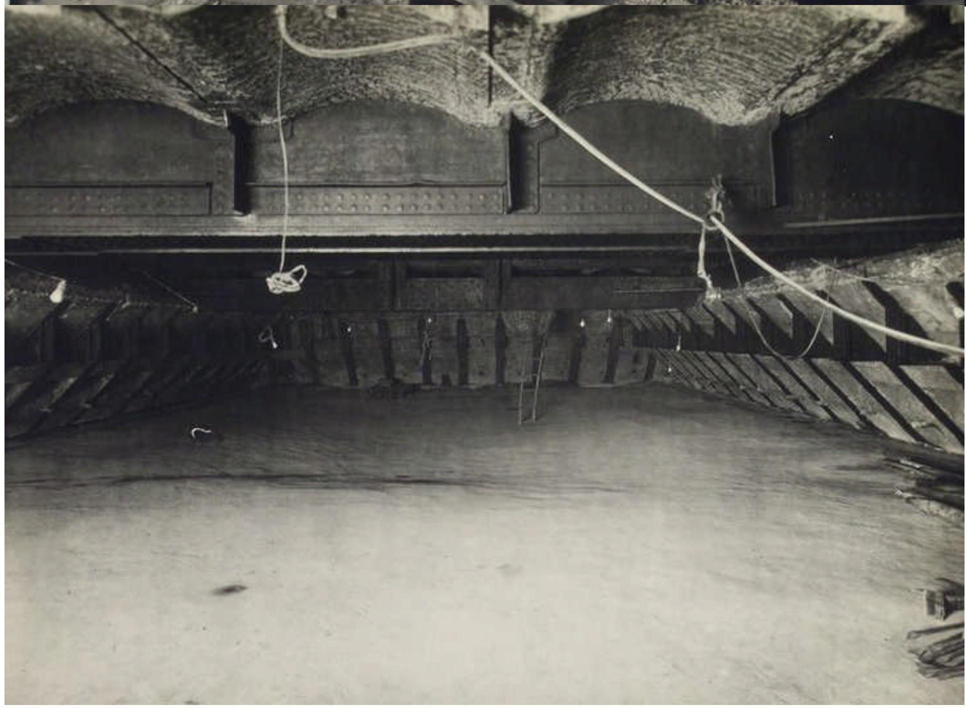
Above: caption: "Steel framing and brick work - River Ventilation Building, New York. 6/10/26."
Left: caption: "River Ventilation Building, N.Y. Erection of steel to fourth floor. 5/4/26."



Top Left: caption: "River Ventilation Building. Steel columns for Pier Deck and mezzanine floors, N.Y., New York. 5/28/26."
Top Right: caption: "Progress of placing electrical conduits in River Ventilation Building, New York. 6/5/26."
Left: caption: "River Ventilation Building, Pierhead Line between Piers 34 and 35, North River, New York. 11/17/26."

"…No excavation was carried on in the working chamber until the cutting edge had penetrated about 9 feet into the mud, as the weight of the caisson displaced the material up to this point. Compressed air was then introduced into the working chamber and the usual shaft mucking operations started. At a depth of 69 feet below mean high water, rock was encountered. This was taken out in lifts about 6 feet deep and the caisson was lowered by successive drops until it reached its final position. The upper half of the outside of the caisson, or the part which is exposed to open water, was covered with waterproofing, which in turn was covered with an 18-inch layer of protection concrete. An additional protection is afforded in the upper portion by a granite facing where the shaft is expose to tidal action…"

RE: excerpt from *The Eighth Wonder*



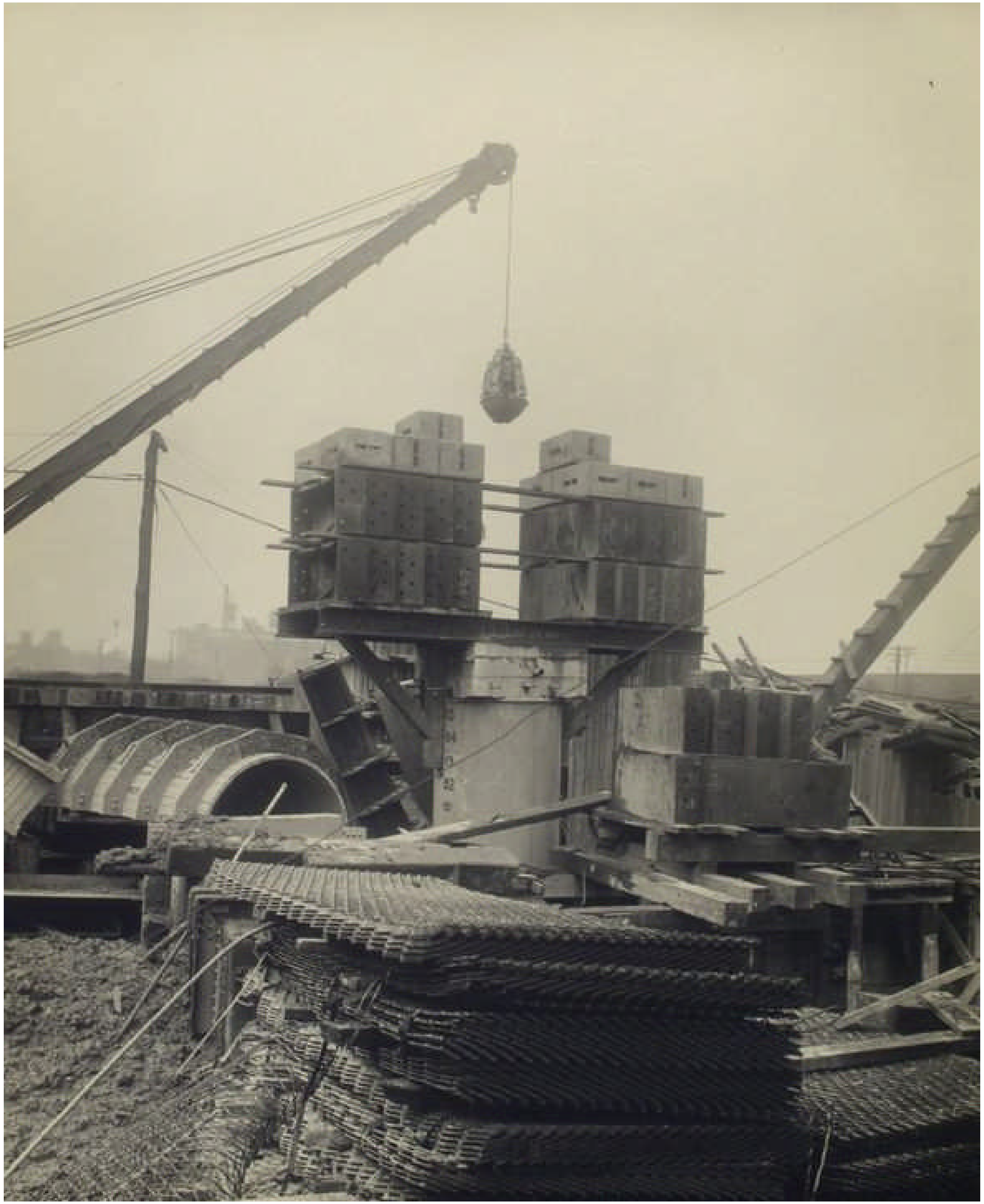
<u>Top Left</u>: caption: "General interior, view of working chamber, New York River Shaft Caisson. 12/20/22."
<u>Top Right</u>: caption: "Working chamber, River Shaft Caisson, New York. 8/22/23."
<u>Left</u>: caption: "Protection Concrete bottom River Shaft Caisson, N.Y. 12/31/23."

"…After the caisson was sealed to the rock and waterproof, the east and west shield bulkheads in both the North and South Tunnel chambers were burned out and both shields were driven through the caisson. A timber and concrete cradle of sufficient strength to carry the shield was erected in each chamber and the shield jacked across. After the shields had progressed a sufficient distance west of the river shaft to permit tunnel bulkheads, these were built in each tunnel and placed in operation. After this, tunneling operations were carried on from the river shaft, releasing the tunnels between the land and river shafts for the placing of concrete lining…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Tunnel shield entering caisson, South tunnel, N.Y. 1/31/24."

NJ Land Shafts



"…The caissons for the north and south land shafts on the New Jersey side were assembled and started sinking in the fall of 1922. After the caissons had passed through the cinder fill of the railroad yard, a timbercrib filled with riprap was encountered which made excavation extremely difficult. The timbers had to be sawed or chopped into short lengths and some of the rock broken up…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Caisson A-2 for foundation's air ducts at land shafts, New Jersey. 5/6/25."

<u>Above</u>: caption: "NJ Holland Tunnel Exit at middle-left of photograph"

<u>Left</u>: caption: "At the time this map was published in 1977, it was already out of date. Note that the Lehigh Valley RR ran along the Morris Canal Basin. The Jersey Central Terminal is shown as it appeared before the construction of Liberty State Park."

NJ Shield Driving

"…The north tunnel shield east and the south tunnel shield west were built first and started out from their respective caissons. After the south tunnel shield west had progressed a sufficient distance to erect a tunnel bulkhead, the face of the shield was bulkheaded and the roof was removed from the south caisson and the south tunnel shield east was erected. As soon as this shield was ready, the roof was replaced on the caisson and the shield was started eastward, so that at the close of 1923 two shields were tunneling eastward, and one westward…"

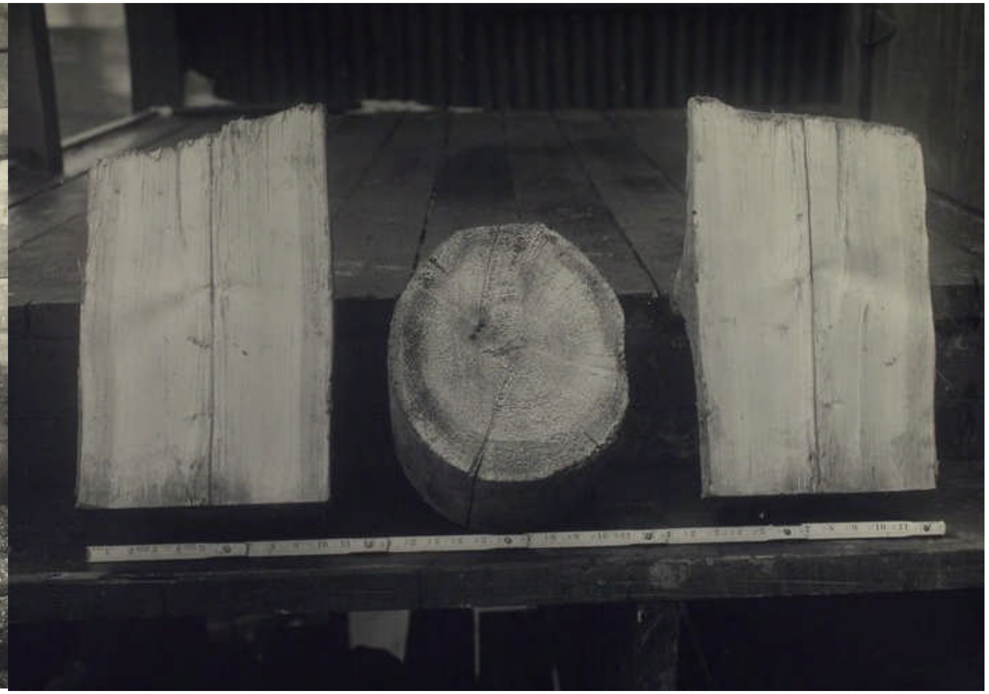
RE: excerpt from *The Eighth Wonder*

"…The method followed in starting these shields out of the shafts was similar to that already described for the New York shields, except that here it was not so difficult as there was adequate cover overhead. After the roof of the working chamber had been replaced, the girders in the side of the caisson, through which the shield was to be advanced, were burned out, after which the plates were removed from the invert to the springing line. The lower pockets of the shield were then bulkheaded and the space between the pockets and the exposed face was filled with clay. After this, the remaining plates were removed, proceeding upward from the springing line. A semicircular annular ring was cleared for the hood and packed with clay into which the hood was forced when the shield was advanced…"

RE: excerpt from *The Eighth Wonder*

"…The material at the face consisted of timber and riprap down to the springing line, similar to the material encountered in shaft sinking, making excavation very difficult. The stones in the crib varied from one-man stones to those three-quarters of a yard in size. The voids between the stones were filled with soft black mud, which did not offer sufficient resistance to prevent the escape of air, necessitating the mudding up of the entire face with clay. As the excavation was carried forward, the escape of air through the heading of the north tunnel at times taxed the full capacity of the power house, 40,000 cubic feet of free air per minute…"

RE: excerpt from *The Eighth Wonder*

"…On June 10, 1923, a small blow occurred at the face of the shield and it became necessary to drop the air pressure sufficiently to allow the water to flow into the tunnel before the blow could be stopped. The progress through the riprap was very slow, as extreme measures had to be taken to avoid blow-outs. After the shield had passed through the old timber and riprap crib, the river bulkhead was encountered which did not offer any unusual difficulties…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "Interior view (in compressed air) North land shaft caisson, N.J. 11-18-22."

Right: caption: "View of old timber pile taken from North land shaft caisson, N.J. 1/10/23."

"…Before tunneling through similar material in the south tunnel east, 5,500 bags of 1:1 Portland cement grout were ejected through the east shield bulkhead of the south caisson and six pipes were sunk from the surface east of the caisson through which 140 bags of 1:1 Portland cement were placed. This grout displaced much of the soft mud and filled the voids in the riprap and greatly facilitated the driving of the shield so that very little air escaped through this material after it had been consolidated in grouting…"

RE: excerpt from *The Eighth Wonder*

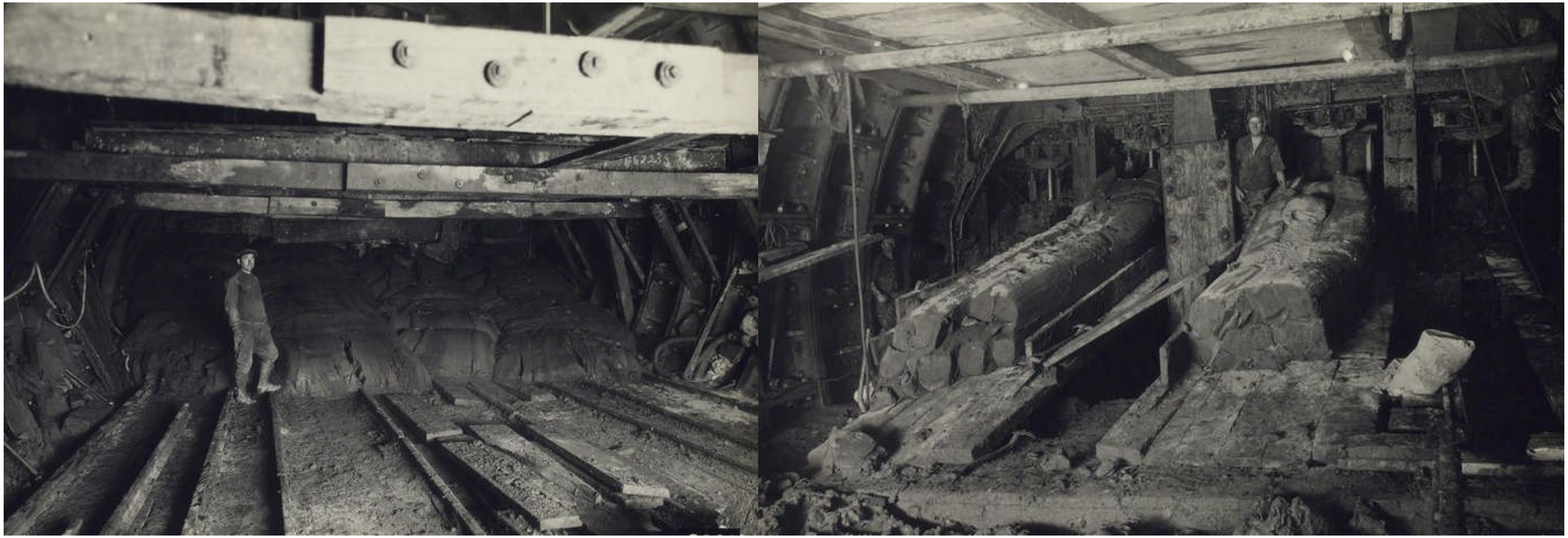
"…After about sixty rings were erected in each tunnel, the shields were stopped to build tunnel bulkheads and to install cages at the shafts and then tunneling was resumed. Immediately east of the river bulkhead soft mud, considerably lighter than Hudson River silt, was encountered in the upper part of the excavation. In this material the tunnel began to rise directly behind the shield and also to move northward…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Tightening Bolts in Tunnel Lining, North Tunnel. By means of ratchet wrench. Each bolt weighs ten pounds."

"…To hold the shield and the tunnel to the proper grade, it was necessary to take in a certain amount of material through the shield. Accordingly, the shield was advanced with the top pockets bulkheaded and a large percentage of the excavation was permitted to enter the tunnel through openings in the lower part of the shield. This material had to be entirely removed after each shove before the erection of the cast-iron lining could proceed and slowed down progress. In addition it was desired to retain this material in the tunnel directly behind the shield so as to increase the weight of the tunnel and reduce the tendency to rise…"

RE: excerpt from *The Eighth Wonder*



"…To meet this situation a different method of tunneling was adopted. The work was stopped and a steel bulkhead semicircular in shape and fitting into the lower part of the tunnel was built to trail about 10 feet behind the shield, and the four pockets of the shield immediately above the springing line were equipped with hydraulically operated doors. When the shield advanced, these doors were opened varying amounts, depending upon conditions, to allow the material to flow through the shield into chutes which cropped the silt back of the trailing bulkhead. This method of tunneling permitted both the shield and the tunnel to be kept on grade…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "North Tunnel East - silt from four pockets below the springing line, New Jersey. 9/13/ 23."

<u>Right</u>: caption: "South Tunnel East - muck coming through doors in shield New Jersey. 12/13/23"

Buried Alive

“Think twice, you only live once”

RE: expression used by the “sandhogs” - the name for the tunnel construction workers. The sandhogs removed mud, blasted through rock and bolted together the rings that formed the lining of the tunnel. They used a total of 115K-tons of cast-iron steel and 130K cubic-yards of concrete to line the *Holland Tunnel*. On a good day, the sandhogs progressed about 40-feet.

“Groping along like so many human moles, the Montague street tunnel crew pushed its way beneath the East river, separating Brooklyn and New York City. One moment the big cutting shield was boring steadily forward - the next, disaster struck with the fury of a tornado. The shield had cut through to the riverbed above! With terrific force the compressed air of the work chamber roared through the slit in the tunnel’s weakened ceiling. Three workmen, stationed near the spot, were scooped up by the force of the giant blast and hurled upward. Like shells from a gun they shot through the rift in the ceiling - up through the waters of the East river - to catapult fifty feet into the air with a force that killed two of them instantly…”

***Modern Mechanix and Inventions,* June 1934**

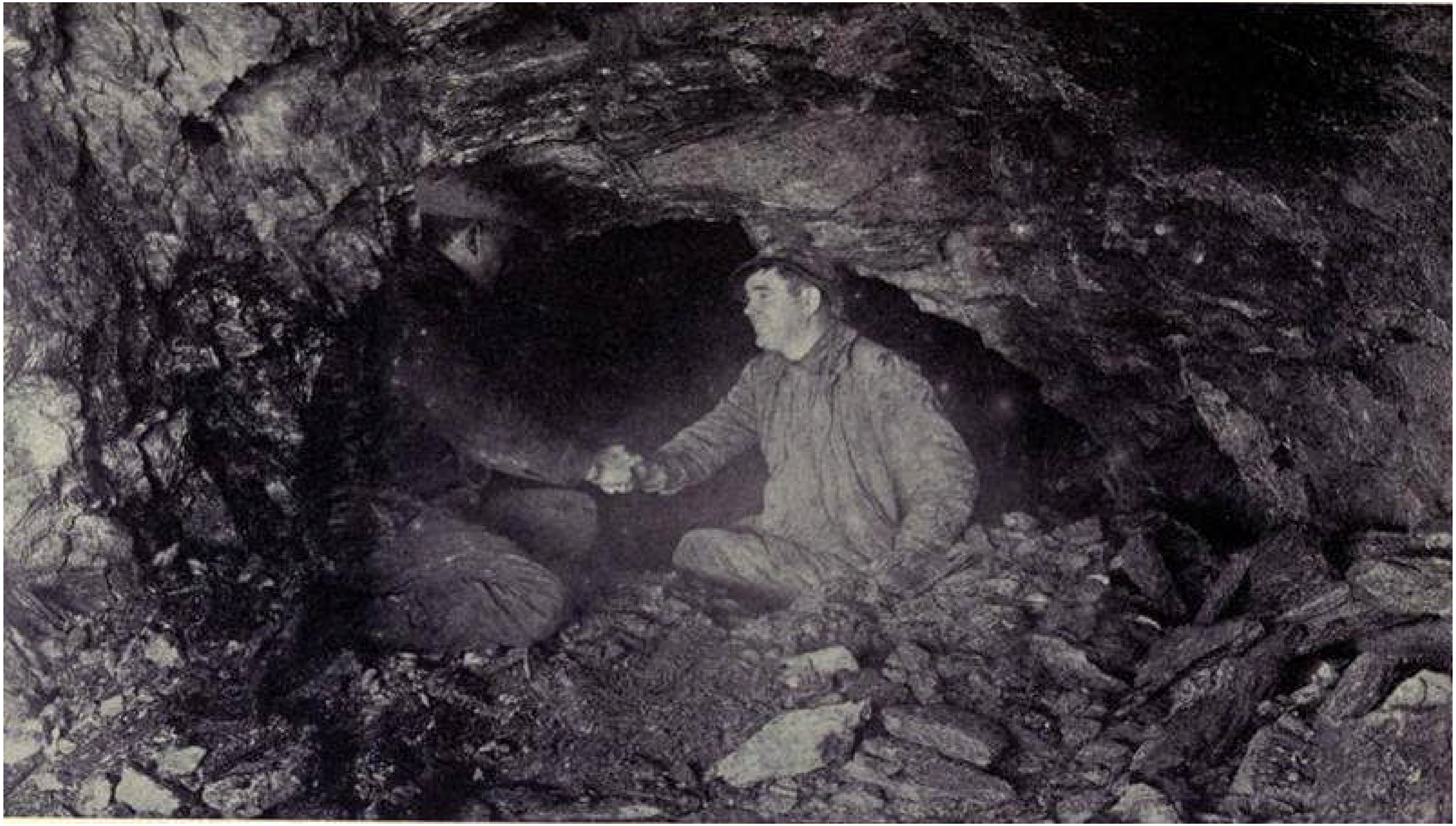
“…Next to these ‘blows,’ as they are called, the dread of the tunnel digger is the premature dynamite blast. During the construction of New York City Water Tunnel No. 2, driven in parts from 500 to 700 feet underground, over fifty workers and technicians were killed and hundreds were wounded. Yet despite the almost constant threat of death, the workers swear fiercely by their hazardous calling. The heritage of danger is handed down from father to son. Take the Redwood brothers, for instance - Harry, Norman and Walter - three rugged, death – defying tunnel shooters whose sons are following in their footsteps even as they followed father, grandfather and great-grandfather before them…”

Modern Mechanix and Inventions, **June 1934**

<u>Above</u>: caption: "Extreme air pressure allows tunnel builders to work only about one hour in five. A crew is shown coming off duty to rest five hours before re-entering the tunnel. Insert shows Walter Redwood, whose career is told in this story."

"…The tunnel-building Redwoods are a famous clan. Expert workmen, they are practically without a peer when it comes to sinking a foundation shaft or driving tunnels through mountains or river beds. Building the Holland Tunnel it was Harry and Norman who jointly superintended the famous and extra-hazardous Holland Tunnel under the Hudson River. When the two huge cutting shields were finally joined - one forging its way from the Jersey side and the other from Manhattan - Harry and Norman reached across the sub-marine and underground boundary lines and shook hands, showing the exact precision with which these men work…"

***Modern Mechanix and Inventions,* June 1934**



<u>Above</u>: caption: "Holing Through! Tunnel superintendent Harry Redwood, of New York side, shaking hands with Norman Redwood, of New Jersey side, North Tunnel"

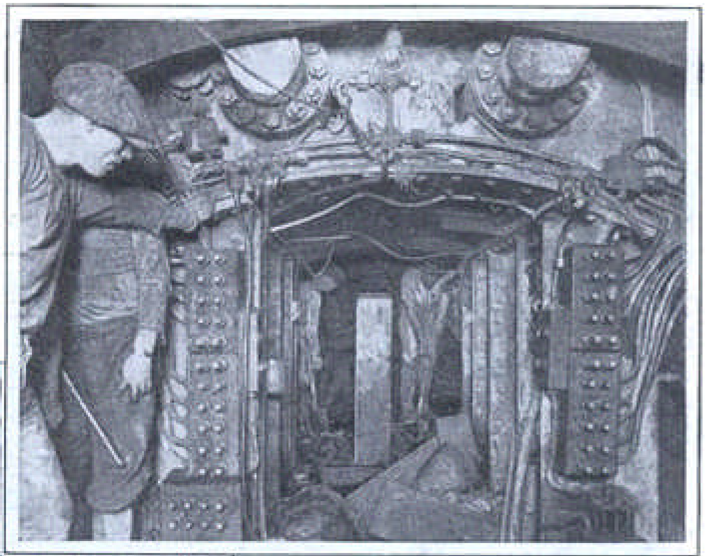
All in the Family

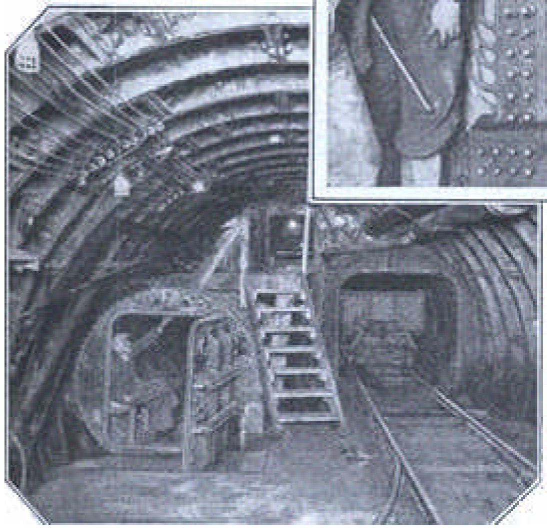
"…When a representative for Modern Mechanix and Inventions visited the Newark spot where the Passaic river bridge is being caissoned, he found eighteen members of the Redwood family working there. Walter, the youngest of the three veterans, finally revealed the history of his tunnel-digging family after considerable prompting had overcome his natural modesty. 'My great-grandfather, Robert Redwood, was first of the line of tunnel borers. We originated in England, you know. Then came my grandfather, also named Robert. He worked in the well-known and historic tunnel from England to Severn, under the water to Wales. My father, William, came by his tunnel-working inheritance quite naturally, and we have all followed suit. My mother's father was also a tunneler, by the way, and so were her eleven brothers. Our sisters are married to sandhogs, and our sons are in the same business. As a matter of fact, there hasn't been an outsider in our family for four generations. If you're not a sandhog, with a sandhog's blood in your veins, then you're not a Redwood. At least, not our Redwoods.'…"

"…Walter Redwood, who is forty-one, started his tunnel career at the age of thirteen in Birmingham, England, on a railroad bore. He was a dynamiter's helper and got five cents an hour for his services. 'In 1910 I came to New York City,' he says. 'There was a demand for tunnel experts in those days and in the following years I worked on practically every important tunnel job in New York City and the rivers which flank it.'…"

***Modern Mechanix and Invention*, June 1934**

Right: caption: "A rear view of the huge shield which is moved forward by a series of powerful hydraulic jacks"





"…'This Newark contract is an air job, calling for work ninety feet under water. Because of the high air pressure under which we work, we put in one hour of actual work while we're off duty the next five. We work just two hours of a twelve-hour day under a pressure of thirty-four pounds to the square inch. This is about as perilous a job as I have ever worked on. We are working in a steel and concrete caisson, eighty by thirty feet. This caisson sinks with my crew of workers. That is, as we dig down and make room, the caisson wedges downward. Every pound of air that we put on takes 250 tons off the weight of the caisson. That is, each pound of compressed air lifts the equivalent of 250 tons weight in pushing the 'deck' or 'ceiling' of the caisson upwards. As soon as the air is dropped two or three pounds, the caisson drops right down. That is the terrific force of its weight. On this job I am in charge of the air-lock. I operate the compressed air instruments and you can easily understand what a slip or a flaw in judgment might mean…"

Modern Mechanix and Invention, **June 1934**

Above: caption: "Above is shown a lock tender with his hand on the air valve which regulates the pressure in the air lock at the head of the stairway. Men enter this lock, where pressure is in-creased one pound per minute, to adjust their bodies to tunnel conditions."

“…‘The most common ailment from which the sandhog suffers is the ‘bends.’ This malady also affects deep-sea divers. It comes from a too sudden change in pressures. Either going from normal to under-pressure or vice versa has been too fast, and you get air-bubbles in your blood, preventing the normal flow. When the sandhog reports for work, he goes down the shaft and enters the air-lock. He sits there as the lock-tender works the pressure up to a point equal to that in the tunnel. The highest pressure he can work under is fifty pounds to the square inch. Under these conditions, he works for just half an hour, resting for the next five. After his time is up in the tunnel, the worker enters the airlock again where the pressure is reduced gradually until it is the same as that above ground.’…”

Modern Mechanix and Invention, **June 1934**

"…'Here is how we go about burrowing underground, and under a river at that. Deep shafts are sunk on either side of the river and elevators are built into them. A huge circular shield of steel about twenty feet in diameter is then lowered into each shaft. Working toward each other from their opposite terminals, the shields are started forward, pushing through rock, mud and gravel under the mighty force of compressed air. A meeting-place for the two shields has been designated at a point midway under the river. As the shield pushes its hood through the course of the proposed tunnel, the passage is filled with debris which the sandhogs tackle with pick and shovel and load onto cars which carry it back to the elevators where it is removed to the surface. When the tunnel is being driven, big steel rings, made up of radial plates, are bolted into place to form the strong ribs of the tunnel. When this set of rings is finished, the shield is then moved forward again, and then more rings are bolted into place. This process continues until the tunnel is holed through.'…"

Modern Mechanix and Invention, **June 1934**

Left: caption: "Artist's drawing: sinking of the preliminary shaft"

Blood Money

"…The average sandhog gets $7.50 an hour, or $15 for a two-hour day. The eldest of the Redwoods, Harry, has often been paid $100 a day for his services. But although the rewards are high, the penalties are even higher. Death lurks in the underground caverns and no man knows, going down to the airlock in the morning, whether or not he will return safely again that night…"

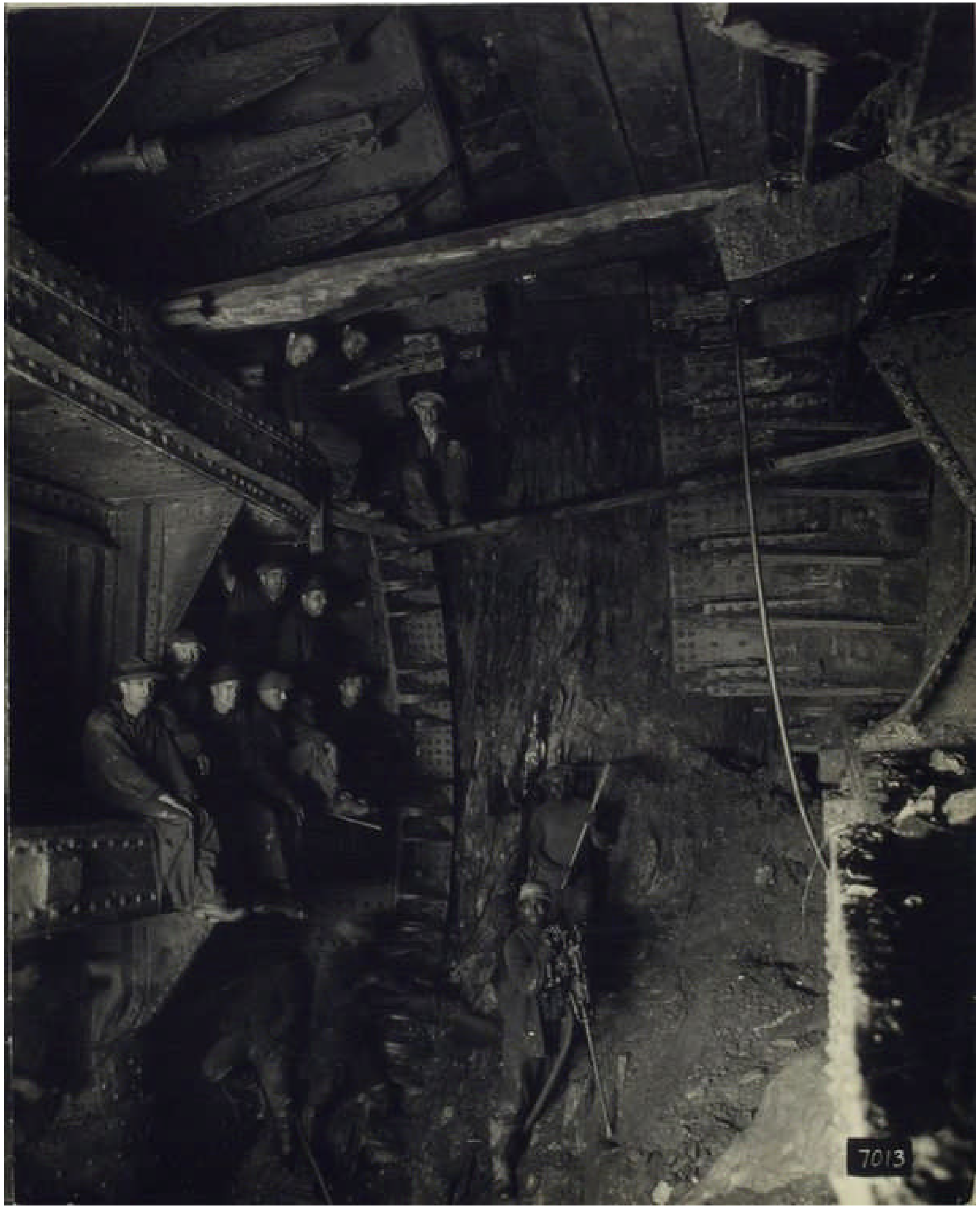
***Modern Mechanix and Invention,* June 1934**

RE: a total of fourteen workmen died during the seven years of construction for the *Holland Tunnel*

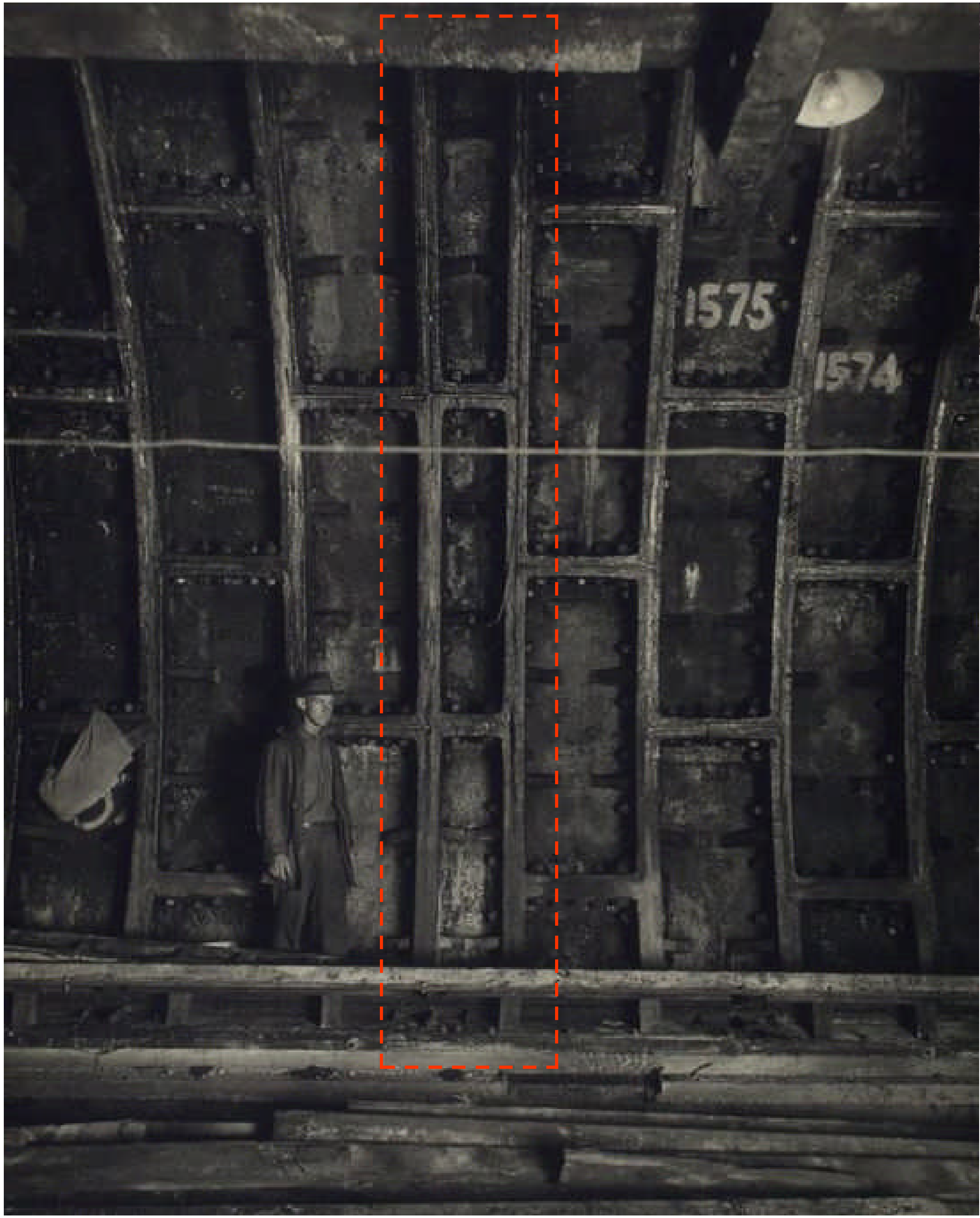
Junction

"…On October 22, 1924, shield driving was suspended in the North Tunnel from the New York side and a bottom heading or junction drift was started to meet a corresponding drift from the New Jersey heading. On October 29, the rock barrier remaining between these headings was blasted away. After this all tunneling operations were conducted from the New York side, as the junction was much nearer the New York shaft. The South Tunnel headings were joined on December 7, 1924. Work on the New York side was suspended and the New Jersey shield driven to meet the New York shield…"

RE: excerpt from *The Eighth Wonder*



<u>Left</u>: caption: "North Tunnel - New York and New Jersey shields the day prior to their junction"



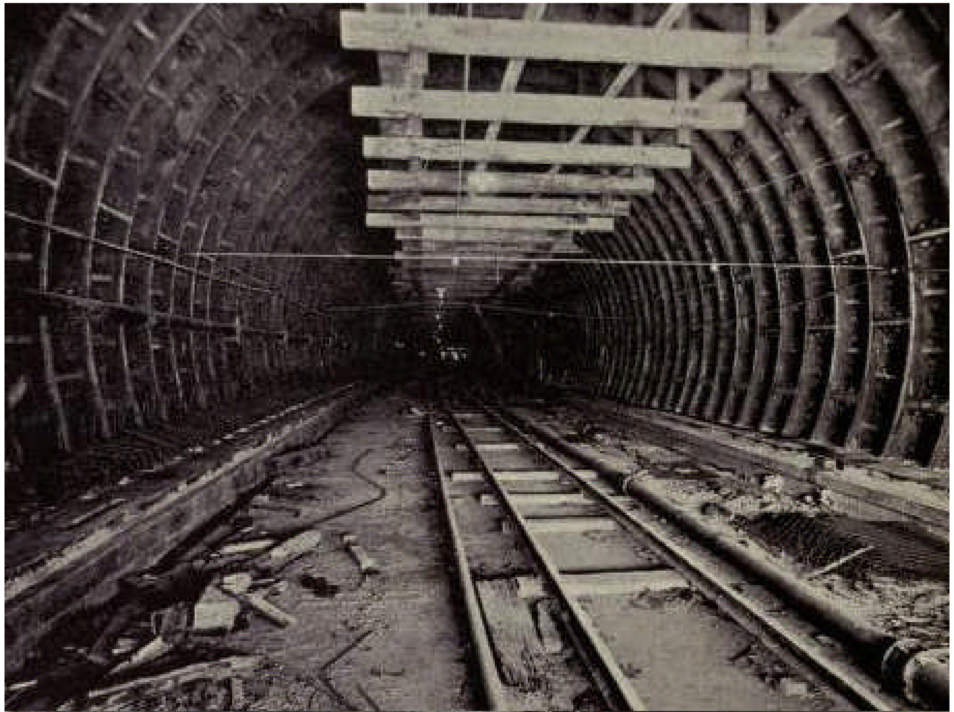
<u>Above</u>: caption: "Curve in South Tunnel, Under West Street, New York City (Radius 1,000 Feet). Showing completed rings of cast-iron lining"

<u>Left</u>: caption: "Closure Ring. North tunnel between N.Y. and N.J."

Concrete Lining

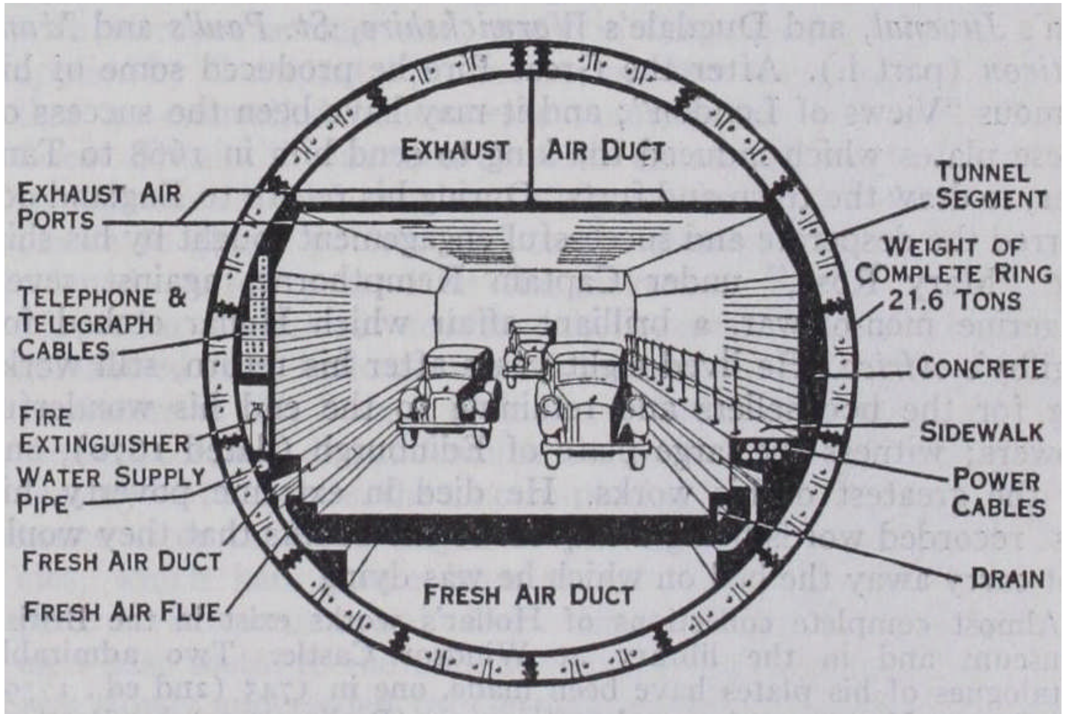
"…In July, 1924, the placing of the concrete lining forming the roadway and air ducts was started on the New York side in the North and South Tunnels between the land and river shafts. The concrete invert was first placed in both tunnels from the land shafts to the river shafts. The remaining concrete was then poured in nine operations. Five types of collapsible steel forms in 60-foot sections, afterward increased to 75 feet, supported and moved by carriages resting on previously placed concrete, were used…"

RE: excerpt from *The Eighth Wonder*

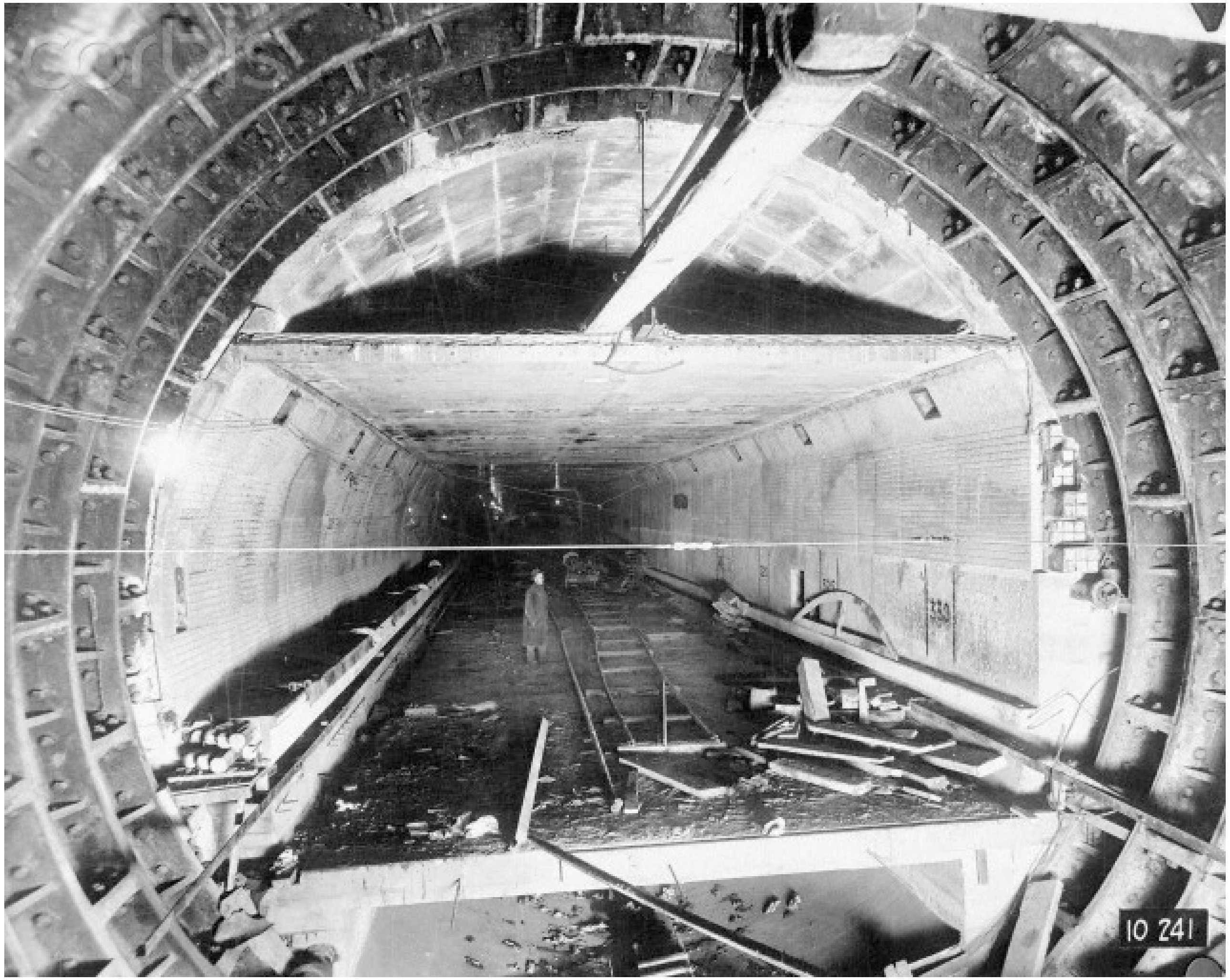


<u>Top</u>: caption: “Concrete Roadway. Beginning of side-walk, and reinforcing of side-walk, North Tunnel. View shows construction track on roadway and roof rebolting and caulking platform.”

<u>Bottom</u>: caption: “Concrete roadway, sidewalk and north wall with low tension ducts (Spring Street). North Tunnel, west of Washington Street, New York. 9/19/24.”


EXHAUST AIR DUCT
EXHAUST AIR PORTS
TUNNEL SEGMENT
WEIGHT OF COMPLETE RING 21.6 TONS
TELEPHONE & TELEGRAPH CABLES
CONCRETE
FIRE EXTINGUISHER
SIDEWALK
WATER SUPPLY PIPE
POWER CABLES
FRESH AIR DUCT
DRAIN
FRESH AIR FLUE
FRESH AIR DUCT

<u>Above</u>: caption: "Arch form, South Tunnel East, N.J. 3/25/25."
<u>Left</u>: caption: "Concreting methods, ceiling slab. North Tunnel East, Ring 350, N.J. 4/1/25."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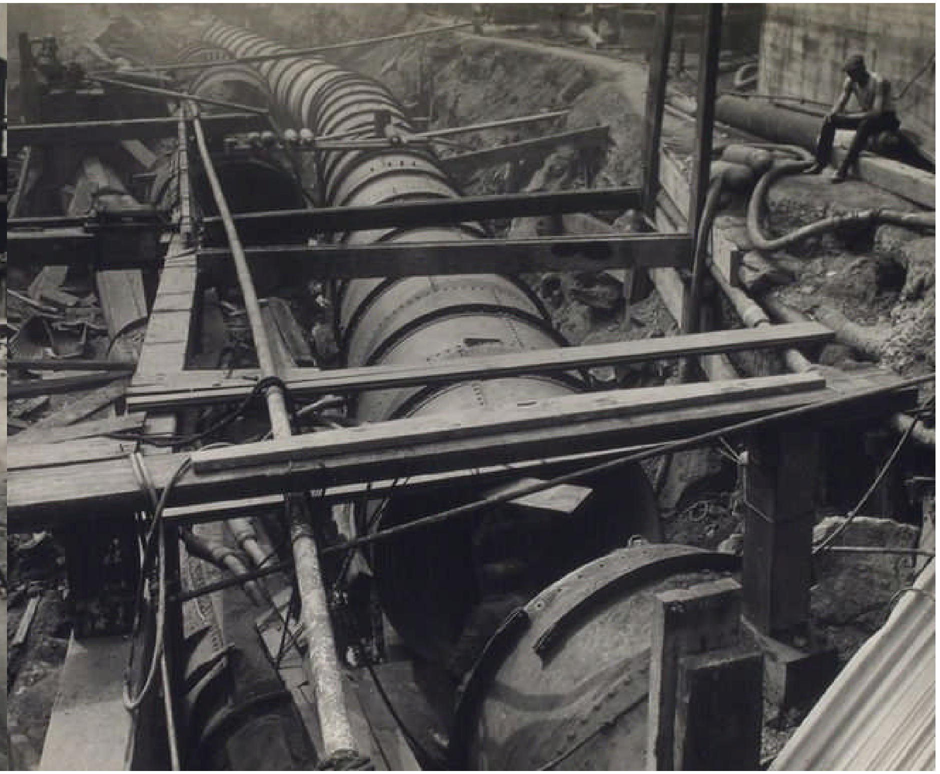
Approach Tunnels

"…The approach tunnels from the land shafts to the open approaches at Dominick and Hudson Streets, New York City, and at Provost Street, Jersey City, were built by the cut and cover method as usually em-ployed in subway construct-ion…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "1926 - Holland Tunnel Construction, New York Entrance"

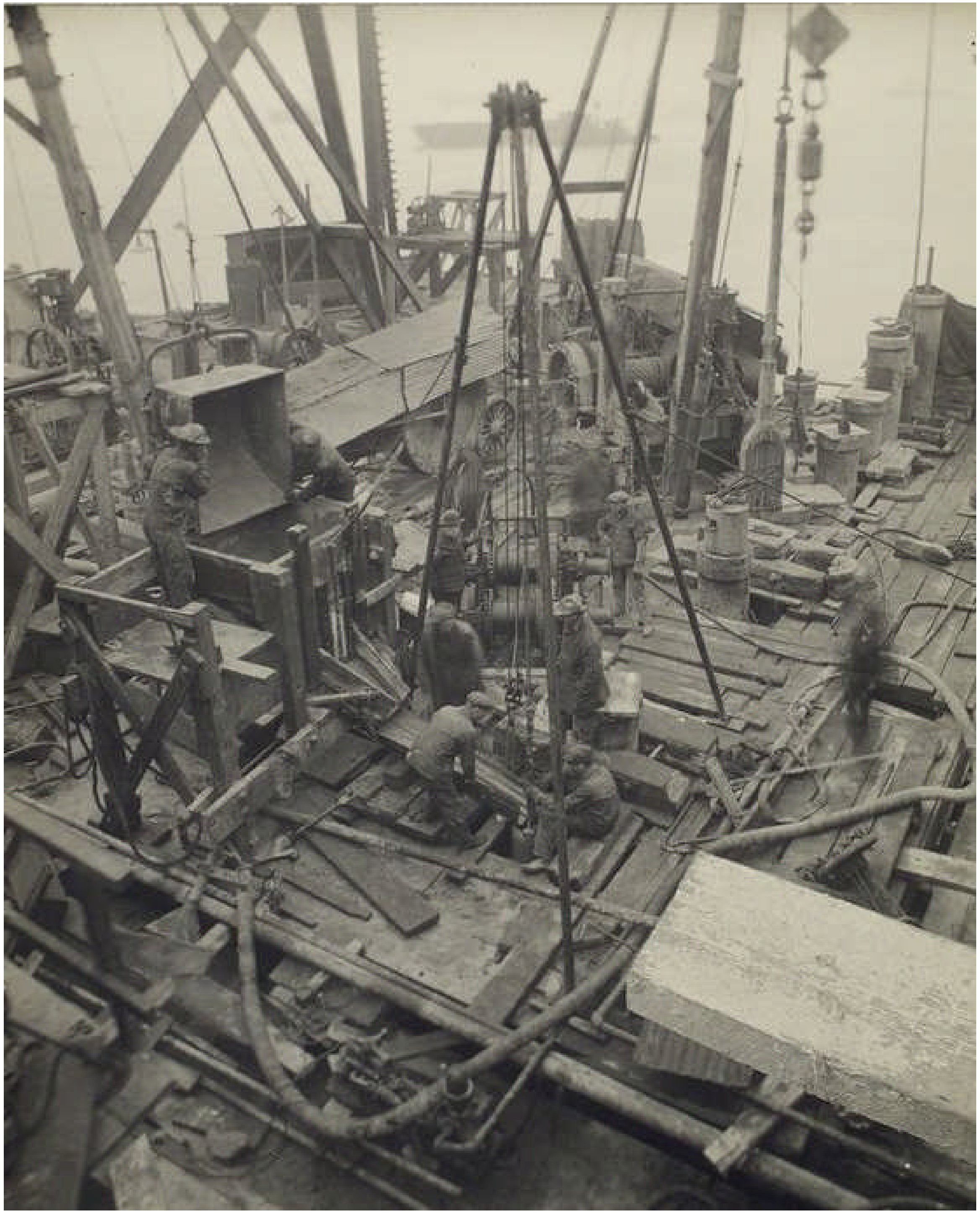


<u>Top Left</u>: caption: “Completed portion 5’ steel sewer, Jersey City, N.J. 5/21/25.”
<u>Top Right</u>: caption: “Reconstruction of 8’ steel sewer to clear way for South Tunnel approach. 6/3/25.”
<u>Left</u>: caption: “North approach, west of portal, Jersey City, N.J. 6/3/25.”

NJ River Caissons

"…The distance between the tubes on the New Jersey side required the sinking of two separate river ventilating shafts. This presented a problem due to depth of the bedrock, 250 feet as compared with 70 feet on the New York side. It was considered that the silt which overlies the bedrock would not afford satisfactory support. Accordingly, it was decided to support the shafts by means of steel casings 24 inches in diameter, filled with reinforced concrete, extending from the bottom of the shafts to ledge rock. They were made in lengths of 20 feet, threaded at both ends for couplings. Three lengths were connected and one end lowered into the silt. The silt inside the pipe was then loosened by churning with a 2,000 pound bit, and the mud and water bailed out. Excavation was continued in this manner to a depth of approximately 20 feet below the bottom of the pipe. The material was firm enough to prevent caving into the hold. Another section of pipe was then added and the entire section driven into the hole previously excavated…"

RE: excerpt from *The Eighth Wonder*



<u>**Left**</u>**: caption: "Rein-forced Concrete piles, South River shaft. New Jersey. 5/15/23."**

"…River-shaft caissons were built, launched, floated into position, and sunk, as on the New York side…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "New Jersey River Shaft Caisson, just after leaving the Ways. Caisson launched at Mariner's Harbor, S.I., floated into position and sunk."

<u>Right</u>: caption: "View of launching of New Jersey (north) River Shaft Caisson. Staten Island Shipbuilding Co.'s Plant, Mariner's Harbor, S.I. 1/3/23."

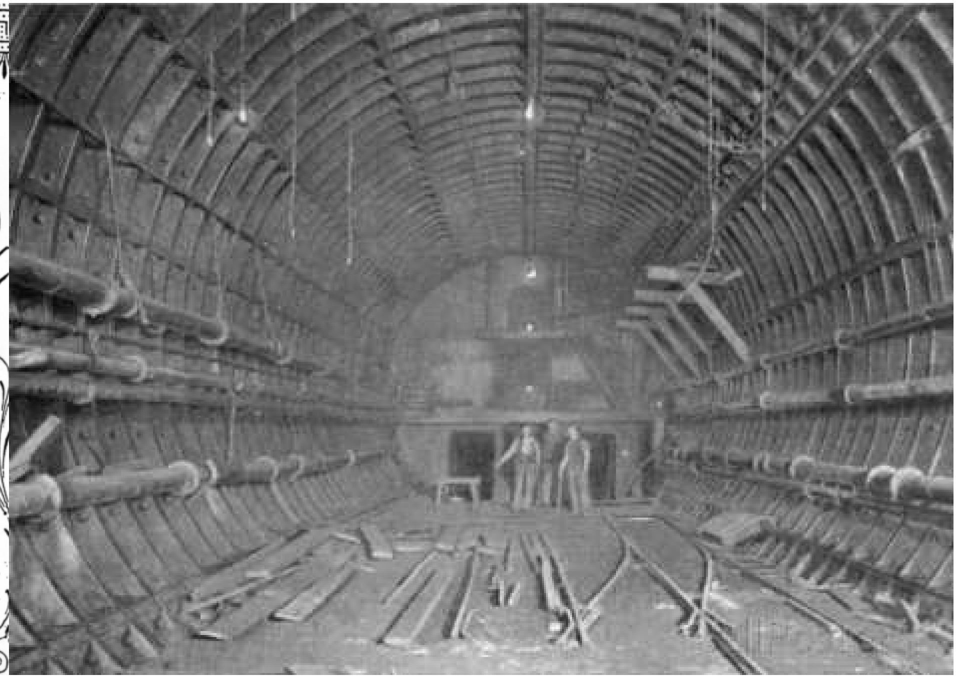
Part 8

The Lungs of the Tunnel

The Problem

"…The problem of ventilation of the Holland Tunnel was unlike any heretofore solved, both in character and magnitude. The only existing vehicular tunnels even approximately comparable to the Holland Tunnel are the Blackwall and Rotherhithe Tunnels under the Thames at London…"

RE: excerpt from *The Eighth Wonder.* Tunnels under the *Hudson River* were not new (the first trans-Hudson rail tunnel opened in 1910). However, the much larger diameter of vehicular tunnels, combined with the effects of vehicle exhaust on occupants, especially for those stuck in traffic inside the tunnel, presented new and challenging problems.



"…The Blackwall, opened for traffic in 1897, has an under-river length of 1,221 feet between shafts. It consists of a single tube 27 feet in diameter with a roadway acc-ommodating one line of traffic in each direction and two sidewalks. Traffic counts in 1920 showed that the maximum number of motor vehicles using the tunnel was less than 100 per hour…"

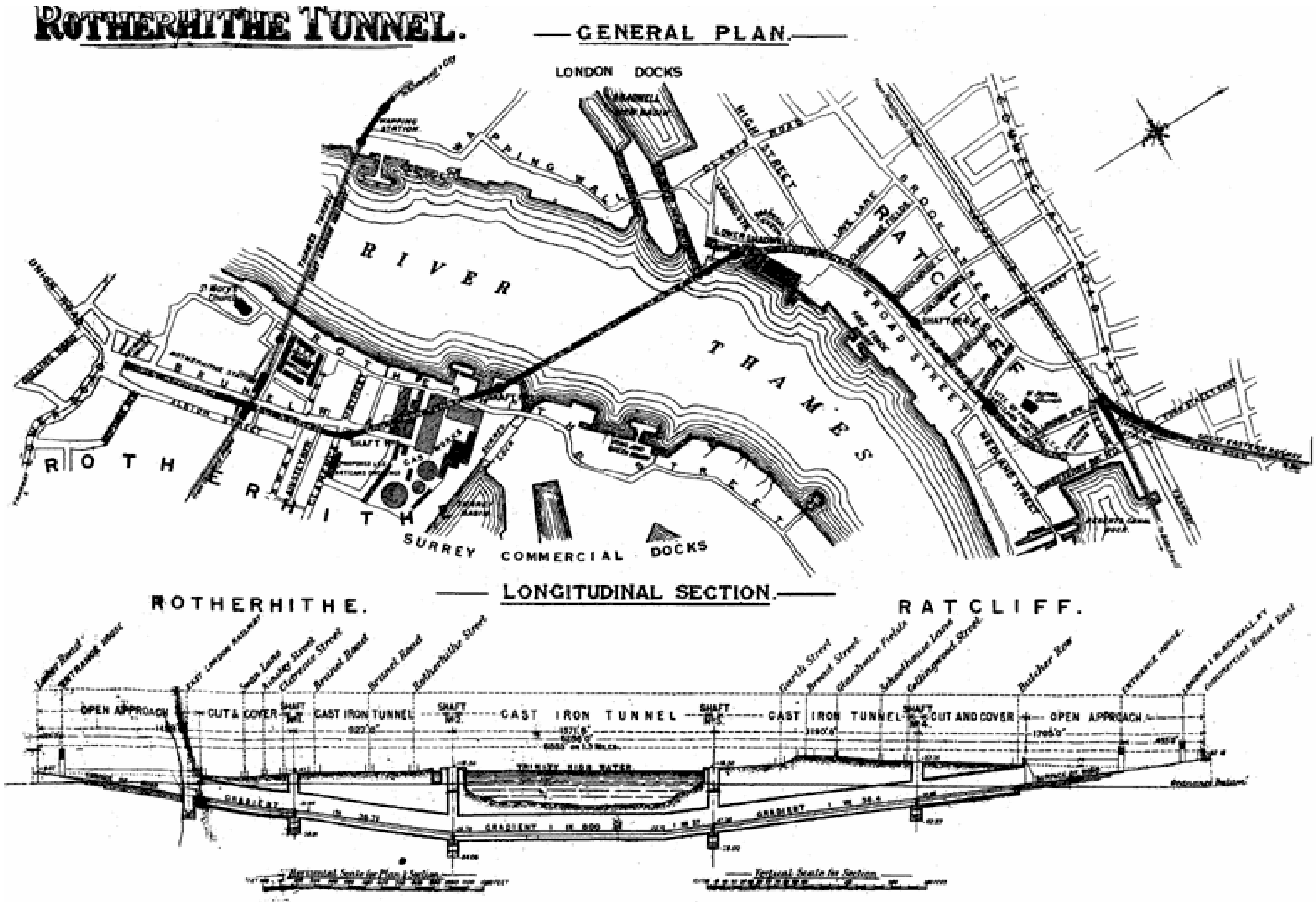
RE: excerpt from *The Eighth Wonder*

Left: caption: "Invitation to inspect the completed sub-aqueous portion of the Blackwall Tunnel"

Right: caption: "Interior of the Blackwall Tunnel during construction"


POPLAR


BLACKWALL TUNNEL
LONDON COUNTY COUNCIL
COMMENCED IN 1892
AND OPENED IN 1897
BY HIS ROYAL HIGHNESS
THE PRINCE OF WALES
HER MAJESTY THE QUEEN



"…The Rotherhithe is 30 feet in diameter, similar to the Blackwall in traffic facilities, with an under-river length between shafts of 1,570 feet. Both of these tunnels are ventilated by the natural movement of air through the shafts and portals…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Rotherhithe Tunnel General Plan and Longitudinal Section"

"…The Holland Tunnel, with a total length of 9,250 feet, an under-river length of 5,480 feet, and a capacity of 1,900 vehicles per hour in each direction, or 46,000 per day, obviously required something more than natural ven-tilation. To this end the ventilation of the tunnel was studied under three heads:

1. ***The amount and composition of exhaust gases from motor vehicles;***
2. ***The dilution necessary to render the exhaust gases harmless, and;***
3. ***The method and equipment necessary for adequate ventilation…"***

RE: excerpt from *The Eighth Wonder*

"…The impurities in the atmosphere of a tunnel used by motor vehicles are the product of the combustion of gasoline. If complete combustion occurred, the carbon content would be in the form of carbon dioxide, which can be tolerated in considerable quantity without injurious effects. In a gasoline engine, however, complete combustion seldom, if ever, takes place. The exhaust gases contain varying amounts of carbon monoxide, depending on such variable factors as the quality of the gasoline, conditions of carburetion, etc…"

RE: excerpt from *The Eighth Wonder.* Prior to construction, Holland's design team (headed by *Ole Singstad*) tested vehicles within closed chambers. After testing volunteer occupants in the cars to determine the effect of the fumes, the design team determined that air containing 0.5% carbon monoxide would be lethal.

A Highly Poisonous Gas

"…Carbon monoxide is a highly poisonous gas, injurious to health in minute quantities if breathed for a long time, and if present in large quantities is injurious even when breathed for a short time. Ventilation requirements are determined by the quantity of this gas in exhaust gases. If sufficient fresh air is supplied to reduce this gas to a safe percentage, other gases and impurities, such as carbon dioxide, methane, and smoke, will also be diluted sufficiently. The first consideration, therefore, was to determine the amount of carbon monoxide that would be liberated in the tunnel…"

RE: excerpt from *The Eighth Wonder*

“Only a small amount of experiments had been made on engine gases, and these results did not give the information necessary to serve as a basis for the planning of the ventilation of the tunnel”

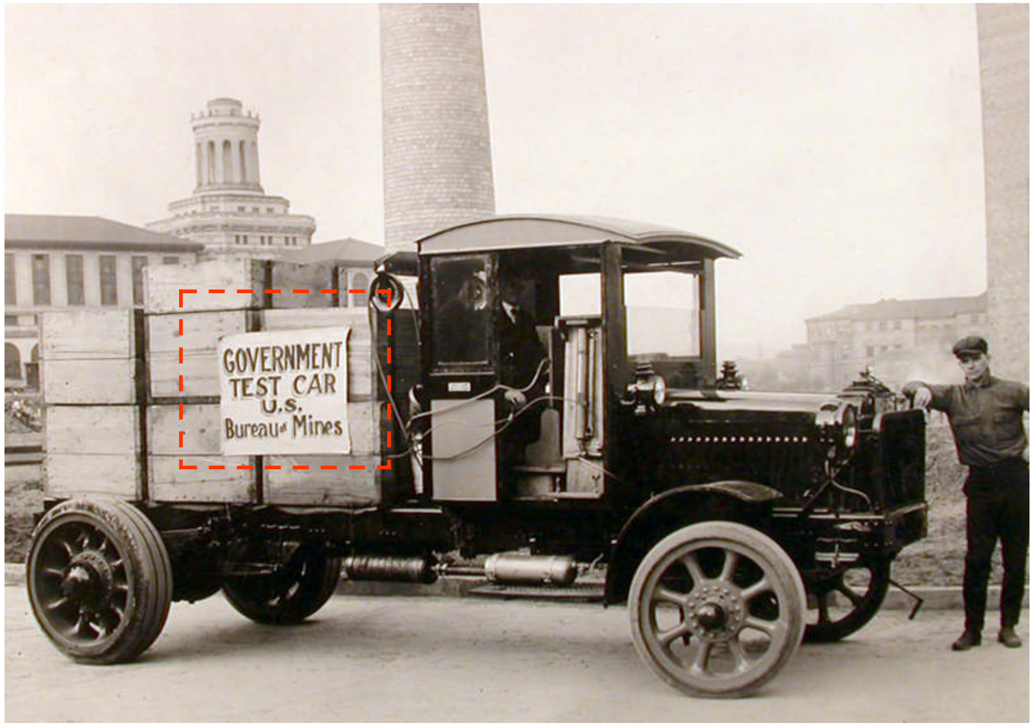
Ole Singstad, **Design Engineer**

"…Investigations were carried out at the Bureau of Mines Experiment Station at Pittsburgh. The schedule called for the testing of passenger cars and trucks of various makes and capacities. The tests were made with car loaded and light, standing with engine racing and idling, accelerating from rest on level grade and on maximum grade, running at three, six, ten, and fifteen miles per hour on level and up and down a grade of 3½% corresponding to the maximum tunnel grade. A total of 101 cars were tested. Gas samples were taken directly from the exhaust pipe throughout the entire duration of the test…"

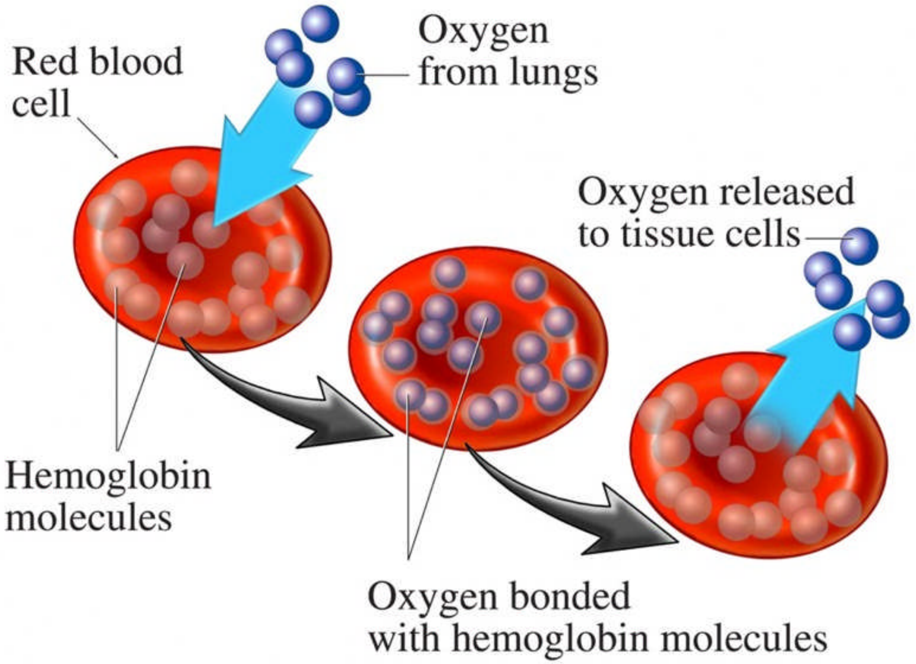
RE: excerpt from *The Eighth Wonder*

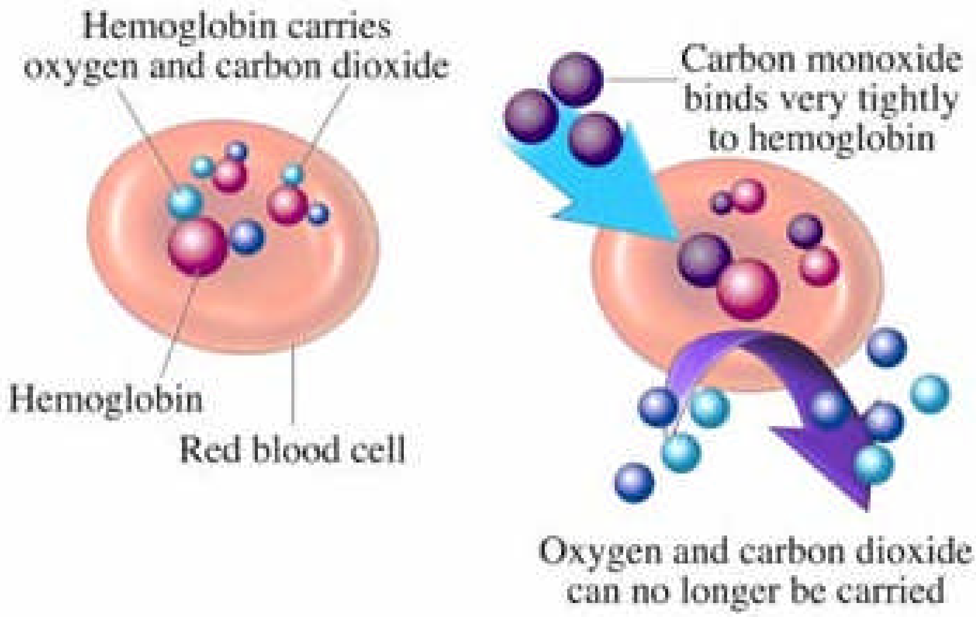
"…In general, the results showed that the exhaust gases contained about 6.8% carbon monoxide and 8.4% carbon dioxide, developing only 67% of the heat value of the gasoline. About one-third of the gasoline fuel was wasted through incomplete combustion. Experiments to determine the proper dilution to render the exhaust gases harmless were conducted at the Bureau of Mines Experiment Station at Yale. They were performed in a gas-tight chamber of 226 cubic feet capacity. Members of the staff spent periods of one hour in air containing amounts of carbon monoxide varying from two to ten parts in 10,000. In addition, tests were performed in a chamber of 12,000 cubic feet with an automobile engine exhausting into the chamber. The duration of all tests was one hour, whereas the length of time required to travel through the tunnel at a speed of only three miles per hour is but 31 minutes…"

RE: excerpt from *The Eighth Wonder*



In the early 1920s, the *New York and New Jersey Tunnel Commission/s* consulted the *U.S. Bureau of Mines* (USBM) on how to prevent deadly concentrations of exhaust fumes inside the tubes of the new *Hudson River* vehicular tunnel. The USBM's mining safety research in *Pittsburgh* had yielded extensive knowledge of tunnels and poisonous gases, thus it was well positioned to offer advice. The Tunnel Commission/s and the USBM embarked on a ventilation research program that resulted in the most comprehensive set of data and analyses that had ever been prepared on automotive exhaust gases and underground air circulation. The *Brockway* 5-ton truck shown above was one of over one-hundred vehicles USBM staff road-tested through the city's streets.





"…The results of the test showed that when an automobile engine is running properly, the exhaust contains no substance that is injurious to any appreciable extent except carbon monoxide. Gasoline engines with cylinders missing, or when cold, over-supplied with oil or gasoline, or smoking from any cause, may throw off disagreeable vapors irritating to the eyes and nauseating to some persons. The physiological effects of carbon monoxide are wholly due to the union of this gas with the hemoglobin of the blood. To the extent that hemoglobin is combined with carbon monoxide, it is by that amount incapable of transporting oxygen to the body. This combination of carbon monoxide with the hemoglobin is reversible, so that when a person returns to fresh air the carbon monoxide is gradually eliminated…"

Ole Singstad, **Design Engineer**

"…Of all physical signs and tests of carbon monoxide poisoning, headache proved the most definite and reliable. Concentrations of gas too weak or periods of exposure too short to induce a headache are to be considered harmless. No one had this symptom to an appreciable degree after a period of one hour in the chamber with four parts of carbon monoxide. With six parts the effect was usually very slight, while with eight parts there was decided discomfort for some hours. Hence a uniform concentration of four parts carbon monoxide in 10,000 of air is designed to afford not only complete safety, but also comfort and freedom from disagreeable effects…"

Ole Singstad, **Design Engineer**

Above: caption: "Effects of Carbon Monoxide Poisoning"

The Longitudinal Method

"…By the longitudinal method of ventilation, the entire tunnel would be utilized as a duct for conveying air through the tunnel. Sufficient air would be supplied through blower fans near one portal and would enter the tunnel through a nozzle or nozzles at a velocity sufficient to force it through its entire length…"

RE: excerpt from *The Eighth Wonder*

"…if in a 29-foot tunnel the air were introduced into the north tube near one portal through a nozzle having a cross-sectional area of 74 square feet, and were exhausted through the opposite portal, the air would have a nozzle velocity of about 282 miles per hour. This would produce a velocity of 72 miles per hour at points where the roadway was occupied by a pleasure car and a truck abreast, or a velocity of 51 miles per hour where there were no vehicles. Such air velocities would be prohibitive in a vehicular tunnel, and the power required to handle the air would be excessive…"

RE: excerpt from *The Eighth Wonder*

<u>Above</u>: caption: "Portal Entry (Manhattan), Holland Tunnel"

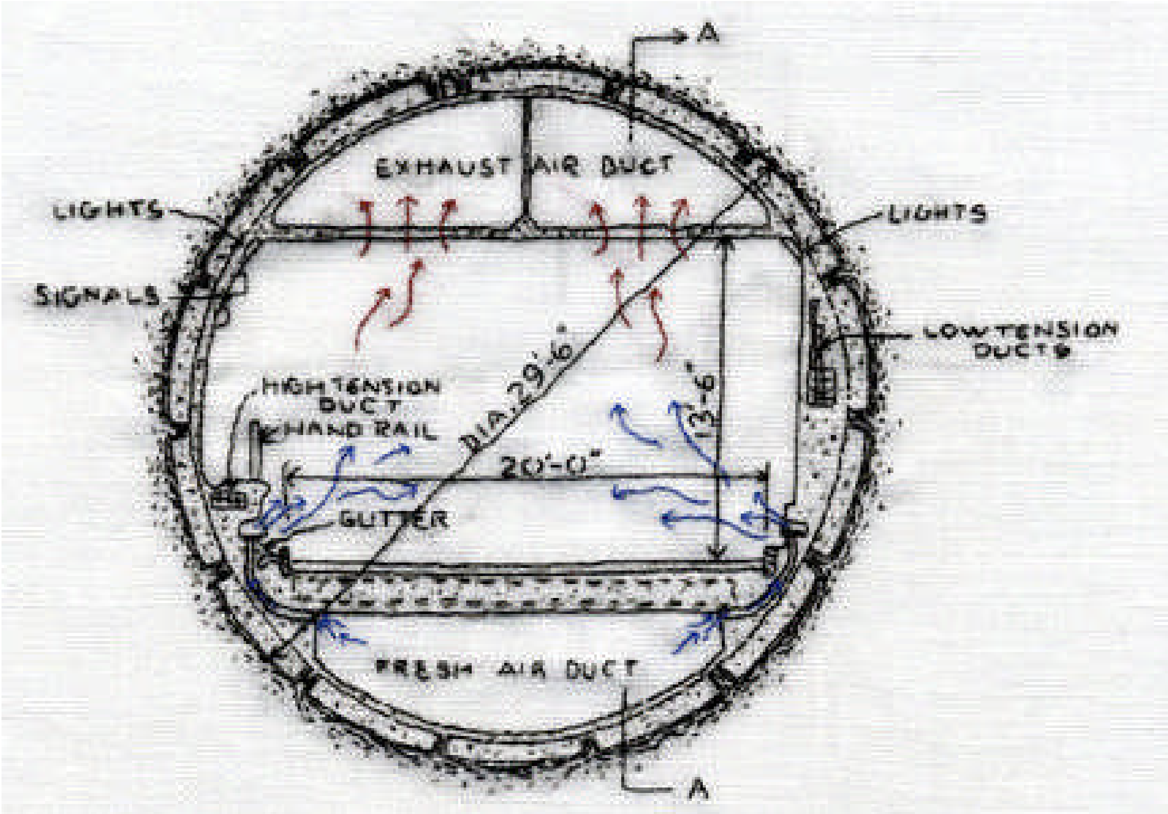
The Distributive Method

"…In the distributive method of ventilation adopted for the Holland Tunnel, the air is introduced into and exhausted from the tunnel through a number of openings at frequent intervals leading from the tunnel road-way. By this method fresh air is supplied at all points throughout the tunnel. The air at any point can be controlled. There is no discomfort or danger from high-velocity air currents. The ventilation is not affected by traffic or the direction of the wind. Exhaust gases are quickly diluted and removed. The space above and below the tunnel roadway is ideally suitable for air ducts. Fresh air, supplied by blower fans at the shafts, is discharged from the main duct under the roadway through adjustable openings into continuous expansion chambers on each side, thence through a continuous slot into the roadway. The air remains in the tunnel an average of one and one-half minutes as it slowly ascends to the ceiling…"

RE: excerpt from *The Eighth Wonder*

“In a tunnel of circular cross-section with the roadway located at an elevation giving maximum clearance for vehicles, there is space available for ventilating ducts both below and above the roadway, one for the fresh air and the other for the vitiated air…the methods of transverse air movement investigated were practicable for tunnel ventilation and that the best method from the standpoint of power saving and safety against fire hazard was the one in which the air is introduced from the duct under the roadway and exhausted through the duct above the ceiling”

Ole Singstad, **Design Engineer**



"…'Gale-jacketing' was the answer. A pumping chamber between the roadway floor and the circular outer shell of the tube and an exhaust chamber in the space between the ceiling and the top of the shell contain roaring air streams. The good air enters the tunnel from vents near the floor and is sucked up through exhaust vents overhead. Powerful blower fans in buildings on shore change the air completely 42 times an hour - about once every minute-and-a-half!..."

***Mechanix Illustrated,* June 1941**

"…Exhaust fans located in the same buildings with the blower fans draw the vitiated air through ports in the ceiling and thence through the upper duct above the roadway, delivering it through stacks to the outer atmosphere…"

RE: excerpt from *The Eighth Wonder*

Above: caption: "Vitiated air duct, North Tunnel, west of Spring Street Shaft, New York"

Coefficient of Friction

"…Experiments to determine the coefficient of friction for flow of air in concrete ducts, to verify formulae used in computing the power required for moving air through a duct from which air is taken off at intervals, and to determine the power losses in bends or elbows in concrete air ducts were conducted at the engineering experiment station at the University of Illinois. A concrete model, the linear dimensions of which were one-half those of the lower duct of the tunnel, and 300 feet in length, was used for direct tests. Outlets with adjustable shutters to control the flow of air were provided at uniform intervals on each side. Measurements of air velocity and static pressure were made at three locations in the duct, one five feet from each end and one midway. Tests were run with all side ports closed and port pockets open at various intervals, and with air velocities ranging from 1,000 feet to 6,000 feet per minute. A total of 186 blowing tests and 17 exhausting tests were run from which to determine the coefficient of friction…"

RE: excerpt from *The Eighth Wonder*

In designing the ventilation equipment it was necessary to know the *Coefficient of Friction* for the flow of air in the concrete ducts such as planned for the tunnel and the power losses where air is taken from or supplied to a duct. No assurance could be found as to any reliable bases for the existing formulas, and it was deemed necessary to verify them by independent tests on large scale models before accepting them as a basis for the design of the ventilation equipment for a project of this magnitude. The *New York State Bridge and Tunnel Commission* and the *New Jersey Interstate Bridge and Tunnel Commission* accordingly entered into a contract with the USBM to conduct these tests. Studies to determine the amount and composition of exhaust gases from motor vehicles were carried out at the USBM experiment station in *Pittsburgh*. A study of the effects of motor exhaust gases was made at the USBM experiment station at *Yale University*.

"…On a full-size model of the expansion chamber proposed for the tunnel, tests were made to determine the proper shape of the chamber and the shape and size of the slot which would give a direction of air flow high enough not to raise dust from the roadway and low enough not to short circuit the fresh air to the inlets into the vitiated air duct over the roadway. These experiments also gave the minimum static pressure required to discharge the requisite quantities of air through the slots at different locations in the tunnel. A total of 112 tests were made on various shapes of expansion chambers and various widths of slot under the several conditions to be met in the tunnel. Experiments on elbows were made in two parts: on galvanized iron single and compound elbows constructed to one-tenth the interior dimensions of the elbows to be used in the tunnel, and on concrete compound elbows to one-half the interior dimensions of those planned for the tunnel ducts…"

RE: excerpt from *The Eighth Wonder*

Bruceton

"…To verify under-tunnel conditions the amount of carbon monoxide produced by automobiles and the physiological effect of exhaust gases, an experimental tunnel was constructed in the workings of a coal mine at Bruceton, Pa. It was located about 1,000 feet from the entrance to the mine and about 135 feet from the surface. The tunnel had a driveway 8 feet by 9 feet wide, with continuous air ducts above the ceiling and below the roadway. It was oval in plan, with a major axis of approximately 135 feet and a minor axis of approximately 110 feet, giving a roadway length of 400 feet…"

RE: excerpt from *The Eighth Wonder*

Above: caption: "In 1921, the USBM's *Pittsburgh Experiment Station* helped develop a safe ventilation system for the new trans-Hudson tunnel. Testing was done at the USBM's *Bruceton Experimental Mine*, shown above."

"…Air for the test was supplied by the mine fan, belt-connected to a steam engine and operated outside the mines. The fan operated normally exhausting, giving upward ventilation in the tunnel. Downward ventilation was acc-omplished by reversing the direction of the air currents through the reversible housing of the fan, which then operated as a blower. In the upward ventilation system, air entered the duct under the roadway, passed through adjustable port openings into the continuous expansion chambers on either side of the roadway, thence into the driveway. In the downward system, air was delivered to the duct in the ceiling, thence through the ports into the upper expansion chambers from which it entered the roadway…"

RE: excerpt from *The Eighth Wonder*

"…A total of seventeen tests were run with cars varying in number from 1 to 8, with concentrations of carbon monoxide in the driveway from 0.5 to 9.4 in 10,000 parts of air, at various temperatures and humidities, and various methods of transverse ventilation. The tests verified the earlier conclusions, and demonstrated that with upward ventilation the exhaust gases crossed the breathing plane of persons in the tunnel but once, while with downward ventilation they crossed this plane twice. There was also a lower concentration of carbon monoxide with upward than with downward ventilation…"

RE: excerpt from *The Eighth Wonder*

The Air Down There

“Air is supplied to the tunnel from the fresh air duct located under the roadway. The air is taken off from this duct through flues 10 feet to 15 feet apart, provided with adjustable dampers and leading into continuous expansion chambers located just above the roadway, one on each side. From these chambers, two continuous transverse fresh air streams sweep across the roadway and dilute the exhaust gases. The air then slowly ascends to the ceiling where it is drawn through adjustable openings, located from 10 to 15 feet apart, into the exhaust duct.”

Ole Singstad, **Design Engineer**

"…Valuable and necessary as were the experiments required to determine the various factors involved in the problem of adequate ventilation for the Holland Tunnel, the data resulting from these preliminary investigations had to be crystallized into tangible units of ventilating equipment. These are the eighty-four giant Sturtevant Silentvane Fans which are the very lungs of the tunnel, Without such fans blowing in fresh air and exhausting the vitiated air the tunnel could not be made to function…"

RE: excerpt from *The Eighth Wonder.* Holland and his design team developed a revolutionary two-duct system; a system that utilized one duct to draw in fresh air and the other to suck out exhaust air, that would be adopted for vehicular tunnels worldwide. To facilitate the exchange of clean and vitiated (dirty) air, the team developed a system of ventilator fans and airshafts to circulate clean air throughout the length of the tunnel. This air is moved by 42 blowing fans and 42 exhaust fans - totaling 6K-hp, arranged in four ventilation buildings (only 56 out of the total 84 fans are in operation at any time, the other 28 fans are reserved for emergencies). It takes approximately 90 seconds to completely change the air in the tunnel.

"…Mr. B.F. Sturtevant, the founder of the company which constructed the fans, was a Maine shoemaker of inventive genius. He had devised a machine to shave a ribbon of wood from a log, form it into pegs, and drive them into shoes. This process, however, created a dust which bothered his workmen. Accordingly, he next constructed a fan which performed as an exhauster and removed the dust. Thus the first fan was created..."

RE: excerpt from *The Eighth Wonder*

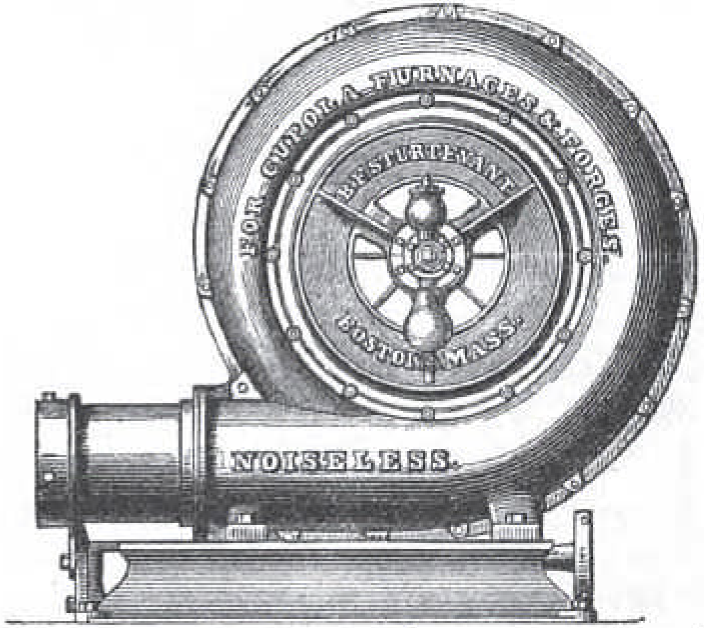
Left: *Benjamin Franklin Sturtevant*

"…Concentrating on this latter invention, he established what grew into the B.F. Sturtevant Company, with its great plants and offices, research laboratories and corps of engineers, and its wide variety of products in the field of fans, blowers, and allied air-moving equipment…"

RE: excerpt from *The Eighth Wonder*

The centrifugal fan, or fan blower, was not a new idea. As applied for the purposes of ventilation, it dates back to the *16th Century*. There were tentative steps in the early *19th Century* to use it as an auxiliary or replacement for chimney draft, but engine speeds and steam pressures were too low. The demand for accelerated combustion wasn't urgent and there was only rudimentary knowledge about the proper application of fans for forced draft. As a consequence, this economic improvement - of critical importance in later years, was ignored. Its natural advantages of low noise and minimum friction (versus piston operated blowers) had been overshadowed by their blast of air. While sufficient for forges and heating furnaces, they were inadequate for industrial processes. By careful attention to correcting the design flaws in the casing and impeller, *B.F. Sturtevant* transformed the simple fan blower into a pressure blower that became a boon to industry. Being the first to apply sound engineering principles to these early crude devices at a critical point in the industrial revolution, Sturtevant became the father of the American fan industry, having built the first commercially successful blower in 1864. A market developed for his blowers for conveying materials and for furnishing draft for forges, cupolas and boilers. In the latter application, forcing combustion air into ashpits allowed the burning of cheap grades of fuel which had previously been impossible with ordinary chimney draft. By 1866, the business had grown to the point where Sturtevant was employing nearly fifty men. Equipping the U.S. Capitol with ventilating fans that year was one of the more notable early installations. In 1869, the modern heating era began with Sturtevant's introduction of a hot blast system. The "Sturtevant System," as it became known, consisted of a steam engine driven fan passing large volumes of air through steel pipe heater coils and distributing it within a factory or building via ductwork. Unlike passive direct radiation and indirect where a radiator was placed in a flue and air allowed to pass over it and into a room, the Sturtevant approach of forced circulation was an efficient, integrated system that could be used for any combination of ventilation, heating, cooling and/or air cleaning demands.

STURTEVANT
Patent Improved Pressure Blower,

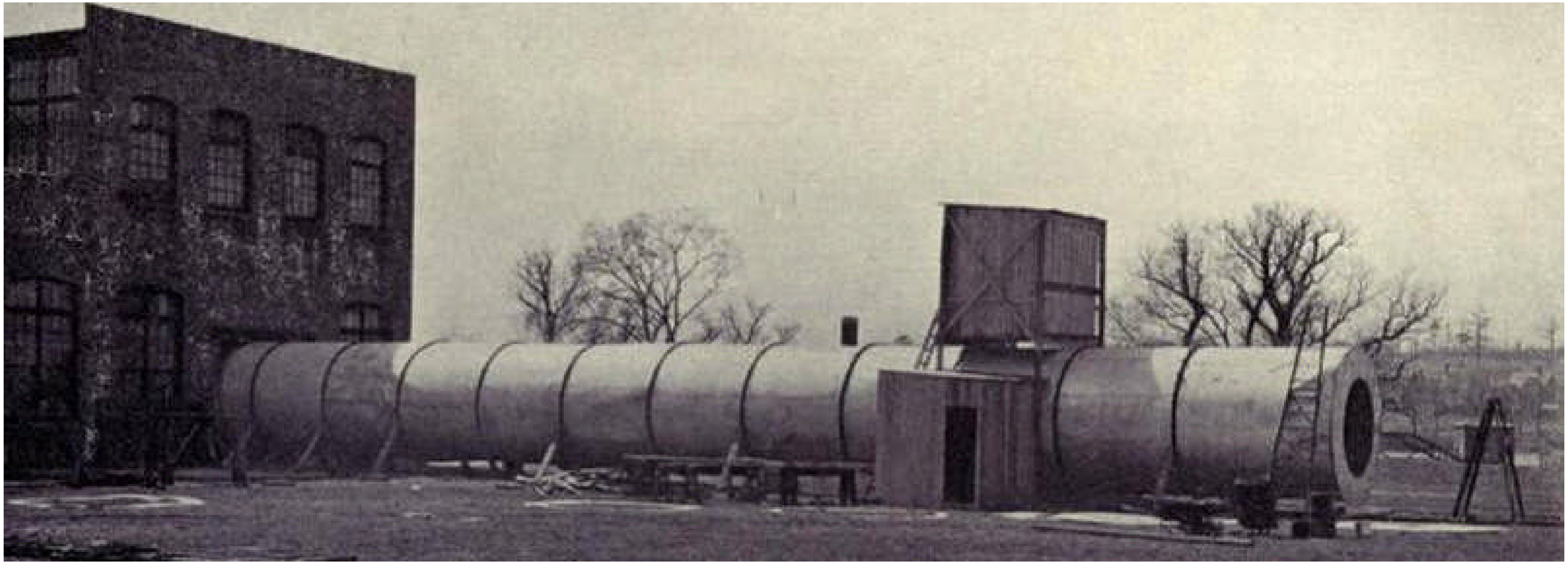


FOR CUPOLA FURNACES AND FORGES.

Also, Fan Blowers for Blast under Boilers, Puddling and Heating Furnaces, and Ventilation of Mines and Public Buildings, and Hot Blast Apparatus for Dry-Houses.

Send for Illustrated Catalogue.

B. F. STURTEVANT, Patentee and Sole Manufacturer, **72 SUDBURY ST., BOSTON, MASS.**



"…A difference of opinion arose as to the type of fan best suited for ventilating the tunnels. This question was definitely settled in the laboratory of the company in tests made by the engineers of the tunnel and of the company. A further problem arose in that the resistance to the flow of air which would be encountered in the actual installation were entirely frictional. There was a great dearth of information about the frictional resistance of ducts, and the company's research department was able to outline a series of model tests for the determination of the factors necessary for the solution of this extremely important point. These tests were later very ably carried out by the tunnel engineers and Professor Willard of the University of Illinois…"

RE: excerpt from *The Eighth Wonder*

Above: caption: "Special Apparatus Erected at Hyde Park Plant of B.F. Sturtevant Company. Used in testing Sturtevant Silentvane Fans for the Holland Tunnel."

"…The selection of the proper type of fans to be used and the determination of the resistances against which they would operate were the two most important requirements of this unprecedented ventilation problem. In addition, through the extended experience of the company's research department, proper methods for installing the equipment were de-termined, and suitable motors for driving the fans and suitable connections to ducts were selected, all of which assured the final success of the installation as a whole…"

RE: excerpt from *The Eighth Wonder*

A Matter of Industrial Pride

"…The company and its engineers felt that, as the largest manufacturers of ventilating equipment in the world, they were directly concerned with the success of the greatest ventilation project in the world. It was a matter of industrial pride on the part of the company and its engineers to do all they could to insure its final success…"

RE: excerpt from *The Eighth Wonder*

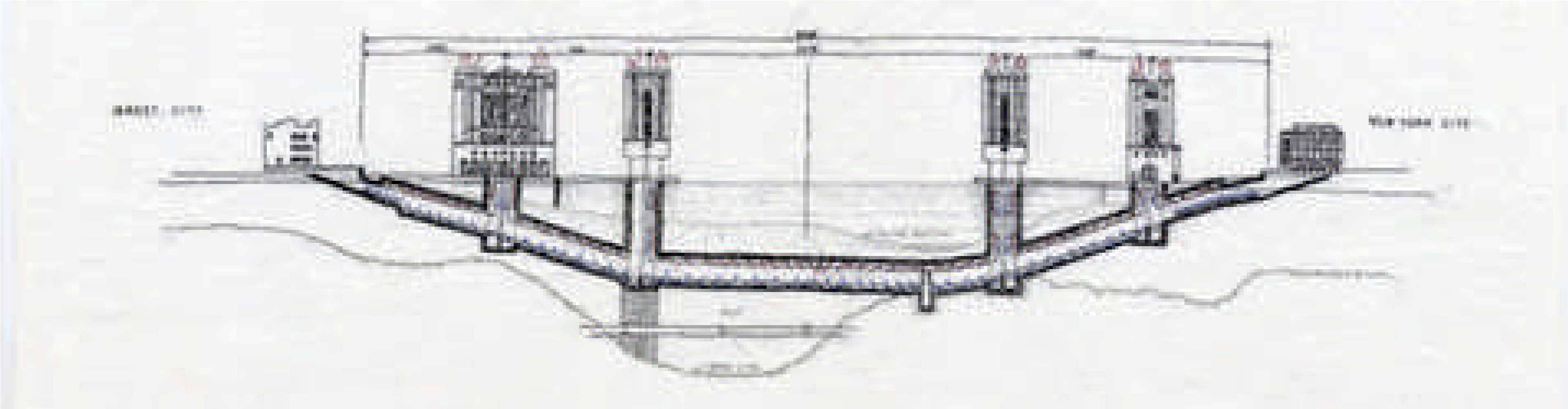
"…In the final bidding the company proved its right to be considered a leader in the industry…The Sturtevant Silent-vane Fan is an outstanding achievement, since it has demonstrated under a variety of tests efficiencies greater than any other type of centrifugal fan. For the work of ventilating the Holland Tunnel it showed efficiencies varying from 15% to 20% higher than any other fan that could have been used for the purpose, and by reducing the amount of power required, the investment in motors was correspondingly less. Its selection was therefore inevitable…"

RE: excerpt from *The Eighth Wonder*

Ventilation Buildings

“The power required to move the large quantities of air is an important factor, and it was found economical to divide the tunnel ducts into a number of sections by locating the ventilation equipment in four shafts, two on each side of the river. Navigation requirements did not permit the location of any shafts beyond the pierhead lines, which at the site of the tunnel are about 3,200 feet apart.”

Ole Singstad, **Design Engineer**



"…The Sturtevant Silentvane Fans are installed in the ventilation buildings, of which there are two on each side of the river, one at the pierhead line and the other inland. Each land shaft ventilated four sections of tunnel – the adjoining portal sections of each tube, the whole intermediate section to the pierhead shaft where traffic is on a down-grade, and one-half of the parallel section where it is on an upgrade. The buildings over these shafts contain four independent sets of blower and exhaust fans. The pierhead shafts ventilate three sections of tunnel – one-half of each of the 3,400-foot river sections and one-half of the inter-mediate section where traffic is on an upgrade. In all there are 14 sets of blowers and 14 sets of exhaust fans. Dividing the upgrade sections of the tunnels into three parts gives added ventilation where the greatest amount of carbon monoxide is expected…"

RE: excerpt from *The Eighth Wonder*

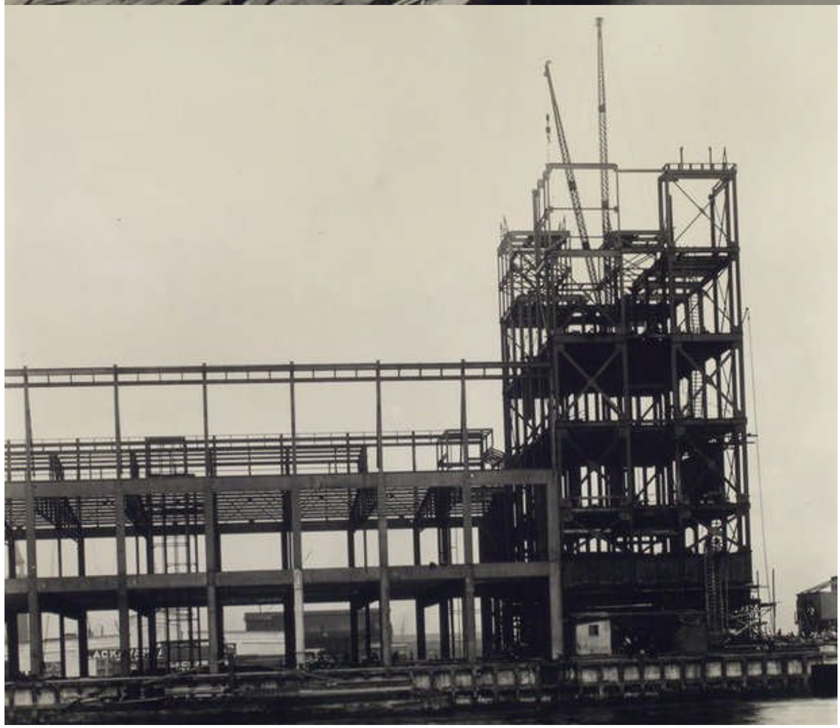
“In the four ventilation buildings are located blower fans connecting through downcast ducts with the fresh air ducts in the tunnel. These fans take air from the fan rooms, the air entering the rooms through large louvred openings in the sides of the buildings. In the same buildings the exhaust fans are located in airtight rooms which are connected through ducts with the exhaust duct in the tunnel. The exhaust fans connect to vertical expanding stacks extending above the roofs of the buildings, through which the vitiated air is expelled to the outside atmosphere. The ventilation ducts in each tube are divided into seven sections by transverse bulkheads, so that the equipment in each building ventilates sections of the tunnel extending from the building to the portal or half-way to the next building except in the case of the entrance downgrade between the land and river buildings in each tube, which is ventilated from the land building alone. Each duct section has three fans, two of them required to be operated at full speed to supply the normal maximum ventilation requirements, the third unit constituting the reserve.”

***Ole Singstad,* Design Engineer**

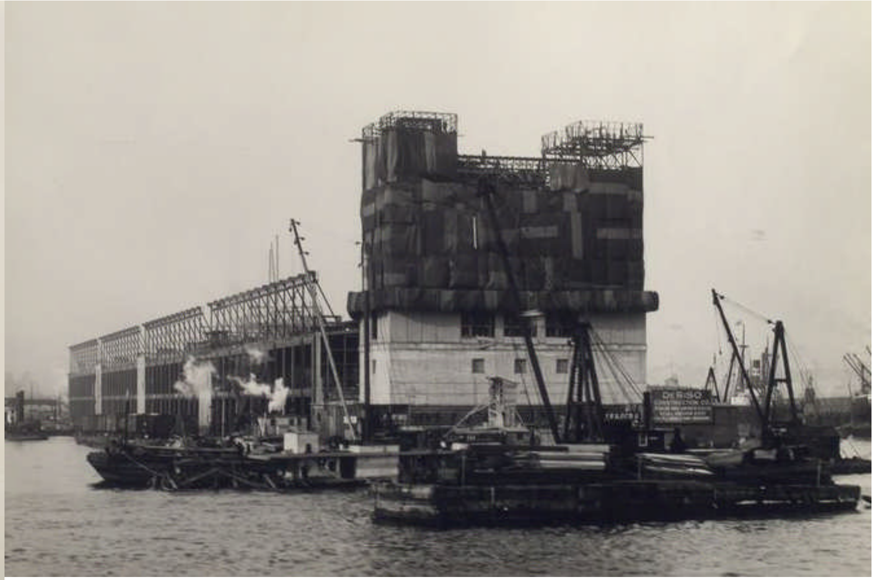
<u>Left</u>: caption: “Brick work - Land Ventilation Building. North side of Canal Street, west side Washington Street, New York. 10/7/26.”

<u>Above</u>: caption: “Brick work complete, Land Ventilation Building, west of Washington Street, between Spring and Canal Streets, New York. 11/17/26.”

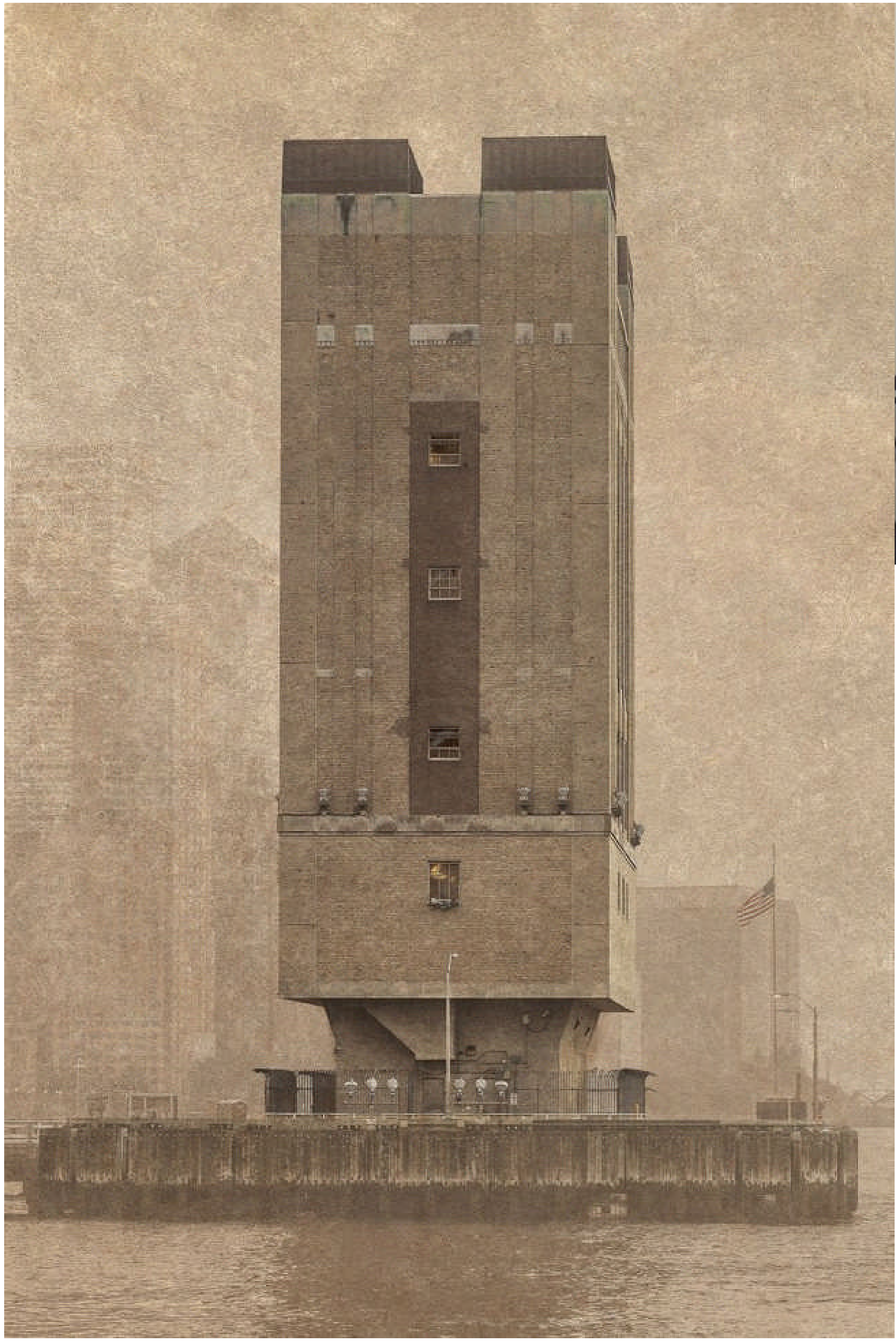
<u>Above</u>: caption: "Excavation and timbering for air duct, east of land shaft to proposed ventilation building, New Jersey. 4/1/25."
<u>Left</u>: caption: "Erection of steel framing. Land ventilation building, New Jersey. 11/22/26."

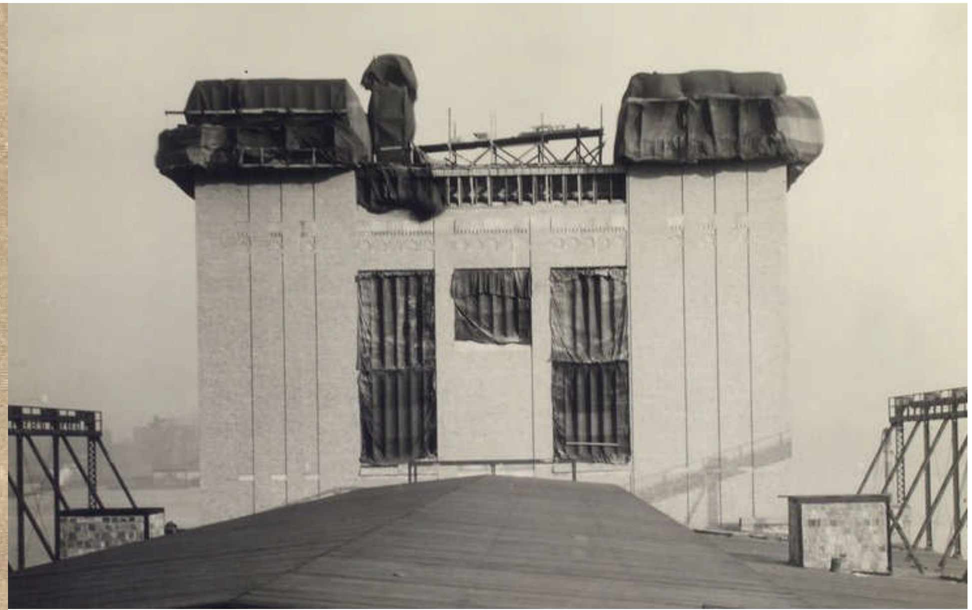


Top Left: caption: “New Erie Pier No. 9, New Jersey. 3/10/26.”
Top Right: caption: “New Erie Pier No. 9, Jersey City, N.J. 4/15/26.”
Left: caption: “Exterior view of steel erection - River Ventilation Building, New Jersey. 10/7/26.”



<u>Left</u>: caption: "Steel framing - River Ventilation Building, New Jersey. 11/22/26."
<u>Above</u>: caption: "Concrete & brick work - River Ventilation Building, New Jersey.12/9/26."





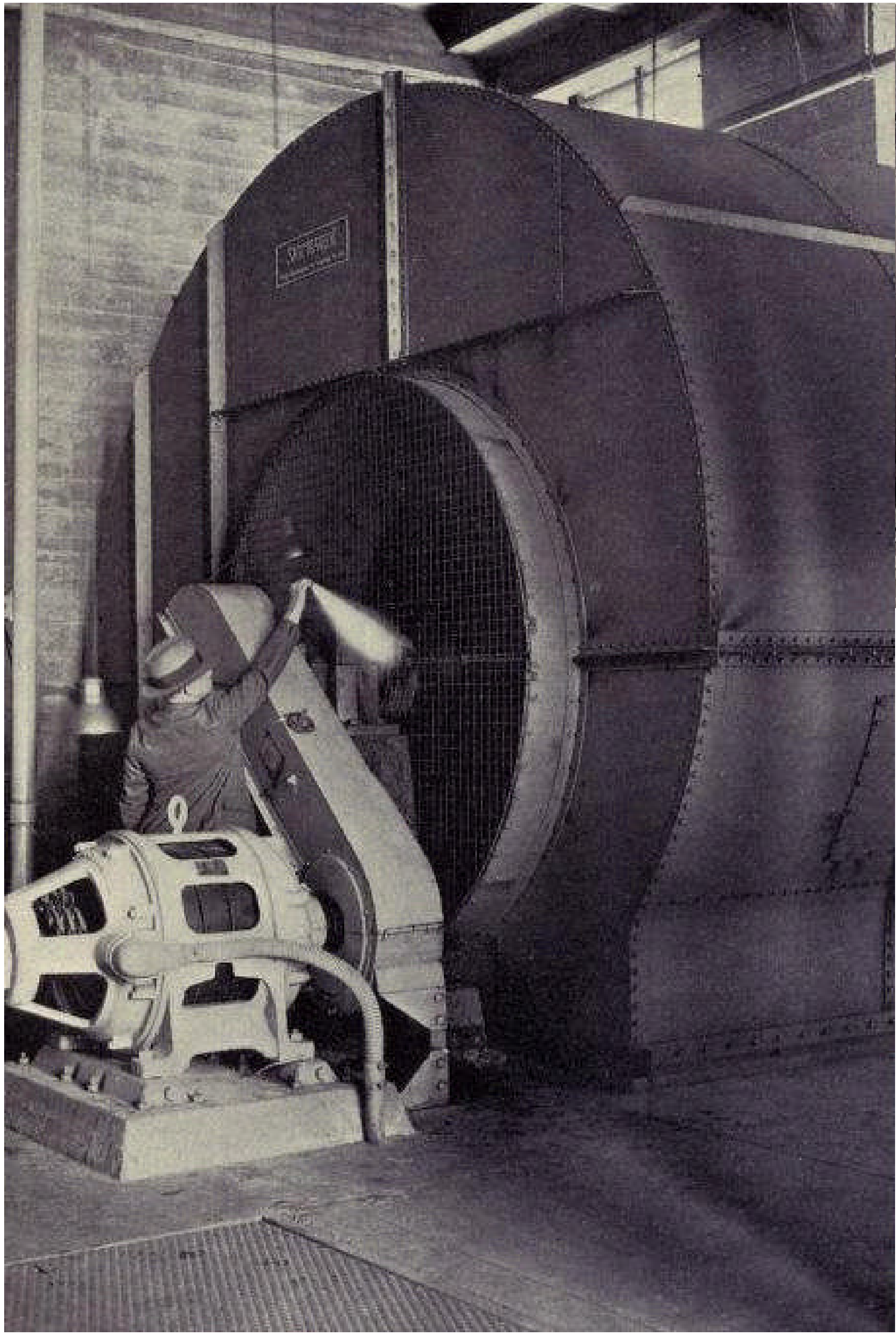
<u>Above</u>: caption: "West side of River Ventilation Bldg. and East End of Erie Pier No. 9, Jersey City. 1/6/27."
<u>Left</u>: caption: "Holland Tunnel Ventilation Tower"

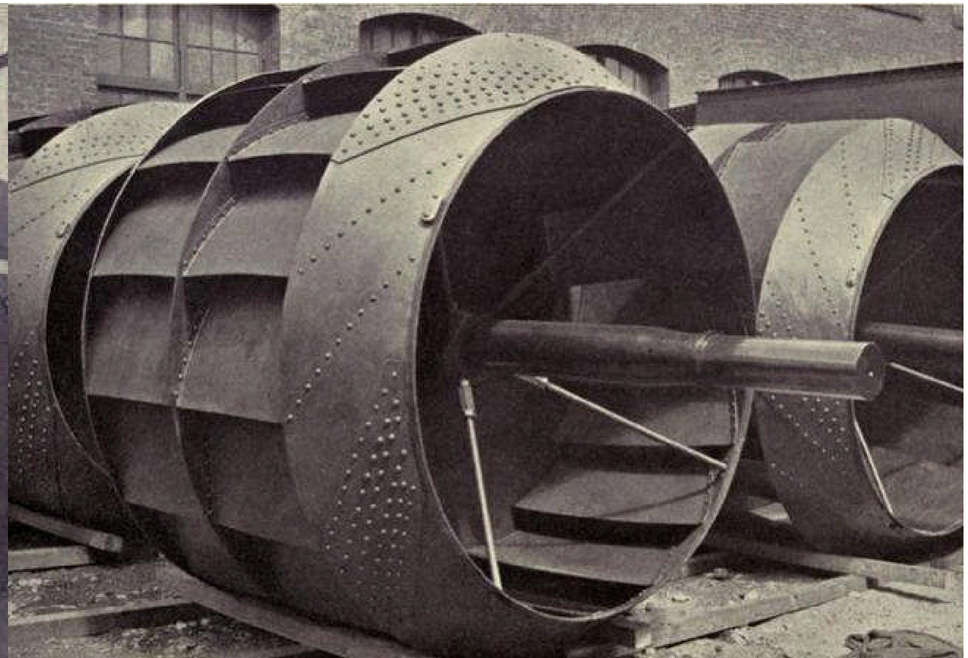
“…There are 28 ducts, 14 blower and 14 exhaust, connecting the various sections of the tunnels with the ventilating buildings. Each duct is equipped with three fans, two of which, when operated together, will supply the maximum quantity of air required. Their capacities range from 81,000 to 227,000 cubic feet per minute and they operate at static pressures varying from 0.6 to 3.75 inches of water. This range in pressure and capacity is due to the great difference in length of tunnel ventilated by different sets, those at the outside of the pierhead shafts having 1,700 feet to serve while the inside fans have only 700 or 800 feet. These fans, during an hour of heavy traffic, will handle 84,000 tons of air, or 1,400 tons per minute. They provide for changing the air in the tunnel 42 times per hour…”

RE: excerpt from *The Eighth Wonder*

"…The fans are of the backward curved-blade type. Under different conditions, one, two, or three fans may be operated on one tunnel duct at any one time. By the use of the Sturtevant Silentvane, assurance is given that they will operate satisfactorily when run in parallel without the danger of any one fan assuming more than its share of the load and overloading the motor. They will also maintain satisfactory efficiency for any stage of loading from 35% to full load. They are electrically driven by wound-rotor motors with resistance in the circuit to make it possible to run them at variable speeds. The combined capacities of the motors is approximately 6,000 horse power, two-thirds of which will be in operation at times of maximum load and one-third in reserve. Chain drives are to be used to make possible speed adjustments or changes in the motors as well as on account of the space limitations in the ventilating buildings…"

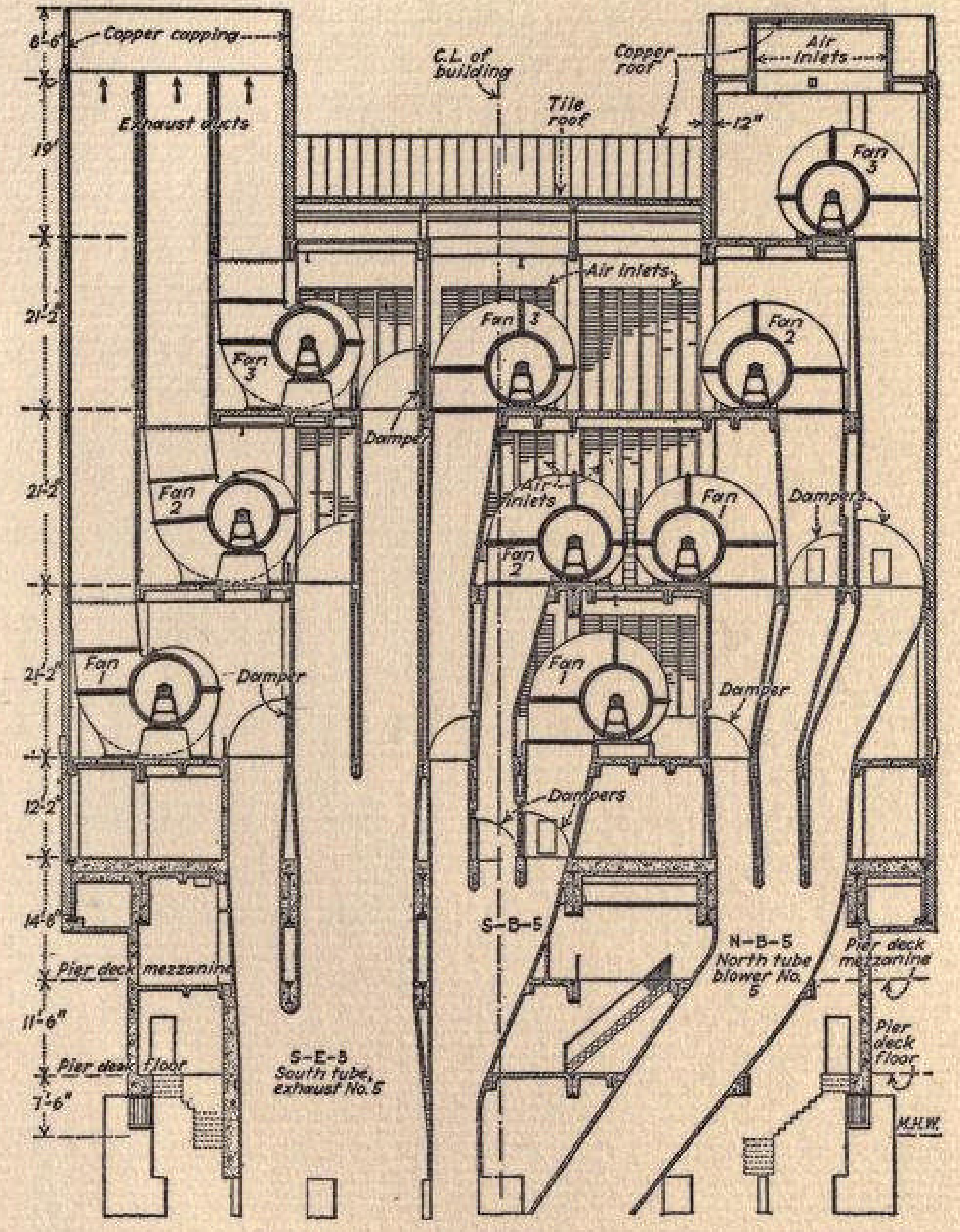
RE: excerpt from *The Eighth Wonder*





<u>Above</u>: caption: “Sturtevant Silentvane Fan Wheels for the Holland Tunnel”

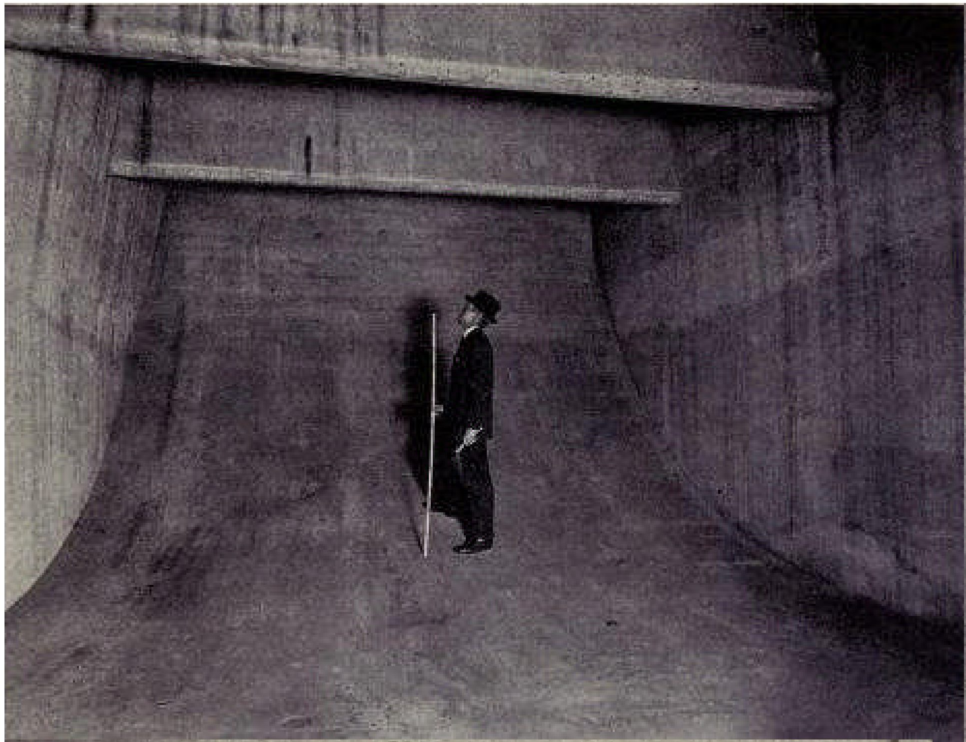
<u>Left</u>: caption: “One of the 84 Sturtevant Silentvane Fans, which are the lungs of the Holland Tunnel”

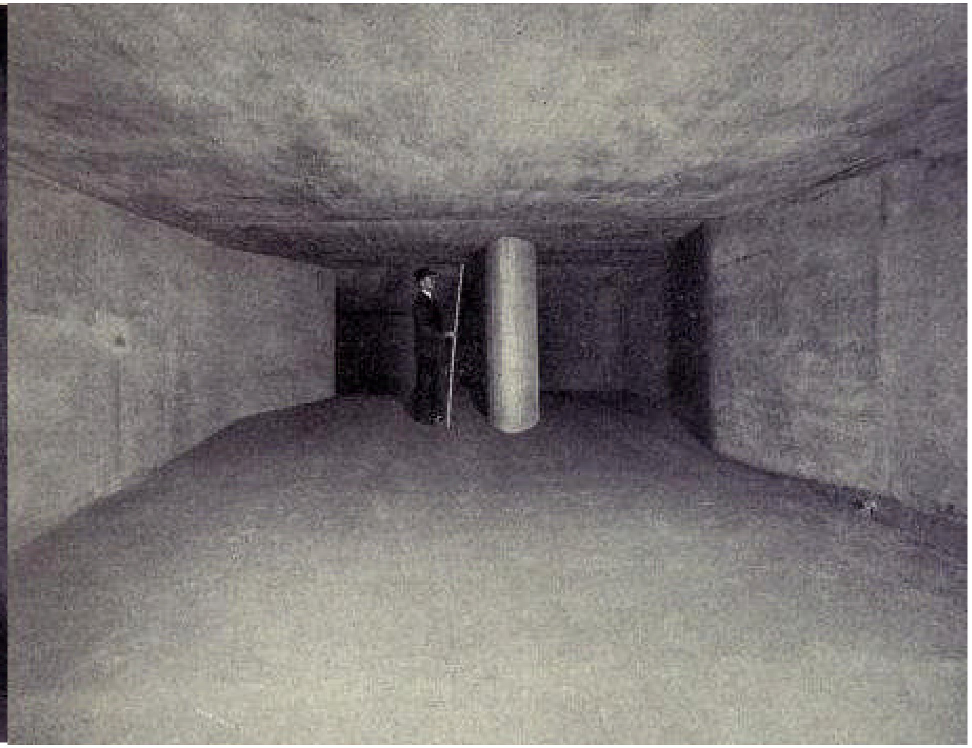


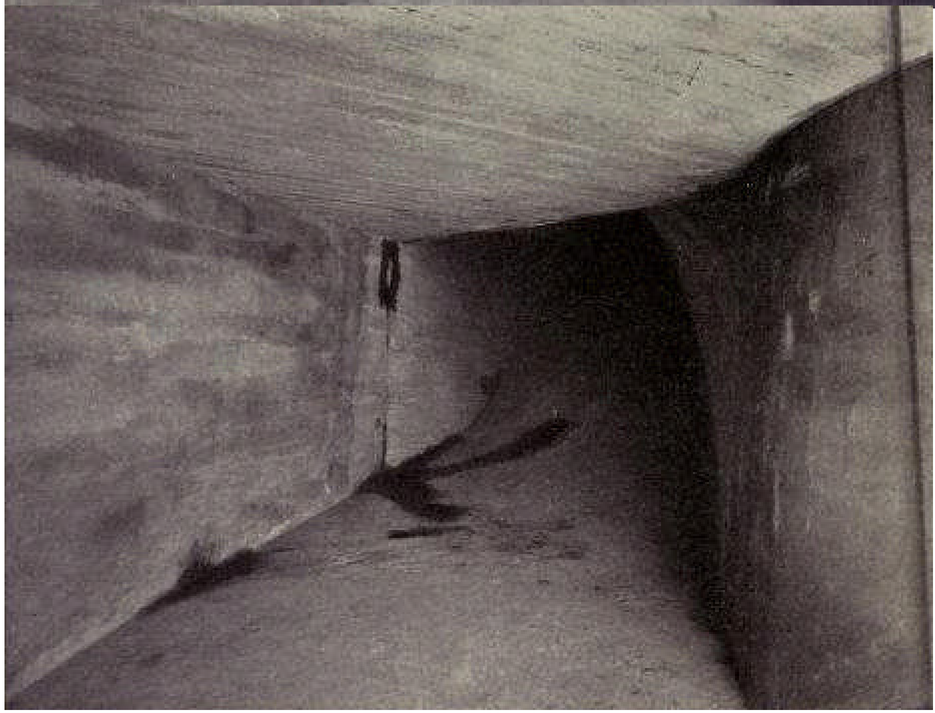
TYPICAL VERTICAL SECTION THROUGH VENTILATING BUILDING

"…The placing of the fans is varied to suit the local conditions in the individual buildings. Generally, the exhaust ducts are at the corners of the buildings and supply ducts are in the central portion. Consequently the compartments containing the exhaust fans are located near the corners under the exhaust stacks, leaving the central portion of the fan floors free for intake fans, and the central section of each outer wall for the air intakes. The intakes are made sufficiently large to give low velocities through the louvres…"

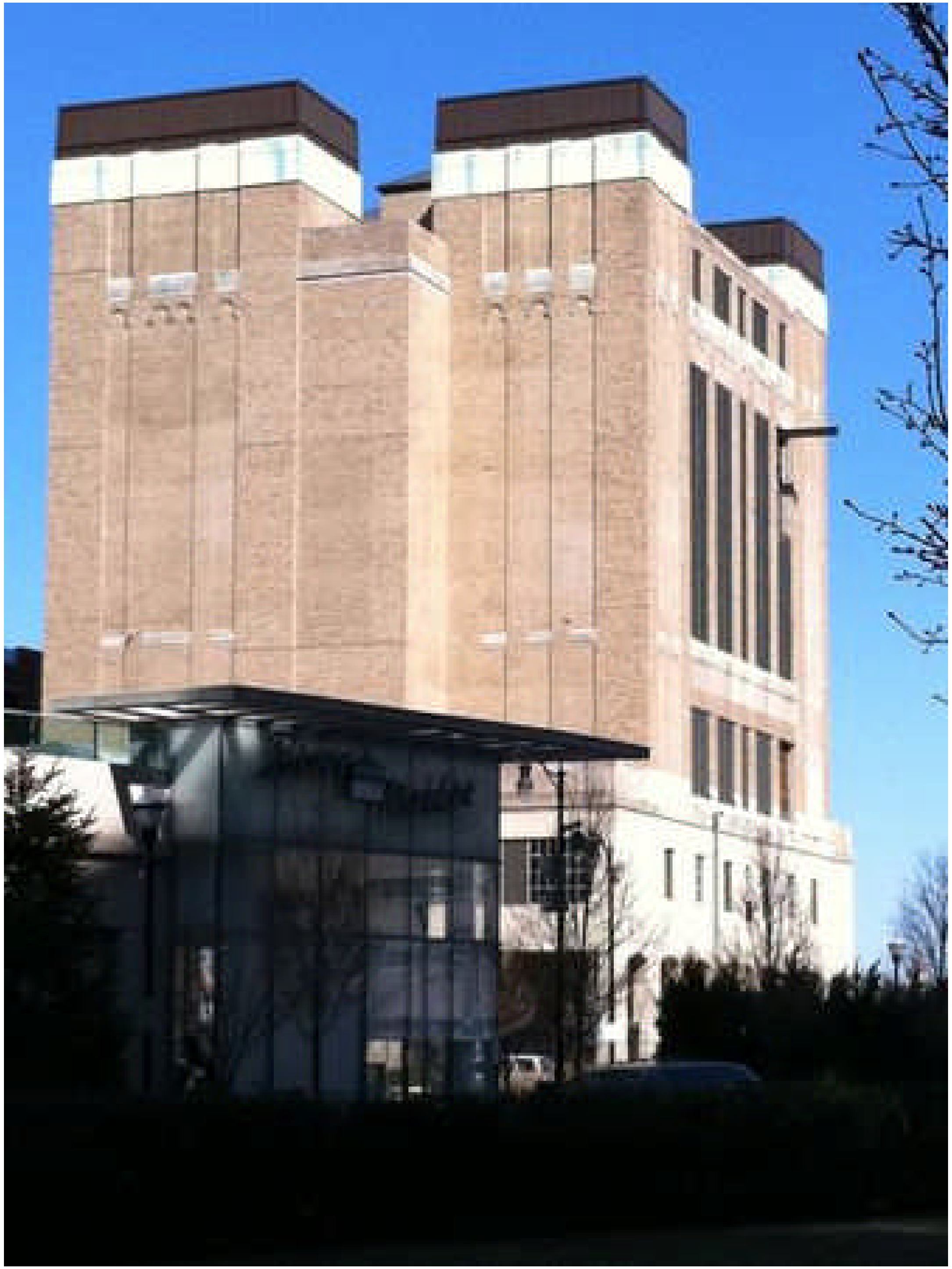
RE: excerpt from *The Eighth Wonder*







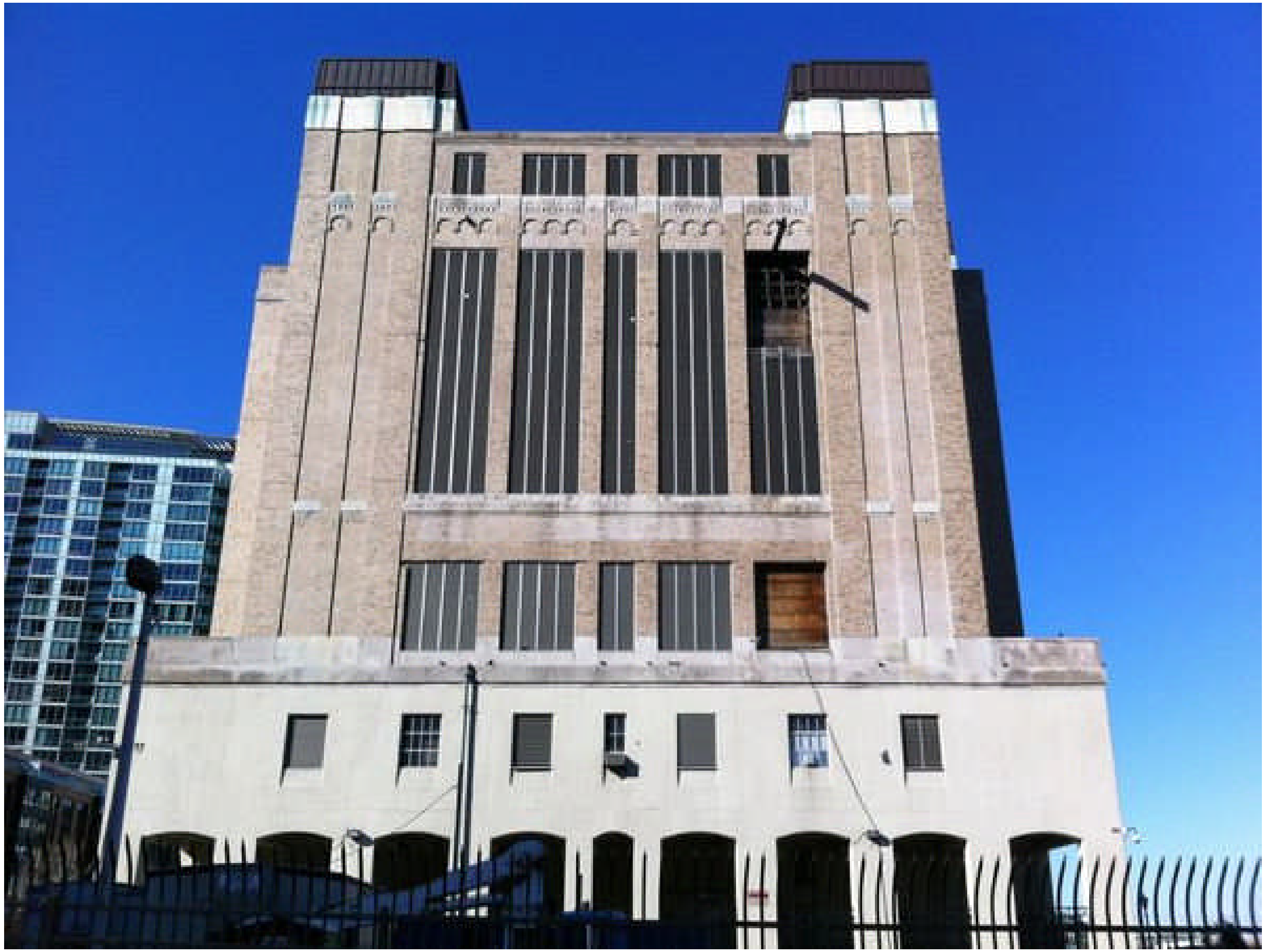
<u>Top Left</u>: caption: "East Blower Air Duct. In Land Ventilation Building, New York City, showing curved back and vanes."
<u>Top Right</u>: caption: "East Blower Air Duct. Land Ventilation Building, New York City."
<u>Left</u>: caption: "Fresh Air Duct in South Tunnel, N.J. Side. Showing the beginning of the transition from its position under the roadway to its position alongside the tunnel."



"…The louvre blades are made of heavy wire glass to give light to the interior of the buildings as they take up most of the space otherwise available for windows. Heavy bronze scr-eens protect them and also serve to keep out birds. The arrangement whereby fresh air is drawn in through louvres high upon the sides of the buildings and exhaust air is forced out through stacks which extend 20 feet above the roof insures a complete sep-aration of fresh and vitiated air…"

RE: excerpt from *The Eighth Wonder*

Left: caption: "NJ Land Ventilation Building, side view"



<u>Above</u>: caption: "River Ventilation Building. Pier-head line between piers 34 and 35, North River, New York City"

<u>Left</u>: caption: "Land Ventilation Building. West side of Washington Street, Canal to Spring Sts., New York City"


VENTILATION BUILDING

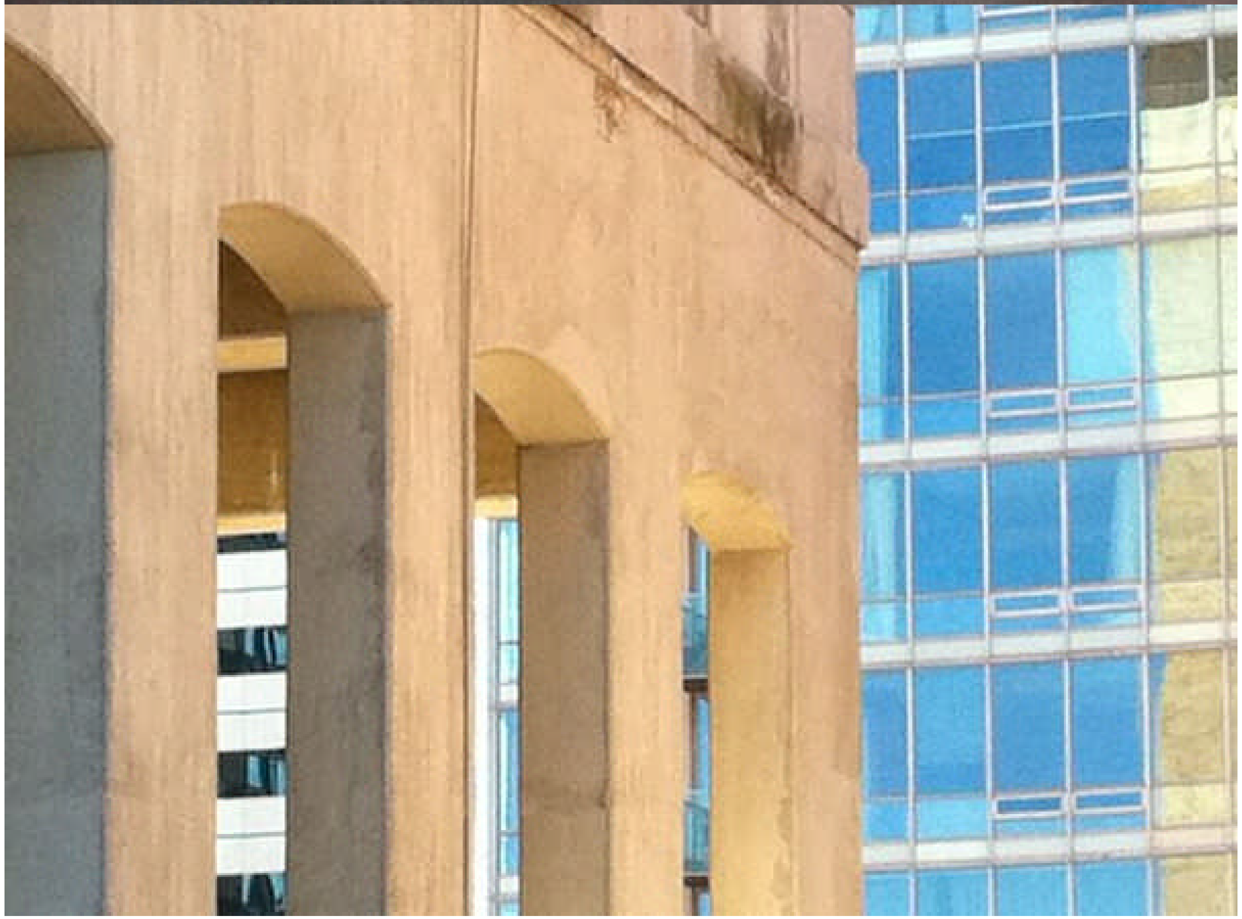
<u>Left</u>: *Erling Owre*, Architect (1877-1961). Born and trained in *Norway*, Owre was hired by Chief Engineer *Clifford Holland* to design and supervise the construction of the sophisticated ventilation towers. His monumental steel, concrete and brick towers, soldiered across the *Jersey City-Manhattan* land and water axis, contrast with the era's predominant *Art Moderne* architectural style.

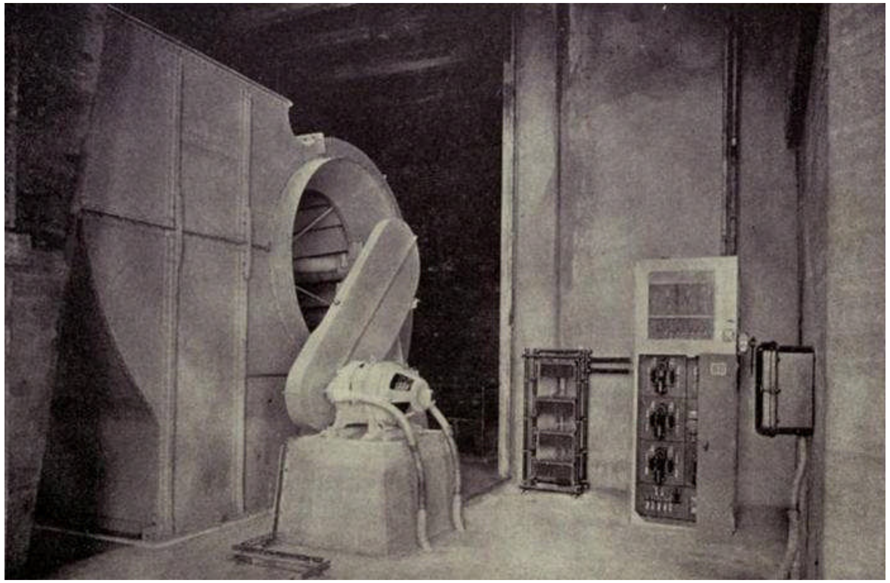
<u>Above</u>: caption: "Holland Tunnel ventilation tower in Newport, Jersey City. Between 1921-1927, Norwegian architect Erling Owre designed four innovative 10-story ventilation structures, two of which were placed in the water with steel foundation piles reaching far down into the Hudson River's bedrock. Owre graced the towers with Byzantine elements only visible up close. However, it is the combined influence of architects Le Corbusier and Frank Lloyd Wright that looms and lingers."

<u>Left</u>: caption: "Land Ventilation Building, New York."

<u>Above</u>: caption: "Aerial view of the Holland Tunnel River Ventilation Tower, with Downtown Jersey City in the background"

<u>Left</u>: caption: "New Jersey Land Ventilation Building, East and South sides, Holland Tunnel. This 10-story ventilation tower is located at the intersection of what is now River Drive and Newport Parkway in the Newport section of Jersey City."





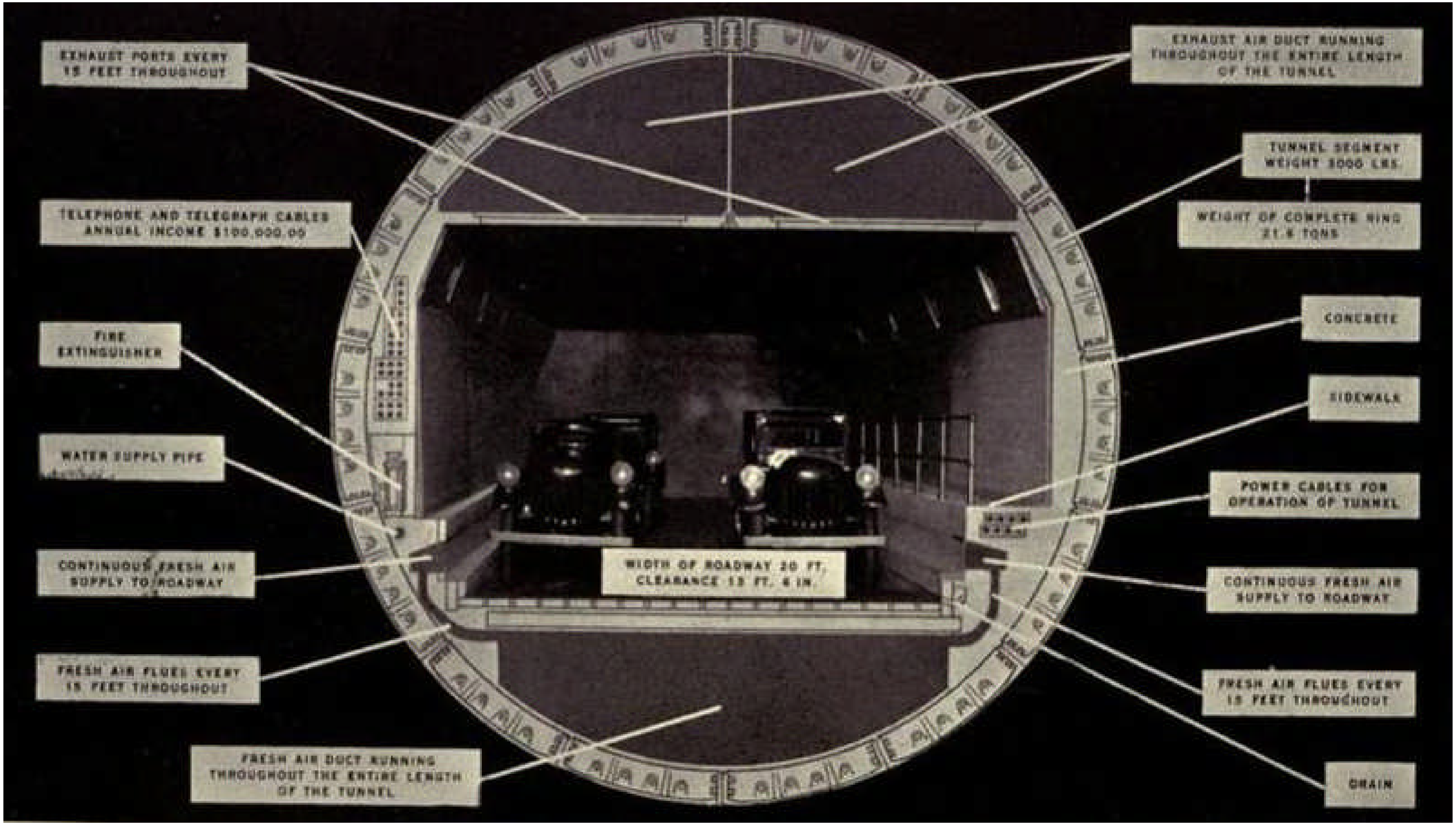
"…The intake fans and their motors are situated in the open portions of the fan floors where they are accessible. The exhaust fans are, of necessity, inside of chambers at the top of the ducts, Their motors, however, are out on the main floor, the drive shafts being run in to the fans through close-fitting collars in the side plates of the duct. Access to the fans is provided through air locks equipped with airtight doors which can be opened against the unequal pressure by wedge latches which force the doors open sufficiently to break the seal. Each duct is equipped with a damper which may be closed when the fan is shut down so that air from the other fans will not be short-circuited through the idle fan. These dampers are motor operated from the control room and are equipped with limit switches…"

RE: excerpt from *The Eighth Wonder*

Above: caption: "Exhaust Fan Unit in N.J. Land Ventilation Building. Showing typical arrangement of exhaust fan, motor, chain casing, resistors, control cabinet, and local control box."

"…Air from the intake fans is forced down into the longitudinal duct under the roadway of the tunnel. From there it is fed through flues 10 to 15 feet apart into a continuous expansion chamber above the curb line at each side of the roadway, the flow of air into this chamber being controlled by adjustable slides over the flue openings. The outer side of the expansion chamber is a copper-steel plate which can be adjusted to give an opening of widths varying from ¾ inches to 1¾ inches through which fresh air flows into the tunnel. Vitiated air is drawn off through openings through the ceiling into the exhaust ducts. These openings are spaced 10 to 15 feet apart and are from 3 to 6 feet long, They also, are provided with slides by which the opening can be adjusted to meet the local requirements for air circulation. By this arrangement of supply and exhaust ports, fresh air supplied to the roadway mixes with the warmer gases and rises to the ceiling where the exhaust ports are located…"

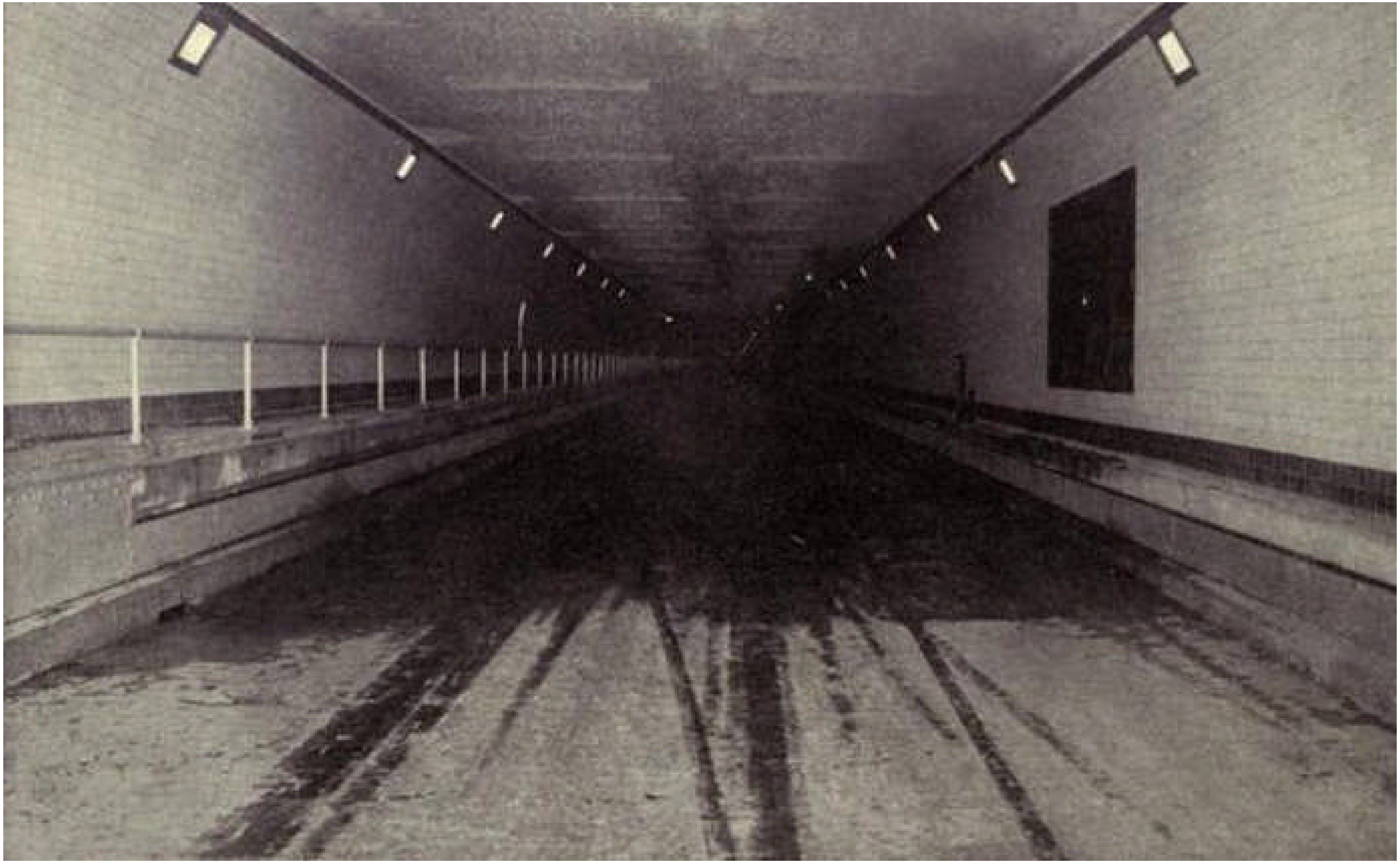
RE: excerpt from *The Eighth Wonder*



<u>Above</u>: caption: “Model of the Holland Tunnel showing many of the hidden details”

"…There will be no longitudinal movement of air in the tunnels except that induced by the movement of vehicles, nor will there be any objectionable winds such as would be created by longitudinal ventilation. Test made with smoke bombs showed that even large quantities of smoke will not spread far from the point of origin, but will rise quickly to the ceiling and be taken out. Similarly, in case of a fire the hot gases will rise to the ceiling, where they will be drawn off. There will not be the same danger of spreading the fire from car to car as there would be with longitudinal ventilation…"

RE: excerpt from *The Eighth Wonder*



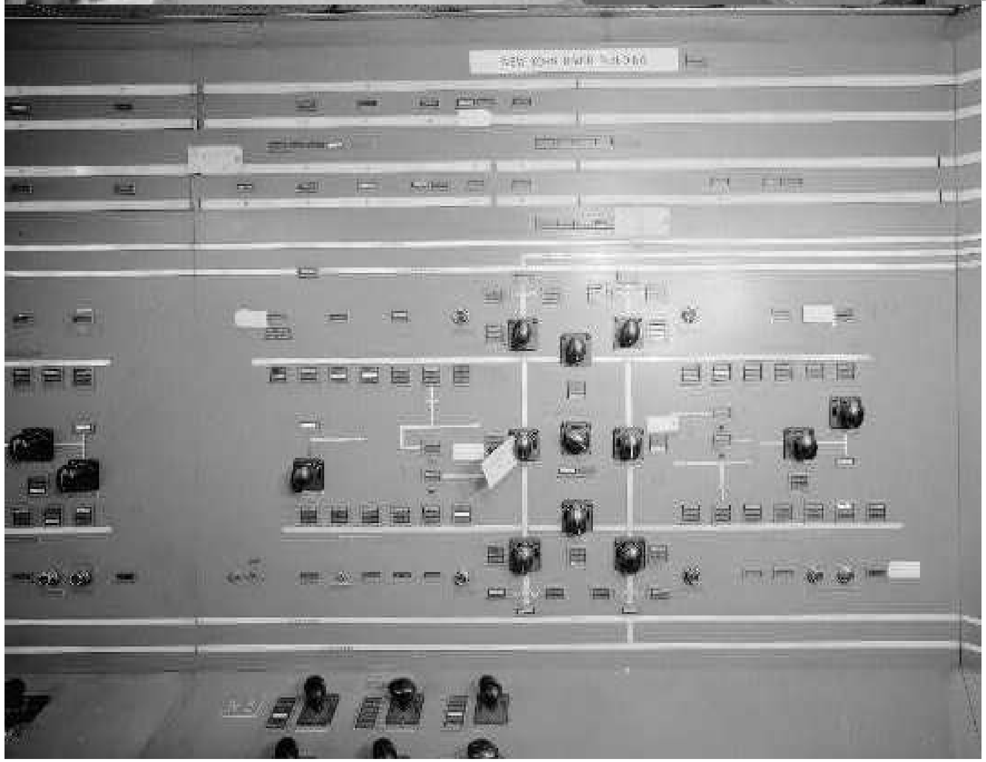
<u>Above</u>: caption: "Condensation in North Tunnel. View showing dry conditions of roadway east of air duct bulkhead where fans were in operation, and wet conditions on roadway west of air duct bulkhead where fans were not in operation."

"…As a check upon air conditions in the tunnel, automatic carbon monoxide recording devices are installed in each exhaust duct which will make a continuous analysis of the gases and record it graphically in the control room of the administration building in New York. There, by observing the chart, the operator can increase or decrease the fresh-air supply as traffic conditions change in the tunnel…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Steel framing - Administration building, south side Canal Street and west side of Varick Street and north side Vestry Street, New York City. 12/9/26."

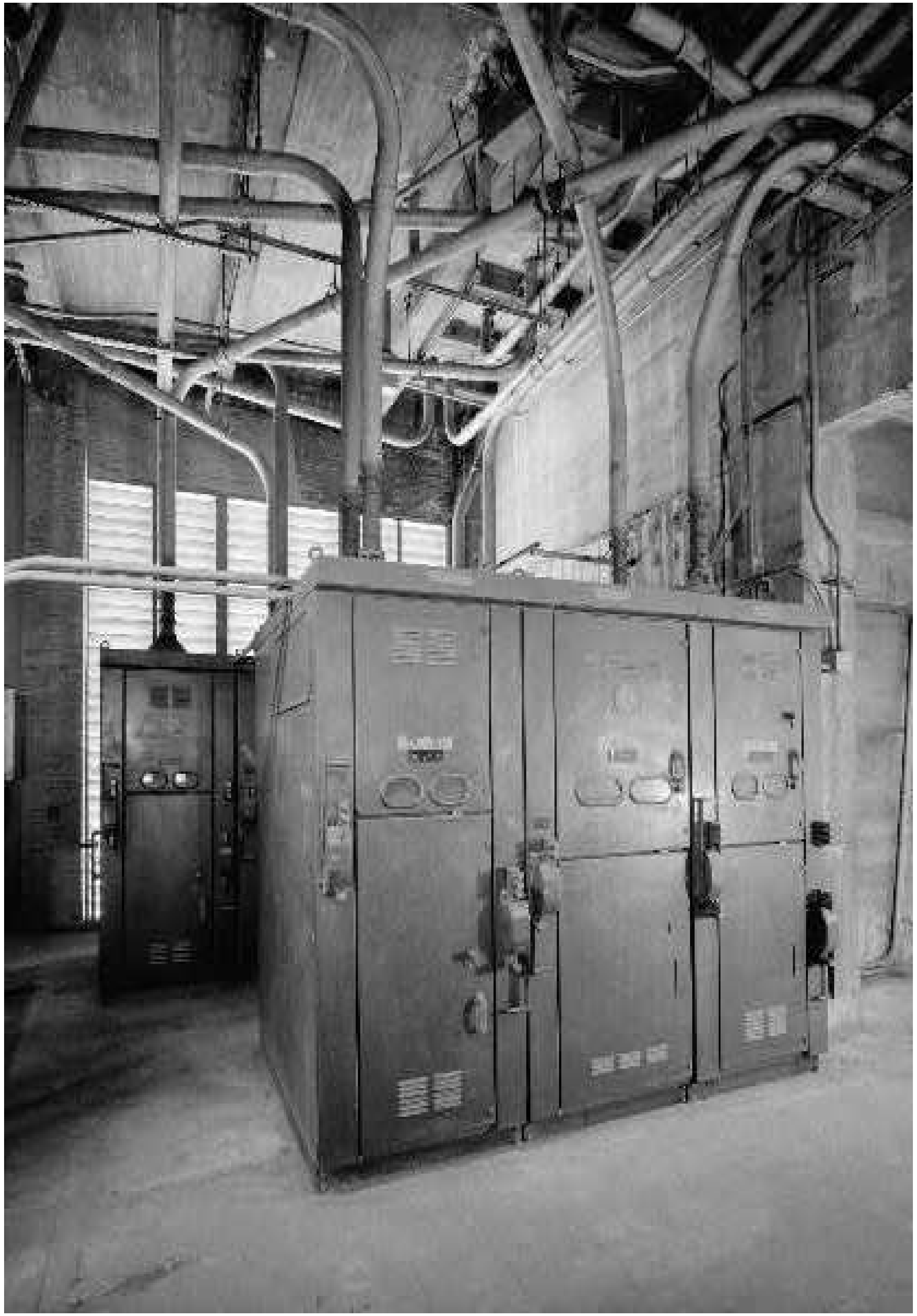

THE HOLLAND TUNNEL
NO TRESPASSING



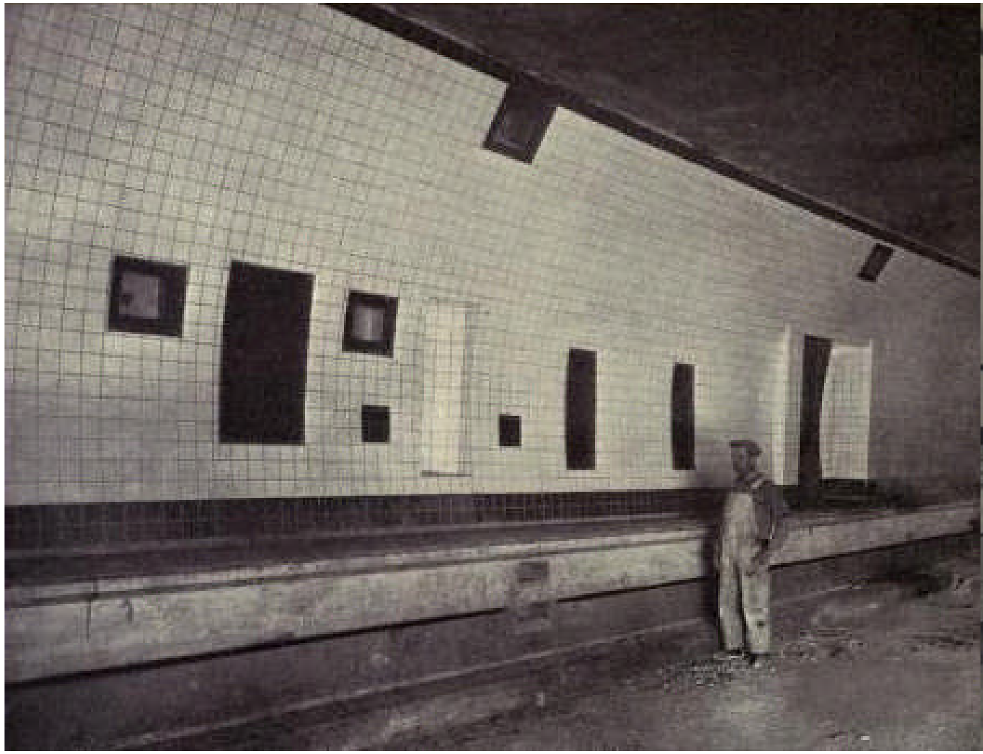
<u>Top Left</u>: caption: "Headquarters and Maintenance Building, Traffic Monitoring Room"
<u>Top Right</u>: caption: "Headquarters and Maintenance Building, Main Control Room for All Ventilation, Mechanical and Electrical Systems"
<u>Left</u>: caption: "Headquarters and Maintenance Building, Close-up of Control Room Panels for New York (side) River Building"

"…An unusually flexible system of power supply has been worked out based on the facts that all the motors are in groups of three, also that the maximum power requirements are less than the capacity of the minimum size power cables installed by the local companies. Three cable from the New York side and three from the New Jersey side are run to the bus bars in each ventilating building, thus giving one motor in each set a separate cable connection to power supply on each side of the river. Inter-connection at the bus bars makes it possible to cut in any or all motors on each cable. This connected, each motor may be supplied with power by six independent cables, each capable of carrying the entire tunnel load; and, as there are at least two independent sources of power at each end of the tunnel, continuity of power supply is absolutely assured. As the transformers are located in the ventilating buildings where smoke from an oil fire might be drawn into the ventilating system, air-cooled instead of oil-cooled transformers are used. Each fan is provided with a control switch at the motor for emergency or repair use. Further local control is provided at the switchboard in each ventilating building where, by a system of signal lights, it will be possible, at all times, to tell what motors are in operation…"

RE: excerpt from *The Eighth Wonder*



<u>Left</u>: caption: "New York Land Ventilation Building, 4th Floor, Detail Showing Main Feeder Station"

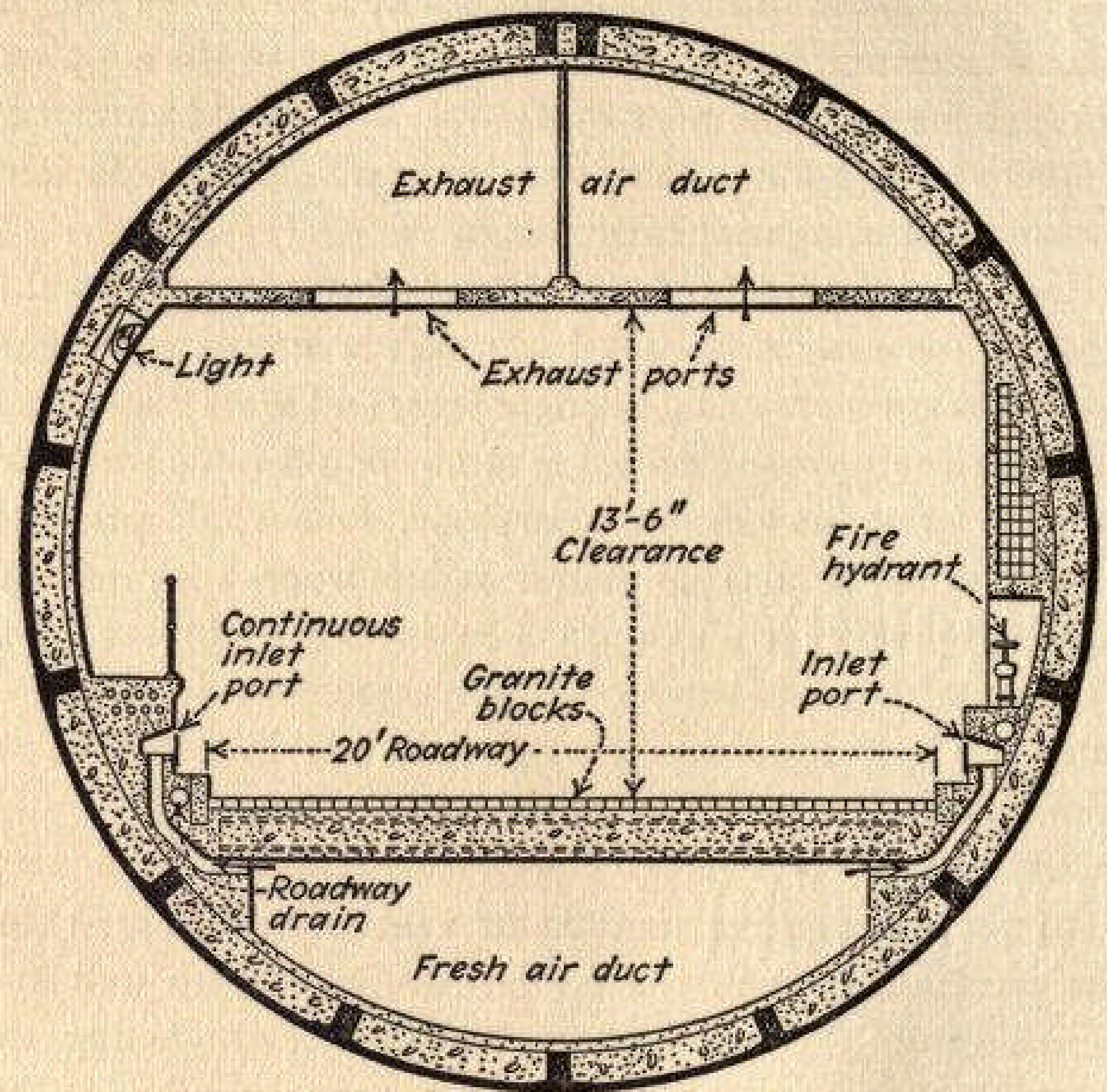
 

"…As part of the studies for the ventilating equipment numerous tests in relation to fire were made, both in the test tunnel at Bruceton and at the laboratories of manufacturers of fire-fighting equipment. These tests included the burning of an automobile drenched with gasoline and with gasoline spilling from a hole in the tank on the car to determine how quickly such a fire could be put out with the hand extinguishers to be placed in the tunnel…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Tile and Bronze Work. (Left to right) Bronze door to relay niche with telephone and fire alarm boxes on each side; tiled refuge niche with fresh-air outlet on each side, two fire extinguisher niches; tiled opening to mid-river sump."

<u>Right</u>: caption: "North Tunnel, west of Spring Street shaft, New York, Inspection Party. 2/10/25."



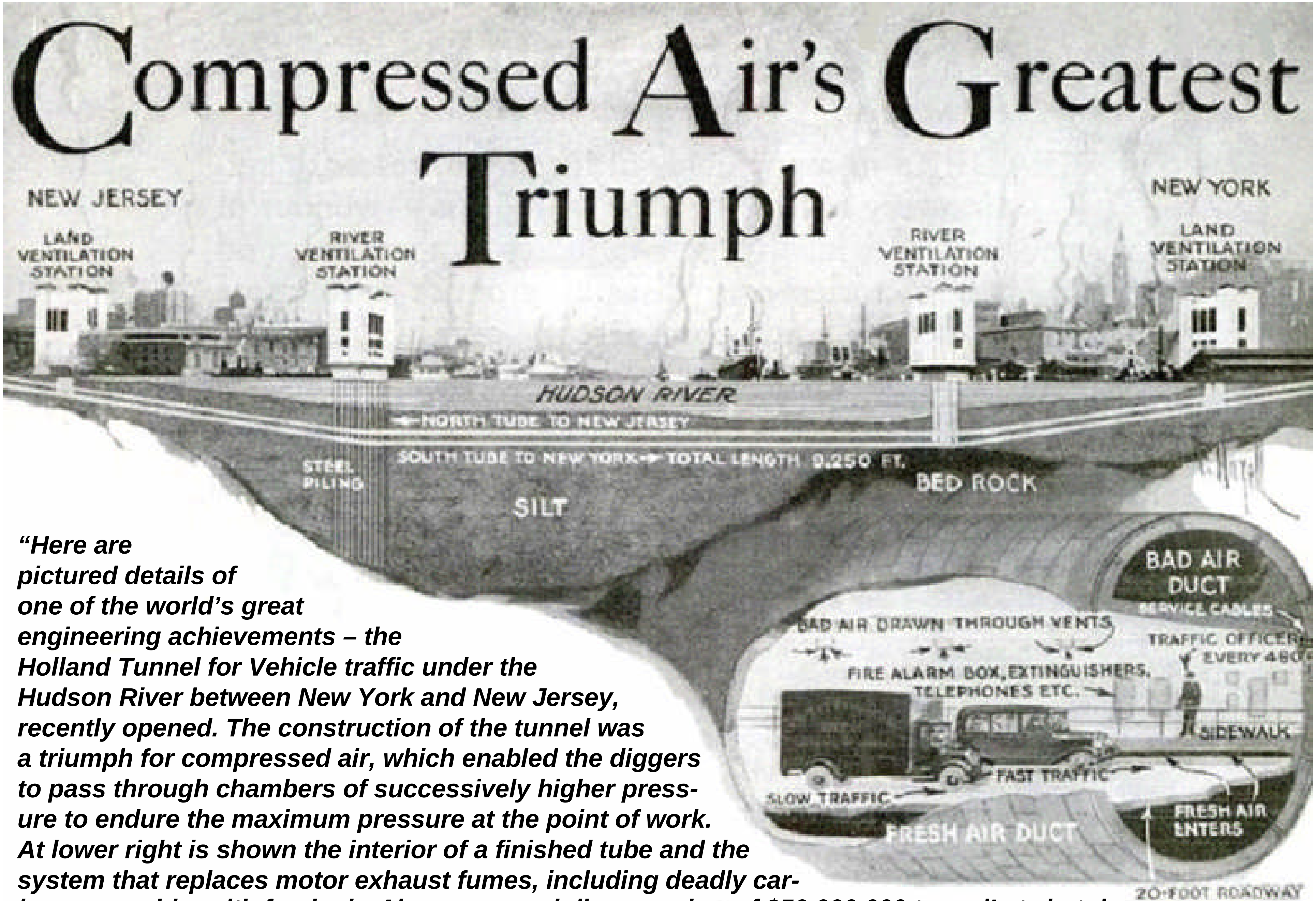
CROSS SECTION — ONE TUBE OF HOLLAND TUNNEL

Police Car Rides Narrow-Gauge-Track "Catwalk" in Tunnel

Patrolmen who regulate the flow of traffic through the Holland Tunnel recently tested a miniature electric car that rolls along the tunnel's "catwalk." The car is designed to give the officers greater control over traffic by permitting them to cover tunnel posts faster. It was tested on a 2200-foot run of miniature railroad track. Only two feet wide, the 1300-pound car can be driven in either direction from a swivel seat inside the glass-enclosed cab. Push buttons control the speed at six or twelve miles per hour. A 240-volt, three-horsepower motor powers the car.


EXTINGUISHER
KEEP IN LANE
SW

Greatest Triumph



"Here are pictured details of one of the world's great engineering achievements – the Holland Tunnel for Vehicle traffic under the Hudson River between New York and New Jersey, recently opened. The construction of the tunnel was a triumph for compressed air, which enabled the diggers to pass through chambers of successively higher pressure to endure the maximum pressure at the point of work. At lower right is shown the interior of a finished tube and the system that replaces motor exhaust fumes, including deadly carbon monoxide, with fresh air. Above, general diagram view of $50,000,000 tunnel's twin tubes accommodating 3,800 vehicles an hour. The tunnel required seven years to construct."

Popular Science, **January 1928**

Wedded


NOVEMBER 13, 1927.

GREAT CROWD TREKS INTO HOLLAND TUBES AFTER GALA OPENING

Thousands Pour In as Coolidge on Yacht Turns Switch With Golden Key.

AUTOS START AT MIDNIGHT

Hundreds of Honking Cars Rush Through Tunnels From New York and Jersey Sides.

OFFICIALS HAIL THE EVENT

Governor Smith, Governor Moore, Edwards, Edge and Others Extol Engineering Triumph.

The Holland Vehicular Tunnel was officially opened at 4:55 o'clock yesterday afternoon by President Coolidge aboard his yacht, the May-

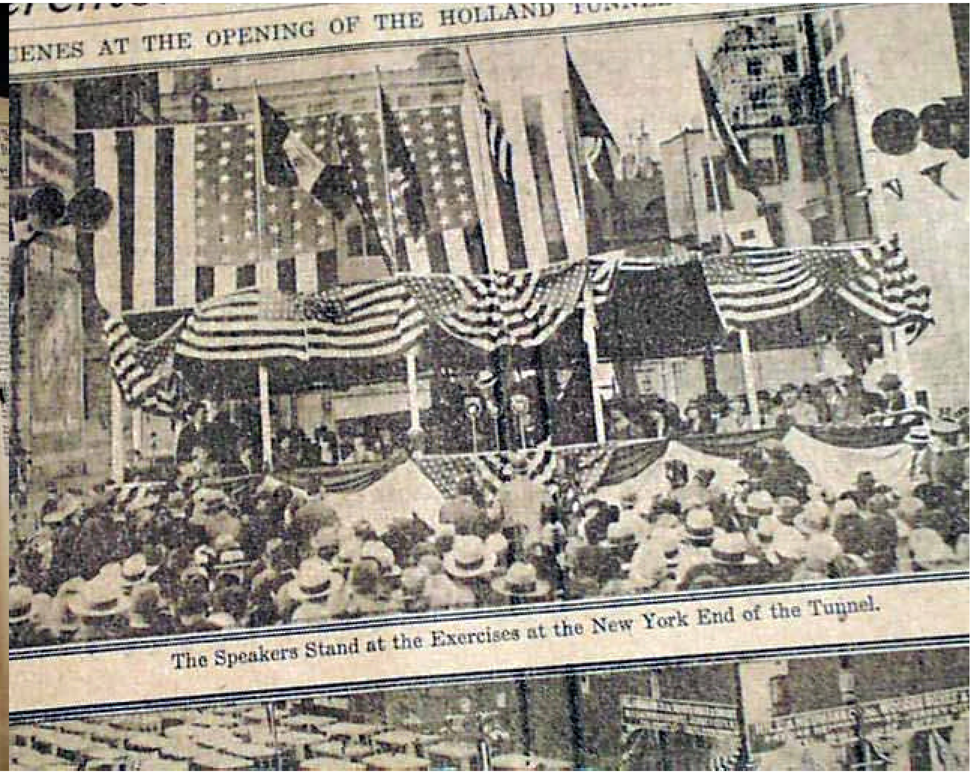
"The Holland Vehicular Tunnel was officially opened at 4:55 o'clock yesterday afternoon by President Coolidge aboard his yacht, the Mayflower, at anchor in the Potomac River. With the golden telegraph key used by President Wilson to explode the charge that opened the panama Canal, President Coolidge turned on the electric current that drew aside from the New York and Jersey City entrances to the tunnel two huge American flags, thus completing the elaborate ceremonies attendant upon what Governor Smith called 'the wedding of the two Commonwealths.'…"

***The New York Times*, Sunday, November 13th 1927**

Impressive Ceremonies in Two States Mark Opening of Holland Tunnel

WORK ON TUNNEL BEGAN 7 YEARS AGO

FEMINISM IS BLAMED FOR WAR BY BETHLEN

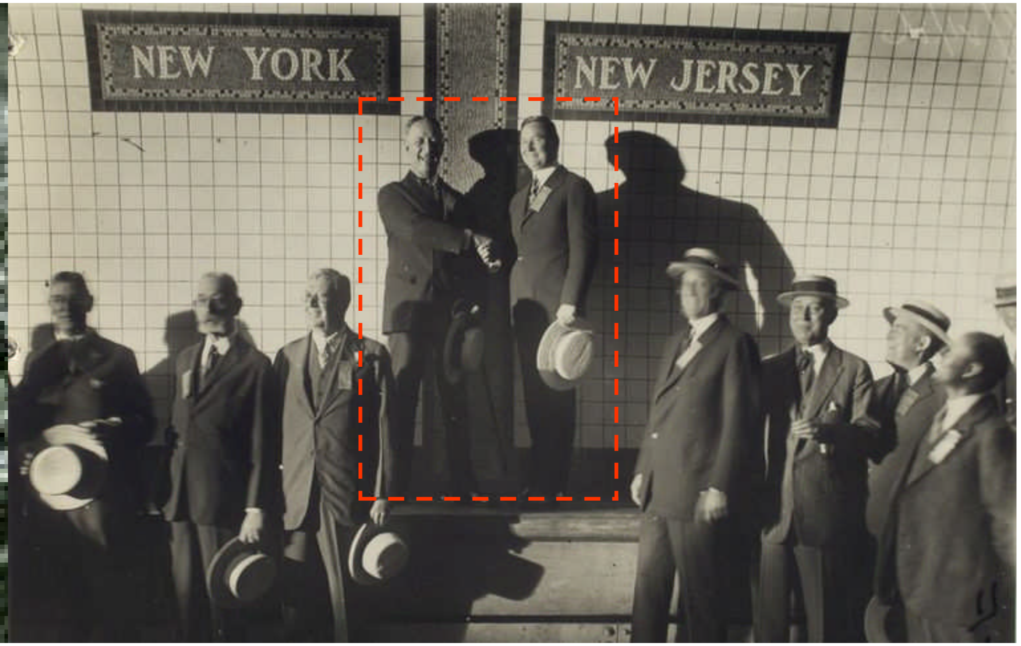


ENES AT THE OPENING OF THE HOLLAND TU

The Speakers Stand at the Exercises at the New York End of the Tunnel.

"…When the two flags had parted before the New York entrance, there surged beneath their drawn folds and on into the chill depths of the white-tiled, brilliantly lighted sub-aqueous thoroughfare, an almost solid mass of pedestrians eager to make the trip from shore to shore afoot. It was estimated that within an hour 20,000 or more persons had walked the entire 9,250 feet from entrance to exit, and the stream of humanity, thinning a little toward the last, continued to traverse the tunnel until 7 P.M., when it was closed until 12:01 A.M. the hour set for the vehicular traffic to begin its regular, paid passage…"

The New York Times, **Sunday, November 13th 1927**

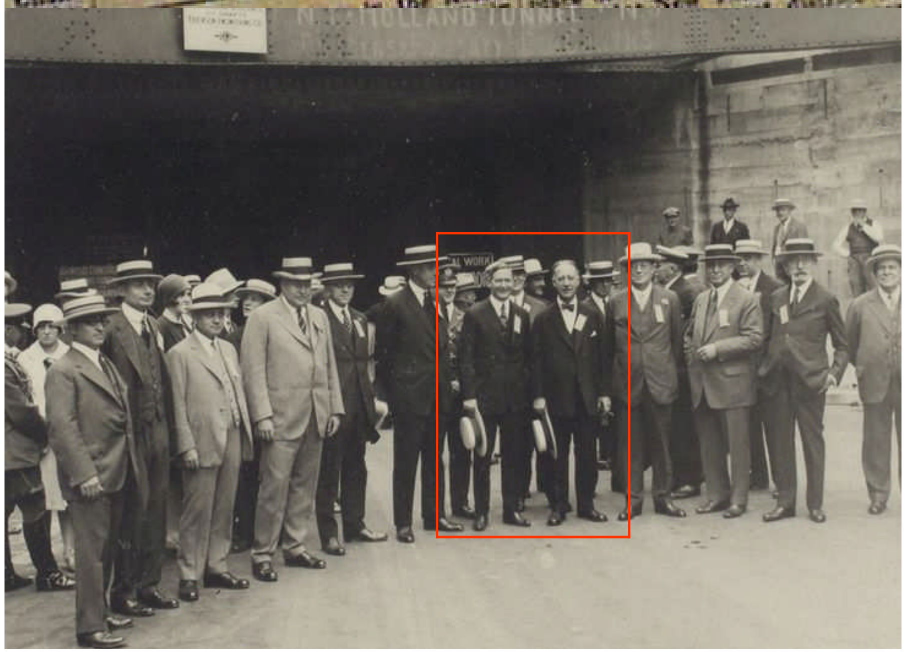


"…The pedestrians in the tunnel furnished the most spontaneous celebrative touch of an entire afternoon of ceremonies conducted on both shores. They literally took possession of the tunnel…A holiday spirit prevailed and the tunnel became, for the time, a new toy with which the crowds played like delighted children. They stopped to feel the air coming through the vents near the roadbed, they discussed the possibilities of establishing restaurants along the tunnel's sides, they shook hands with each other at the State line, some standing in New Jersey and gripping the hands of others standing in New York…"

***The New York Times,* Sunday, November 13th 1927**

<u>Left</u>: caption: "Holland Tunnel opening ceremony, November 12, 1927"

<u>Right</u>: caption: "New York meets New Jersey in The Holland Tunnel, November 12, 1927 (pictured: NY and NJ Governors Al Smith and A. Harry Moore)"

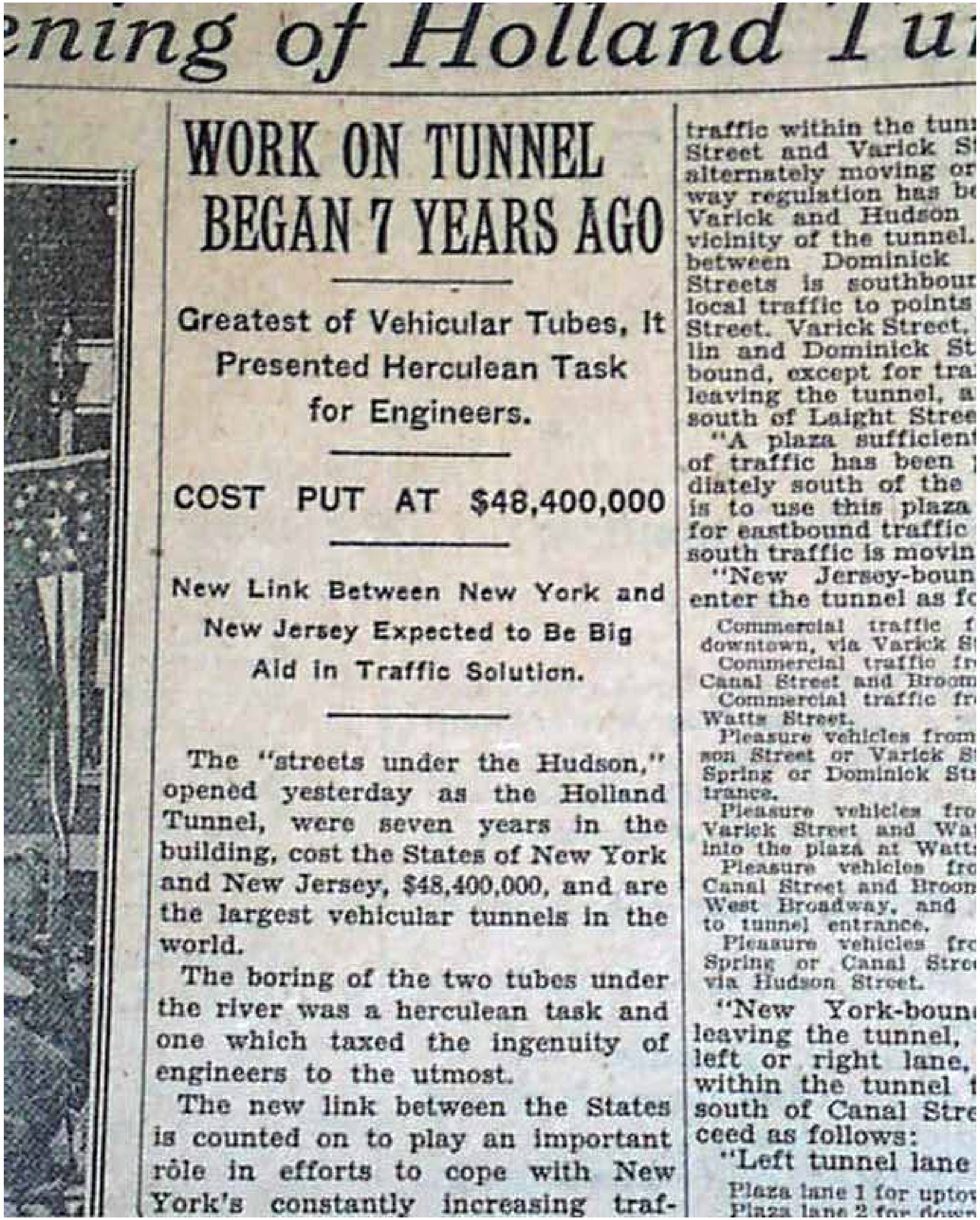


"…Vehicular traffic began pouring into the two tubes promptly at 12:01 A.M., when the first 'fixed crossing' between Manhattan and New Jersey was thrown open for regular paying business. Lines of honking cars were waiting at both the New York and Jersey City entrances…"

The New York Times, **Sunday, November 13th 1927**

<u>Left T&B</u>: the Governors of NY and NJ during opening day ceremonies

The Streets Under the Hudson



ening of Holland Tu

WORK ON TUNNEL BEGAN 7 YEARS AGO

Greatest of Vehicular Tubes, It Presented Herculean Task for Engineers.

COST PUT AT $48,400,000

New Link Between New York and New Jersey Expected to Be Big Aid in Traffic Solution.

The "streets under the Hudson," opened yesterday as the Holland Tunnel, were seven years in the building, cost the States of New York and New Jersey, $48,400,000, and are the largest vehicular tunnels in the world.

The boring of the two tubes under the river was a herculean task and one which taxed the ingenuity of engineers to the utmost.

The new link between the States is counted on to play an important rôle in efforts to cope with New York's constantly increasing traf-

traffic within the tun
Street and Varick S
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way regulation has b
Varick and Hudson
vicinity of the tunnel.
between Dominick
Streets is southbou
local traffic to points
Street. Varick Street,
lin and Dominick St
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of traffic has been
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is to use this plaza
for eastbound traffic
south traffic is movin
"New Jersey-boun
enter the tunnel as f
Commercial traffic f
downtown, via Varick S
Commercial traffic fr
Canal Street and Broom
Commercial traffic fr
Watts Street.
Pleasure vehicles from
son Street or Varick S
Spring or Dominick St
trance.
Pleasure vehicles fro
Varick Street and Wa
into the plaza at Watt
Pleasure vehicles fr
Canal Street and Broo
West Broadway, and
to tunnel entrance.
Pleasure vehicles fr
Spring or Canal Stre
via Hudson Street.
"New York-boun
leaving the tunnel,
left or right lane,
within the tunnel
south of Canal Stre
ceed as follows:
"Left tunnel lane
Plaza lane 1 for upto
Plaza lane 2 for down

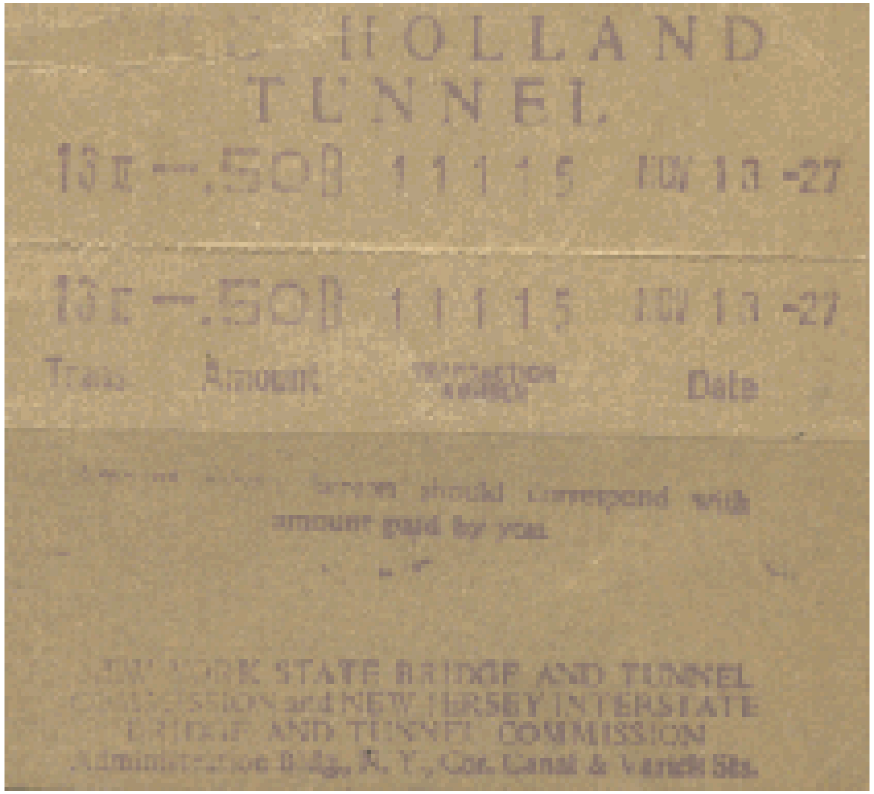
"The 'streets under the Hudson,' opened yesterday as the Holland Tunnel, seven years in the building, cost the States of New York and New Jersey, $48,400,000, and are the largest vehicular tunnels in the world. The boring of the two tubes under the river was a Herculean task and one which taxed the ingenuity of engineers to the utmost…"

***The New York Times,* November 14th 1927**

The *Holland Tunnel* opened at midnight on November 13th 1927, providing the first fixed vehicular crossing between *New York City* and *New Jersey*, at a cost of $48,400,000. POTUS *Calvin Coolidge* formally opened the tunnel with the same key that opened the *Panama Canal* in 1914. At one minute past midnight, a truck making a shipment to *Bloomingdale's Department Store* in *Manhattan* was the first non-official vehicle through the *Holland Tunnel* and was the first vehicle to pay the toll at the *Canal Street* toll plaza. In its first day of operation, the tunnel saw 52K vehicles pass through its twin tubes. The *Port of New York Authority* (later the *Port Authority of New York and New Jersey*) took over jurisdiction of the Holland Tunnel in 1931. In 1934, *Julius Henry Cohen*, the financial counsel of the Port Authority, issued new Port Authority bonds in a unique financing proposal. The new "General Issue" bonds took the surpluses generated by the Holland Tunnel to finance the money-losing *Staten Island-New Jersey* bridges (*Goethals* and *Outerbridge Crossing*) as well as for the future construction of a second *Hudson River* vehicular tunnel (the *Lincoln Tunnel*).

<u>Above L&R</u>: caption: "Holland Tunnel toll booths (1927)"

<u>Above</u>: caption: “Lincoln Tunnel First Toll Coll-ected”
<u>Left</u>: caption: “Holland Tunnel Toll Booth, 1927”



From a purely financial point of view, the tunnel was a great success. Whereas its total cost (not including interest during construction) was $48,400,000, profit over operating costs was more than $3,500,000 during the first year (one-half going to each state). For the first year the tunnel operated at about one-half of estimated capacity. However, traffic has been at near capacity since the middle thirties and the tunnel was fully paid for out of toll charges by the end of 1940.

<u>Left</u>: caption: "First toll receipt: November 13, 1927"

No Easy Task

"…That the construction of the Holland Tunnel was no easy task is evidenced by the great increase in both time and money required for its completion. The original plans called for an expenditure of approximately $28,000,000 and for completion in 1924, or three and one-half years. Actual expenditures have run 50% greater, and as this is written, the opening will not be until the fall of 1927…"

RE: excerpt from *The Eighth Wonder*

"…many difficulties had to be overcome in bringing the work to a successful conclusion. The proceedings involved in the taking of real property at entrances and exits, changes in the grades of streets, the closing of a portion of 11th Street in Jersey City, negotiations with the railroads at the Jersey City end for the acquisition of parts of the railroad yards, all took time. It was not always easy to harmonize the views of the State Commissions. Alterations necessarily had to be made in the preliminary plans as further information resulted from investigation and experience…"

RE: excerpt from *The Eighth Wonder*

<u>Above</u>: caption: "Holland Tunnel (New Jersey Entrance), 1927"
<u>Left T&B</u>: during the 1970's, a new nine-lane toll plaza was built in *Jersey City* to collect tolls in the eastbound direction only (westbound motorists no longer had to pay a toll). Until that time, scattered booths on the *New York* side of the tunnel collected tolls in both directions, causing serious traffic jams throughout lower *Manhattan* and inside the eastbound tube.

"…That the undertaking cost the lives of its first two chief engineers – not from accident, but from the drain on their vital energy – is perhaps the most striking evidence of the magnitude of the undertaking…"

RE: excerpt from *The Eighth Wonder*

<u>Left</u>: caption: "Clifford Milburn Holland, 1883-1924"

"During the first twelve-month period, ending in November, 1928, a total of 8,517,689 vehicles used the tunnel. Of this number nearly 80 per cent were passenger cars. The average daily traffic was 23,372, while the average Sunday and holiday traffic was 36,391. The tunnel took about 43 per cent of the auto traffic crossing the Hudson, a figure far in excess of the estimate made in the plans. There was no shutdown except for a few hours on certain nights when the north tunnel was closed in order to take accurate readings of the distribution of air in the various parts of the tube. There was no serious accident, largely because of rigid enforcement of traffic regulations, brilliant illumination, and prompt handling of stoppages in the tunnel."

Ole Singstad, **Chief Engineer (November 1928)**

A Modern Wonder

"…Doubtless other tunnels under the Hudson will be built. Other problems in successful ventilation will be solved. The Sturtevant Silentvane Fan will be put to other uses of equal importance to humanity. But for many years to come the Holland Tunnel will remain one of the modern wonders of the world – a triumph in the science of ventilation."

RE: excerpt from *The Eighth Wonder*

<u>Above</u>: caption: "The Holland Tunnel Completed. Seven years of study, re-search and labor"

The real test of the tunnel's performance concerned the revolutionary ventilation system. Orders were given to operate at a normal maximum capacity on the first day. About 3,760,000 cubic feet of fresh air per minute was provided. Nearly 52K vehicles, of which about 98% were passenger cars, went through the tube. The average carbon monoxide content in both tunnels was 0.69 part per 10K parts of air. The highest was 1.60 parts per 10K (the permissible standard was 4 parts per 10K parts of air). The longitudinal air draft caused by vehicular movement at times reached 10 mph. It was found, too, that there was never enough fog or smoke to interfere with safe traffic and, in fact, the public and the press proclaimed air conditions were actually better in the tube than in some streets of *New York City*. The general cleanliness of the tunnel was also praised by the traveling public and press.

Like the Flaming Tail of a Comet

“Moving traffic lights, probably the first of their kind in the world, have just been installed experimentally in the Holland Tunnel between New Jersey and New York. Unlike ordinary traffic signals, they are designed to speed up passing drivers, replacing the frantic gestures of tunnel policemen. Because this vehicular tube beneath the Hudson River has become more and more frequently choked with traffic, the odd scheme was decided upon in an effort to increase its capacity. Tunnel engineers installed a 1,000-foot row of ten-watt bulbs along the footwalk on the New York-bound side of the tunnel for the tests. They also designed and built a control system similar to that used in animated electric signs. A motorist entering the tunnel during rush hours sees a yellowish flash of light racing along the wall beside him, like the flaming tail of a comet. It is traveling at thirty miles an hour, and he is expected to keep up with it. Seventy-five feet ahead of him, and behind, similar lights guide other drivers. Thus they stimulate laggards, admonish speeders, and also aid in keeping cars the legal distance apart in the tunnel. Officials are reserving their plans for completing the system until further tests, but it is said to have worked with encouraging success. At this writing it was planned to distribute cards to patrons of the tunnel, explaining the purpose of the lights. A woman driver, frightened by the new lights, crossed the center line of the double-lane tube in defiance of regulations. Questioned by the police, she explained that she thought the tunnel was on fire.”

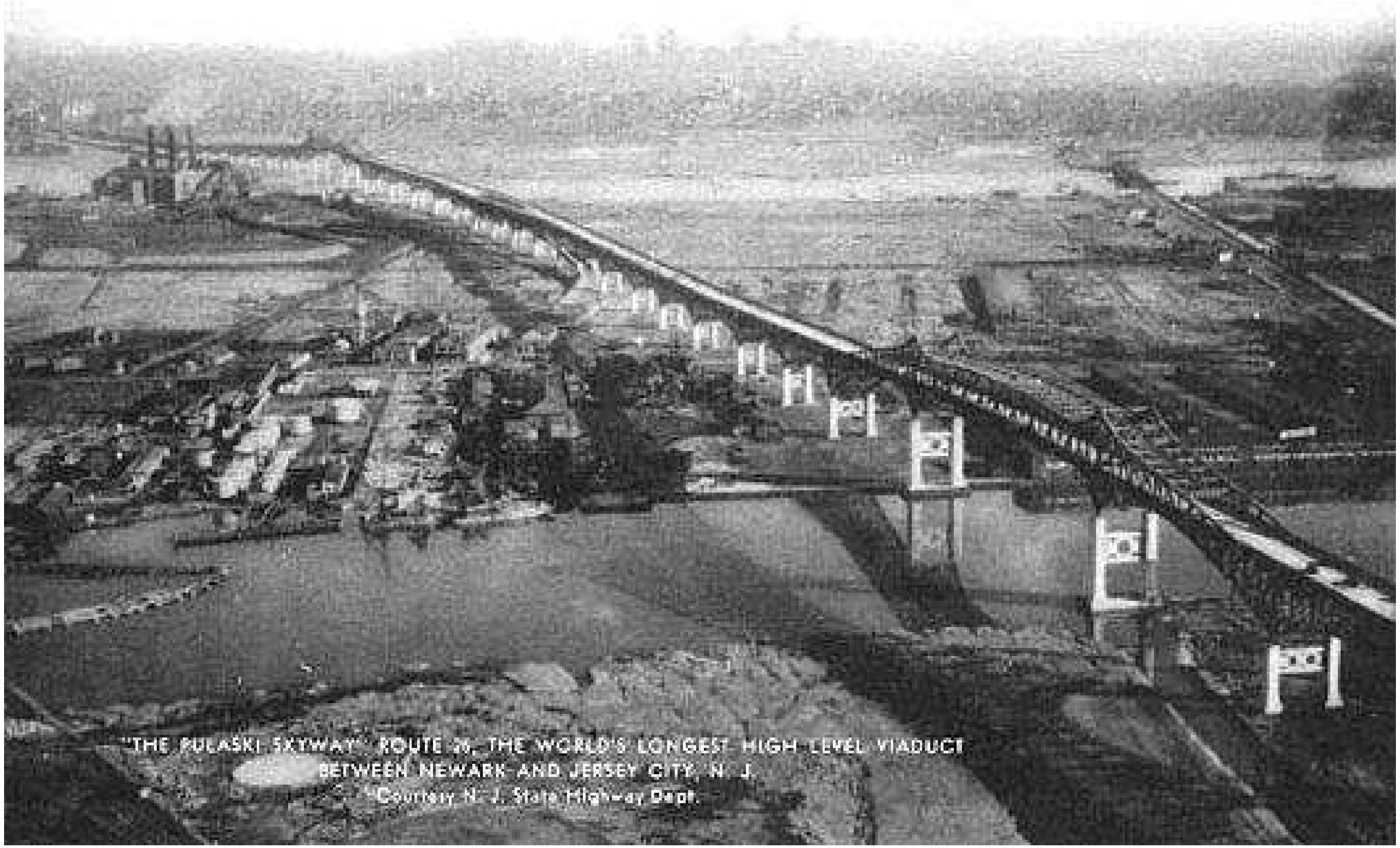
Popular Science, **March 1932**

Skyway

"A thirteen-mile superhighway linking two of the nation's greatest cities has just been opened between New York City and Newark, N.J. Starting at the New Jersey end of the Holland vehicular tunnel, its steel-and-concrete viaduct soars across rivers, marshes and crossroads to permit high-speed motor traffic. By this route, mail trucks from the trans-continental airport at Newark will reach New York in a fraction of the time now required. Shown at left in a striking aerial view, the $21,000,000 highway is called the costliest per mile ever built but the densely populated section it serves is said to justify the expense."

Popular Science, **February 1933**

RE: opened in 1932, the *Pulaski Skyway* spans the *Passaic* and *Hackensack River/s*, connecting *Newark* and *Jersey City*


"THE PULASKI SKYWAY" ROUTE 25, THE WORLD'S LONGEST HIGH LEVEL VIADUCT
BETWEEN NEWARK AND JERSEY CITY, N. J.
Courtesy N. J. State Highway Dept.

Fire in the Hole

“Nearly 200 fires broke out in vehicles that were going through the tunnel. All fires, however, were extinguished by policemen using chemical fire extinguishers, and without the aid of a special fire-fighting apparatus mounted on an emergency truck. Over 2,000 disabled vehicles were towed out of the tunnel, and a number of arrests were made, summonses and warnings issued.”

Ole Singstad, **Chief Engineer (November 1928)**

RE: statistics concerning the Holland Tunnel’s first year of operation

"…Fully enclosed trailer carrying eighty 55-gallon drums of carbon disulfide entered the New Jersey portal of tunnel, in violation of Port Authority regulations and allegedly un-placarded in violation of ICC regulations, in very heavy, slow traffic approximately 8:30 AM. The drums broke free and ignited upon striking roadway approximately 2,900 feet into tunnel. A truck rolled to a stop in left lane. Four trucks caught fire and were abandoned adjacent to the trailer in the right lane. Five additional trucks stopped 350 feet to the rear grouped tightly in right lane also ignited. Approximately 125 automobiles, buses, and trucks filled both lanes back to New Jersey portal…A three-man emergency crew drove west through eastbound tube on wrecker and jeep upon receiving the 8:56 AM fire alarm, and commenced fighting the fire with a 1-inch-diameter hose and spray nozzle. They assisted two tunnel patrolmen overcome by smoke, extinguished fires in two trucks of eastern group, and towed one to the New York portal. An FDNY rescue company and battalion chief drove west through westbound tube, and crossed to the fire scene to relieve the tunnel emergency crew. Some firemen in distress recovered by breathing at the curb-level fresh air ducts…Ten trucks and cargoes completely destroyed, 13 others damaged. 600 feet of tunnel wall and ceiling demolished; walls spalled in places to cast iron tube plates. 650 tons of debris removed from tunnel. Tube reopened to traffic 56 hours after fire started. All cable and wire connections through tube disrupted at fire. Total damage estimated at $1 million…66 injuries, 27 requiring hospitalization; no fatalities."

Federal Highway Administration

RE: on May 13th 1949, a chemical truck loaded with eighty drums of carbon disulfide burned on the *New Jersey* side of the south tube of the *Holland Tunnel*

<u>Top</u>: caption: “Photo shows the damage done to a large section of the Holland Tunnel, which links New York and New Jersey, when a chemical-laden truck caught fire and exploded. Twenty other trucks and cars were burned by the blast, and seventy persons were hospitalized for gas poisoning.”

<u>Bottom</u>: caption: “Holland Tunnel emergency vehicles, 1950”

On March 25th 2002, a multiple-alarm fire at an abandoned warehouse and storage facility in *Jersey City* threatened the western portals of the *Holland Tunnel*, including the toll plaza. For several days, the Port Authority closed the tunnel to all traffic while firefighting operations were underway.

<u>Above</u>: caption: "The Mecca & Sons warehouse at the Holland Tunnel entrance plaza caught fire on March 25, 2002 and was demolished in the following weeks"

Legacy

“There are going to be a lot more tunnels built in this country in the future. I don’t mean they will replace bridges entirely, of course. But we have proved pretty conclusively that, especially in large cities, the tunnel in the long run is the most economical method of spanning a body of water. It comes down to this: a bridge requires approaches nearly a mile in length. Not only are they unsightly affairs but they damage, if not totally destroy, real estate values in the area. A tunnel needs an approach of only a block or two - and no overhead structure. Surrounding property is hardly disturbed at all by tunnel approaches…The field is expanding rapidly and will expand still further. Moreover, tunnel work gives employment for a number of years on one job alone. If I were back in engineering school again, I’d make it my business to specialize in tunnel building right from the start. It’s a fascinating career! ”

***Ole Singstad,* Tunnel Engineer (1941)**

"…Twice the cost, twice the operating fees, twice the difficulty to engineer, and half the traffic…"

RE: excerpt from a 1941 *Triborough Bridge and Tunnel Authority* publication. In the late 1930s, a controversy raged over whether an additional vehicular link between *Brooklyn* and lower *Manhattan* should be built as a bridge or a tunnel. The "Brooklyn-Battery Bridge" would have decimated *Battery Park* and encroached on the financial district. The bridge was opposed by the *Regional Plan Association* (RPA), historical preservationists, *Wall Street* financial interests, property owners, various high society people (including *Eleanor Roosevelt*), the Manhattan Borough President, Mayor *Fiorello LaGuardia* and NYS Governor *Herbert H. Lehman*. Despite this formidable opposition, Moses favored a bridge. More traffic also meant more tolls, which meant funding for Moses' projects. He also clashed with *Ole Singstad*, Chief Engineer of the project, who preferred a tunnel. It was only a lack of federal approval that thwarted the bridge project. POTUS *Franklin Roosevelt* ordered the *War Department* to assert that the sabotage of bridge in that location would block *East River* access to the *Brooklyn Navy Yard* upstream (despite the fact that the *Brooklyn* and *Manhattan Bridge/s* were also upstream). Moses was forced to settle for a tunnel: the *Brooklyn–Battery Tunnel* (officially the "Hugh L. Carey Tunnel").

"…tiled ventilated vehicular bathroom smelling faintly of monoxide and inviting claustrophobia"
Robert Moses

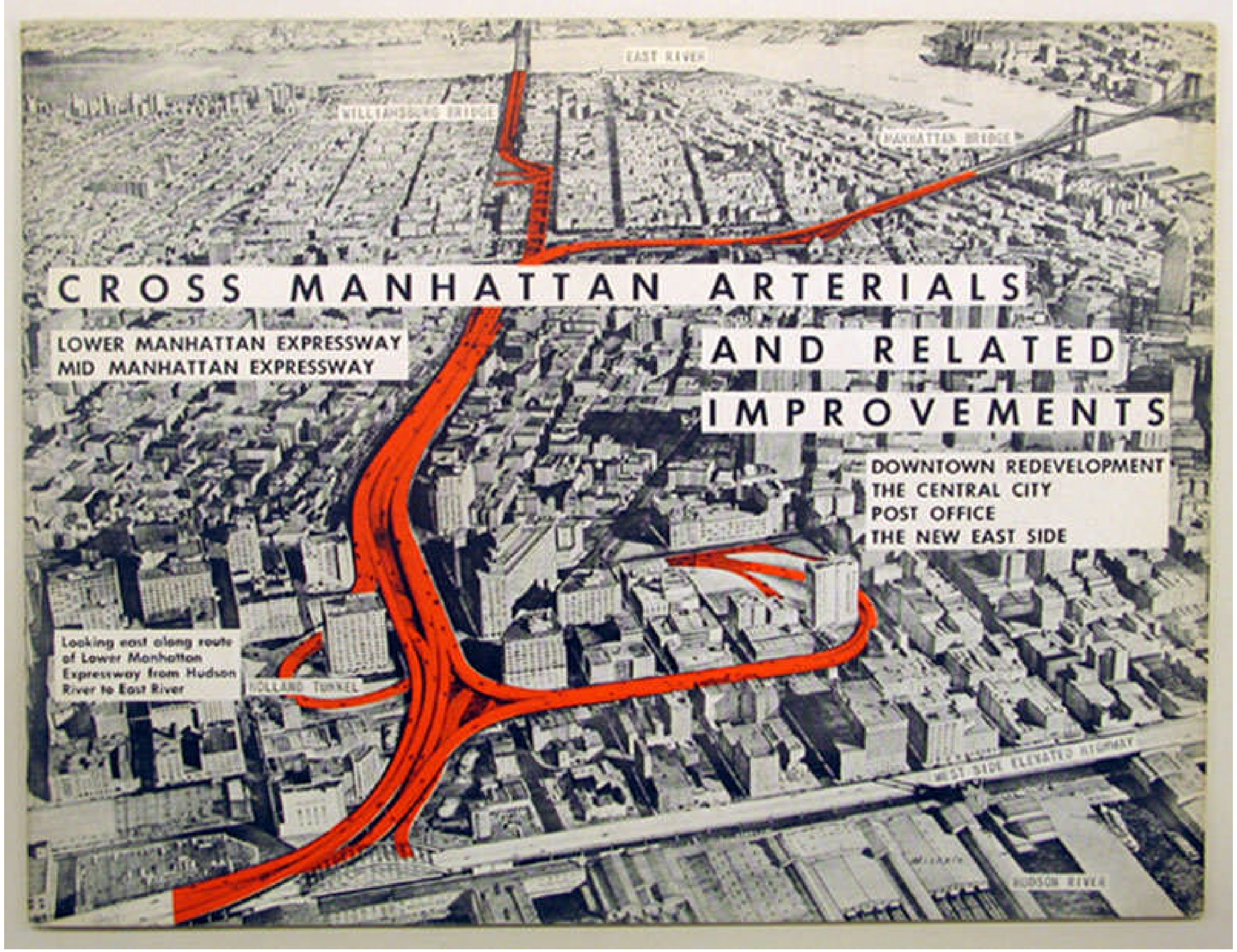
RE: his opinion of tunnels. The *Brooklyn-Battery Bridge* project would not be the only time Moses pressed for a bridge over a tunnel. He clashed again with *Ole Singstad* and tried to upstage the tunnel authority when the *Queens-Midtown Tunnel* was being planned a few years later. He raised the same arguments, which failed due to their lack of political support.

<u>Left</u>: caption: "Robert Moses with a model of his proposed Brooklyn-Battery Bridge"

LOMEX

“Lower Manhattan Crosstown Highway: This is a much-needed crosstown connection between the Manhattan and Williamsburg bridges, and the Holland Tunnel, serving local cross-Manhattan traffic as well as traffic from the bridges and the tunnel. This connection would not only provide additional needed capacity for crosstown traffic, but would also help relieve congestion on north-south streets by minimizing delays at heavily traveled crosstown streets, such as Canal Street. Several agencies have made studies of this improvement, and have recommended various routes and types of construction. While the Commission is definitely in accord with the principle of providing an express crosstown highway in the area indicated, it does not now recommend any particular route or type of construction.”

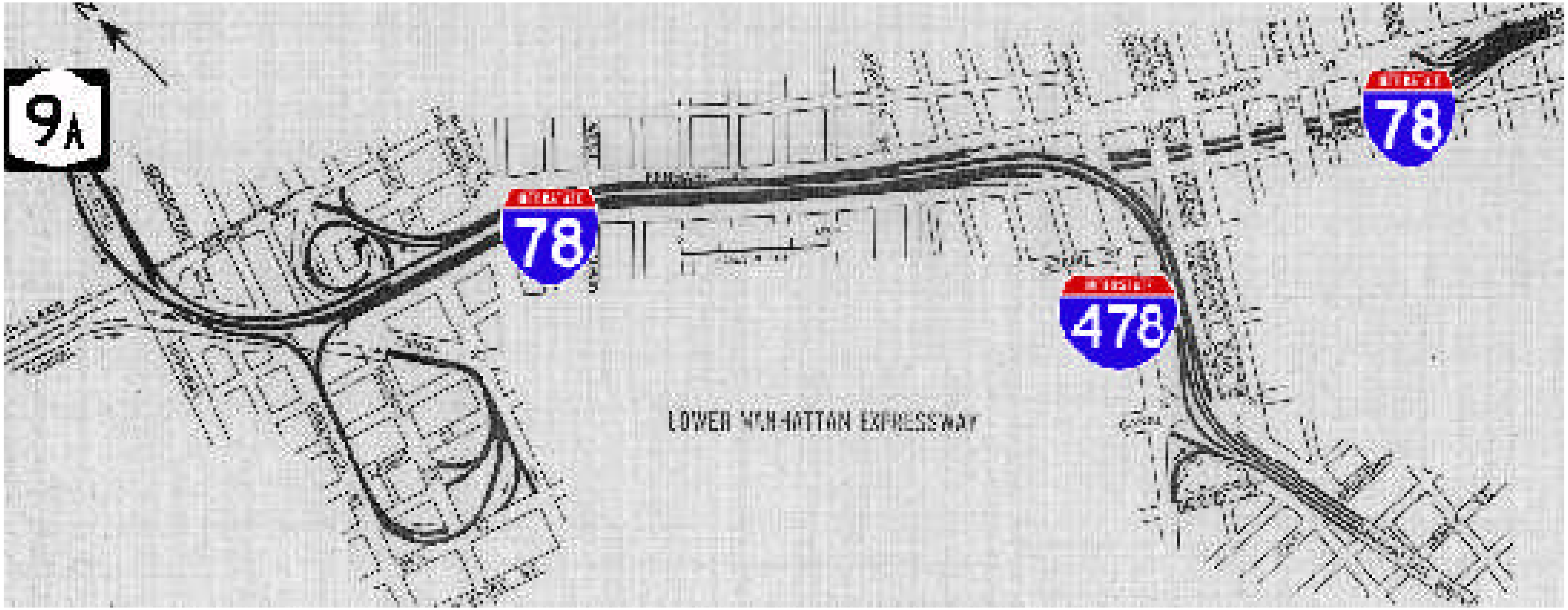
RE: 1941 description of the *Lower Manhattan Expressway* (a.k.a. “LOMEX”). The first proposal for a controlled-access highway across lower *Manhattan* appeared in the 1929 *Regional Plan Association* (RPA) report: “Plan of New York and Its Environs.” As an integral part of the tri-state network of expressways and parkways, the Lower Manhattan Expressway was to connect the *Holland Tunnel* with *Brooklyn*.



EAST RIVER
WILLIAMSBURG BRIDGE
MANHATTAN BRIDGE
CROSS MANHATTAN ARTERIALS
LOWER MANHATTAN EXPRESSWAY
MID MANHATTAN EXPRESSWAY
AND RELATED
IMPROVEMENTS
DOWNTOWN REDEVELOPMENT
THE CENTRAL CITY
POST OFFICE
THE NEW EAST SIDE
Looking east along route of Lower Manhattan Expressway from Hudson River to East River
HOLLAND TUNNEL
WEST SIDE ELEVATED HIGHWAY
HUDSON RIVER

***Robert Moses* recommended that construction of the road be expedited not only to relieve congestion, but also to serve defense needs. In 1943, the *NYC Planning Department* floated six different proposals for LOMEX. The cost of the proposal, including construction and right-of-way acquisition, was estimated at $23.0 million. However, city officials recommended postponing the LOMEX project until the *Brooklyn-Battery Tunnel*, *FDR* (*East River*) *Drive* and *Harlem River Drive* projects were completed. In 1946, Moses resurrected LOMEX, this time proposing a direct route between the *Holland Tunnel*, *Williamsburg Bridge* and *Manhattan Bridge*. The proposal was the subject of a 1949 study. In 1955, It was the subject of the "Joint Study of Arterial Facilities" conducted by the *Triborough Bridge and Tunnel Authority* and the *Port of New York Authority*.**

<u>Above</u>: caption: “Artist's conception from the 1950’s shows the elevated Lower Manhattan Expressway looking east. In the foreground is the interchange with the Holland Tunnel, with the elevated West Side Highway running along the bottom of the photo. In the distance are connections with the William-sburg Bridge (top center) and the Manhattan Bridge (top right).”



<u>Above</u>: the segment of LOMEX from the *Holland Tunnel* to the *Williamsburg Bridge* received the *I-78* designation, while the spur to the *Manhattan Bridge* received the *I-478* designation. The three connecting river crossings also received Interstate designations, making the entire LOMEX project, then estimated at $104 million, eligible for 90% Federal funding. State and city officials were under pressure to build the expressway: if it were not built, Federal funding for the connecting river crossings would have been reduced from 90% to 50%. To accommodate future traffic along the lower *Manhattan* corridor, Moses proposed construction of a third tube to the Holland Tunnel. The third tube, which would allow four lanes of traffic in one direction during rush-hour periods, was to be constructed in conjunction with the expressway. While the PA voiced support for an eventual third tube, it did not allocate funds for the proposal.

The Meat Ax

"You can draw any kind of pictures you like on a clean slate and indulge your every whim in the wilderness in laying out a New Delhi, Canberra and Brasilia, but when you operate in an overbuilt metropolis you have to hack your way with a meat ax…The route of the proposed expressway passes through a deteriorating area with low property values due in considerable part to heavy traffic that now clogs the surface streets. Construction of the expressway will relieve traffic on these streets and allow this locality to develop in a normal manner that will encourage improved housing, increased business activity, higher property values, a general rise in the prosperity of the area, and an increase in real estate tax revenues. This has been the experience again and again in localities in the city where modern parkways and expressways have been built. The Grand Central Parkway and the Belt Parkway have produced these results, and it is now happening along the Long Island Expressway. There is every reason to expect that it will also happen in the case of the Lower Manhattan Expressway."

Robert Moses

RE: by the 1960s, public hearings on the LOMEX project had become more contentious. Construction of the expressway was to have displaced 1,972 families and 804 businesses. Moses planned construction of new apartment units for those displaced by the expressway, but remained intransigent regarding his controversial methods of achieving his goals.

NYC Mayor *John Lindsay* and *Robert Moses* had based their claim on the need for LOMEX on two studies undertaken by the engineering firm of *Madigan-Hyland*. The studies were based on 1958 traffic counts, meaningless by 1968 when the project won *Bureau of Public Roads* (BPR) approval (even more so by 1978 when the expressway would be open for traffic). These concerns, along with a November 1968 study predicting increased carbon monoxide levels in the vicinity of the proposed road, sealed the doom of the *Lower Manhattan Expressway*. The NYC *Board of Estimate* de-mapped the project in August 1969 and on March 24th 1971, NYS Governor *Nelson Rockefeller* officially killed LOMEX. Interstate funding for this highway and the *I-478* designation, were subsequently transferred to the *West Side Highway* reconstruction (a.k.a. "Westway").

"Apparently the expressway has been shelved for the present. On the other hand, most of the parties concerned, including the Downtown Manhattan Association, the Regional Plan Association and others, agree that there must eventually be a Lower Manhattan Expressway. Nobody knows how access to the Holland Tunnel will be provided, how access to the new Battery complex will be provided, how the tenants will be moved, where and at whose expense, or how the pollution issue will be resolved."

Robert Moses

RE: in 1998, discussions focused on reviving plans for *I-78* through NYC began, but opposition remains strong to the various schemes proposed

Above: caption: "Artist's conception from 1959 showing the elevated Lower Manhattan Expressway from street level"

Recognition

The *Holland Tunnel* was formally designated a "National Historic Civil and Mechanical Engineering Landmark" on May 2nd 1984 at ceremonies attended by officials of the two national Societies and the *Port Authority of New York & New Jersey*. A commemorative bronze plaque mounted on a five-foot high granite pedestal (above) was unveiled at the *New York Plaza* of the Holland Tunnel (west side of *Varick Street* between *Watts* and *Broome Street/s*, near the entrance to the north tube).

According to the Port Authority, the *Holland Tunnel* carries approximately 100K vehicles per day between *Jersey City, New Jersey* and *Canal Street* in lower *Manhattan*. Originally part of the easternmost section of the transcontinental *Lincoln Highway* (*U.S. 30*), the Holland Tunnel connects to *I-78*, *Business US 1-US 9* and *NJ 139* in Jersey City. According to the *New York State Department of Transportation* (NYSDOT), the I-78 designation actually continues one-half mile past the New Jersey-New York border. However, signs leading to the tunnel on either side of the Hudson do not have I-78 shields. The designation was part of the legacy of *Robert Moses*' LOMEX plan to continue I-78 across lower Manhattan into *Brooklyn,* which would have required construction of a third tube for the Holland Tunnel).


EMERGENCY VEHICLES ONLY
E-ZPass ACCEPTED ALL LANES
HOLLAND
TUNNEL TRUCKS KEEP RIGHT
ONLY
ONLY
ONLY
ONLY

Part 9

A Bridge Too Grand

A Vision Splendid

"…In the City of New York is a man who for thirty years has held a vision so splendid that few have had the imagination to appreciate it. He is Dr. Gustav Lindenthal, consulting engineer. His vision centers in a solution of New York's transportation problem, one feature of which is building a great bridge across the Hudson River. It is an undertaking which offers far greater difficulties than were encountered in building any of New York's present bridges…"

Popular Science, **December 1920**

<u>Left</u>: Gustav Lindenthal (ca. 1909)

"…At last, after many delays, the latest of which was due to the war, the preliminary work necessary for the construction of the Hudson River Bridge is well under way. A staff of engineers which includes some of the most distinguished men in the country has been formed, and back of the great work is a group of leading financiers, railroad men and others who have a wide practical acquaintance with transit problems…with an undeniable touch of genius that Gustav Lindenthal conceived the problem of connecting Manhattan and New Jersey, not by a series of separate structures, but by one vast bridge whose proportions would be such that it could easily take care of the whole of the traffic which surges to and fro between Manhattan Island and the mainland…"

***Popular Science,* April 1921**

Unprecedented Dimensions

"…Mr. Gustav Lindenthal, the eminent bridge engineer, has evolved a design for a bridge across the Hudson at 57th Street, which will allow so great an increase in the facilities which make for the growth of Manhattan, that the bridge is of interest to the entire country…"

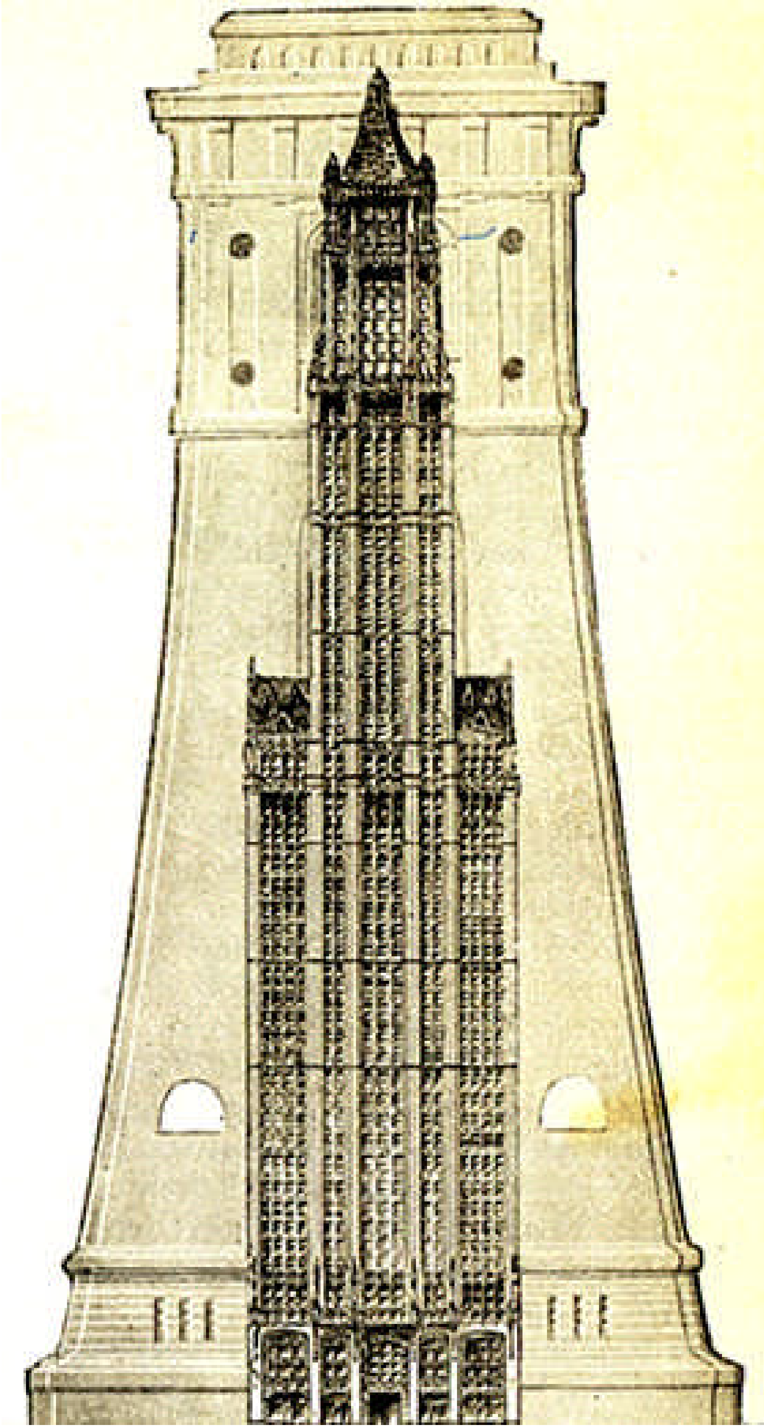
Baltimore and Ohio **magazine, January 1923**

"…It was not idealism or any striving for the spectacular that led to the conception of this bridge upon such a gigantic scale. Rather, its dimensions have been determined by the severest application of the principles of economy. In all construction engineering work, whether upon land or sea, it has been proved over and over again throughout the past decades that there is economy in concentration. We see it in the 900-foot steamer, the 400-ton locomotive, the 100-ton freight car, the multi-storied office building, and in the huge factories which are characteristic of American Manufacturing industry. Similar economies both in the first cost and the cost of operation, will be achieved by solving the vast traffic and transportation problem between the Western continent and Manhattan Island, by the construction of a single bridge of unprecedented dimensions…"

Popular Science, **April 1921**

"…The principal stresses to which the bridge will be exposed will be those due to its own dead load. So great is this that, even with the bridge loaded to capacity, the live load would cause a comparatively negligible addition to the dead load stresses. The same is true of the wind loads. The great width of the extremely rigid floor system, coupled with the inertia of the bridge, serves greatly to simplify the problem of providing against wind stresses…"

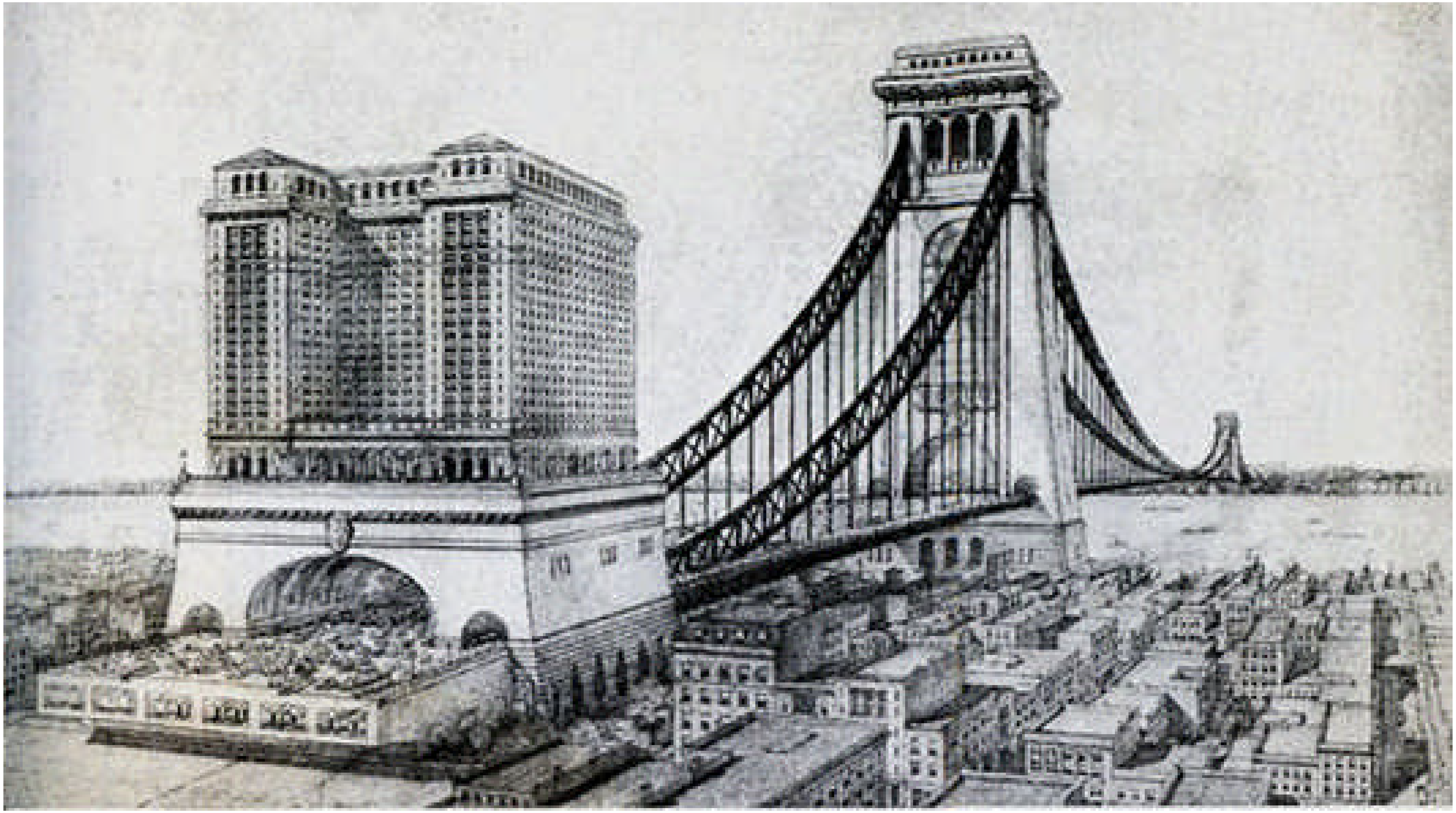
***Popular Science,* April 1921**



"…The other prominent features are the towers. In order to give the most economical sag to the chains the towers have to be of great height and strength. Their bases are to be 200 feet by 400 feet and their overall height 800 feet above water level. They are to be founded on rock which is from 100 to 200 feet below the water…Each tower will be built of steel encased in a shell of masonry for utility and as protection from the weather…"

Baltimore and Ohio **magazine, January 1923**

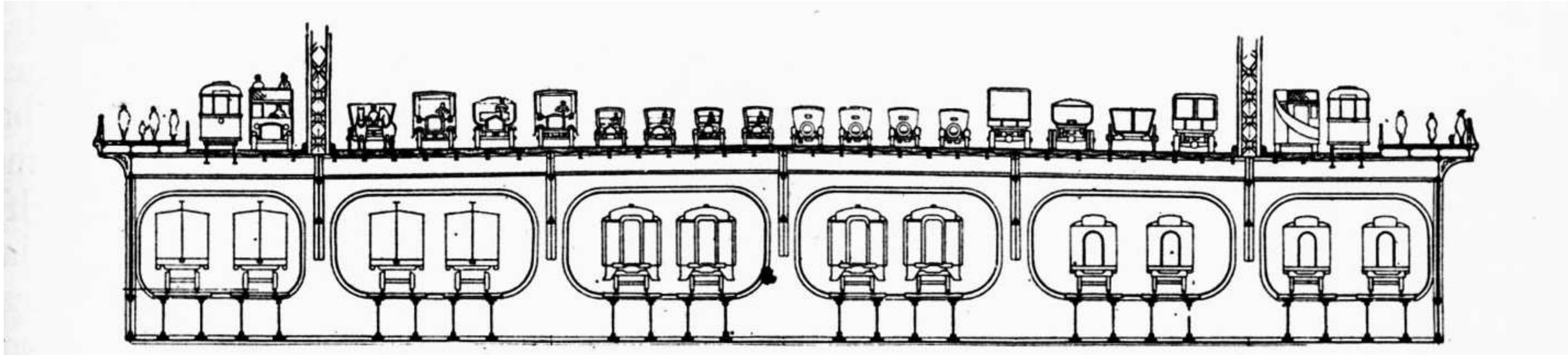
Left: caption: "One of the two towers which will support the bridge - 825 feet high – compared with the famous Woolworth Building" (*Scientific American,* 1921)



"…The anchorages are in the rock on either shore and their function is to resist the pull of the chords. Masonry concrete blocks 400 feet long by 355 feet wide and some 240 feet high, will be required to properly anchor the chords…"

Baltimore and Ohio **magazine, January 1923**

<u>Above</u>: caption: "The proposed bridge across the Hudson River – from the Architect's drawing." The structure atop the anchorage was to be a hotel/office building.



"…So much for the bridge structure. Its capacity on the upper decks is four surface car lines, two fifteen foot sidewalks, and width of roadway sufficient for 16 lines of vehicles; on the lower decks, facilities for 12 standard gauge railroad tracks…"

***Baltimore and Ohio* magazine, January 1923**

Above: caption: "Cross-Section of the Proposed Hudson River Bridge, at the Center of the Span. The central roadway, between the suspension cables, will be 155 feet wide, capable of accommodating sixteen lines of vehicular traffic. At each side, also, there will be room for trolley, bus, and pedestrians. Below that roadway will be provisions for twelve railroad tracks for passengers and freight trains. The extreme width of the bridge at the center of the span is 235 feet. In contrast, it may be mentioned that the Brooklyn Bridge accommodates only two rapid-transit railroad tracks, two trolley tracks, two lines of vehicles, and one roadway for pedestrians."

"…Its upper deck will furnish facilities for vehicular traffic and other surface traffic. The lower deck, when and as desired, can furnish with economy facilities for three other great public needs:

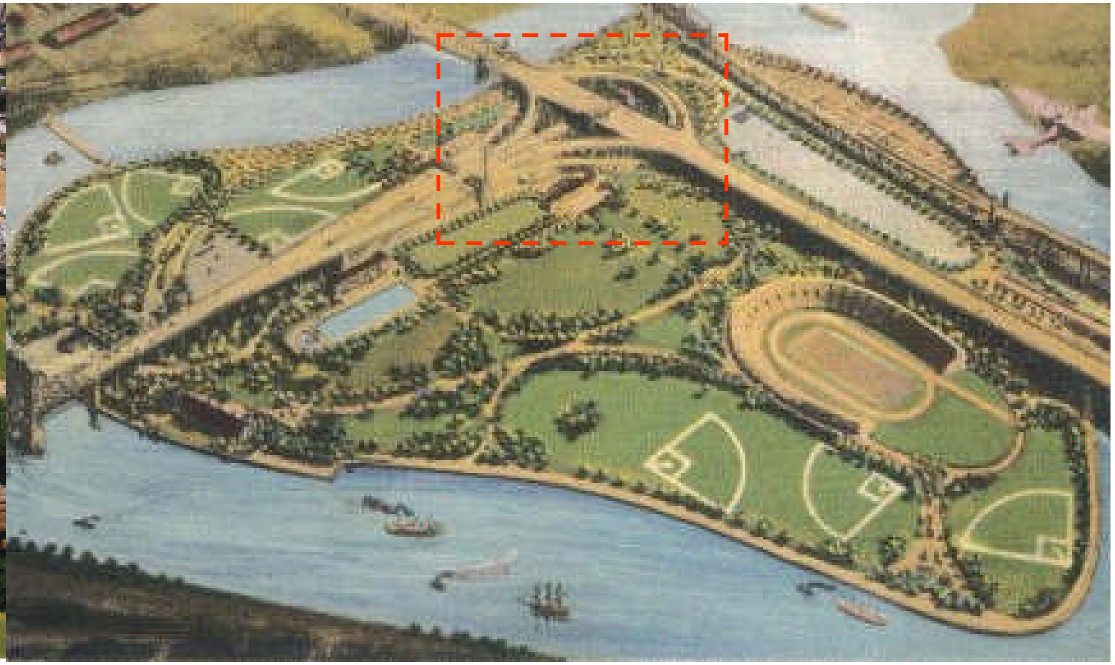
1st – Tracks for rapid transit suburban trains from New Jersey;

2nd – Tracks for passenger trains, other than for commuters, to a union station in Manhattan;

3rd – Tracks for freight delivered direct to Manhattan

Each or any one of these three facilities can be an independent unit built and maintained and operated as a separate unit as and when economically justified, or a combination of two or all three of the facilities can be worked together with the economies resulting from such a combination…"

***Baltimore and Ohio* magazine, January 1923**

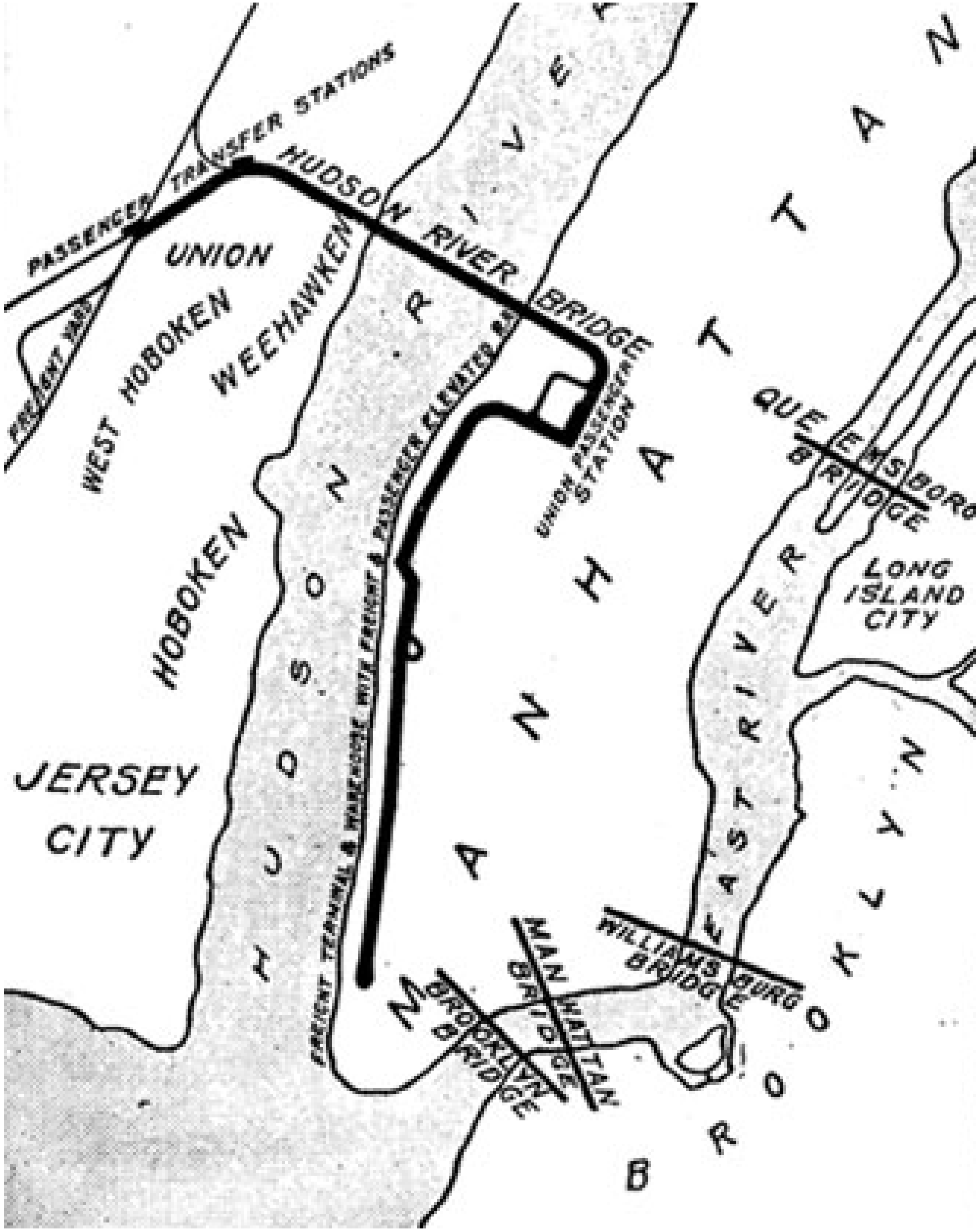
"…In taking care of vehicular and other traffic of the upper deck, the plan of approaches on either side of the bridge has been as carefully worked out as the busiest railroad junction. They provide that the tremendous traffic can be distributed into the street system on either side without causing congestion. The combined area into which the bridge pours its traffic is several times the width of the roadway on the bridge, with its sixteen lines of traffic, and by the use of flying junctions it is so arranged that the combined vehicular and surface traffic is delivered into the stream of street traffic on the proper side of the street for traffic moving in the same direction, and all traffic entering the bridge can do so without crossing at grade opposing traffic on the streets or the opposing streams of traffic leaving the bridge…"

***Baltimore and Ohio* magazine, January 1923**

Above L&R: Three roadways totaling twenty-two lanes of traffic converge create a "Flying Junction" of ramps and underpasses for the Triborough Bridge (1936) on *Randall's Island*, NYC

"…The plans for suburban trains from New Jersey have not yet been definitely worked out to a conclusion on account of the constantly changing status of rapid transit service in Manhattan. Suburban service has not been considered profitable and has few financial friends but it is a necessity of the Metropolitan life and it is inconceivable that an opp-ortunity for the use of such an efficient and comfortable entrance into Manhattan will not have proper distributing means available. It has great possibilities of daily service to many people and our preliminary study is to collect a portion of the commuters from all the New Jersey railroads and distribute them into Manhattan from an elevated structure along West Street reaching from 57th to Cortland Street and also into such existing subways as have capacity avail-able…"

Baltimore and Ohio **magazine, January 1923**



"…The freight terminal proposed in Manhattan consists of an elevated freight railroad located on blocks, lying on the east side of West Street from 46th Street to Cortland Street. These elevated running tracks are encased in an almost continuous building, extending from 42nd Street to Cortland Street, the building being 200 feet wide and five or more stories high and the cross town streets uninterruptedly through the building…"

Baltimore and Ohio **magazine, January 1923**

Left: caption: "Map of proposed Hudson River Bridge showing Union Station and railroad lines"

"…The suggested system of financing the whole enterprise does away with the necessity of delaying traffic to collect tolls. Automobiles would have an easy access to Manhattan from New Jersey, and by making use of the present East River bridges would have a direct passage to Long Island. No less than eighteen tunnels under the North River would be required to accommodate the traffic which would pass over this single great bridge, and the cost of that number of tunnels would be at least two-thirds greater than the cost of the bridge…"

***Popular Science,* December 1920**

"…Figures of cost have been avoided as they are confusing except to an expert…To the believer in Americanism, it is clear that the public is entitled to health, comfort and happiness in the consideration of any economic question…To the student of political economy, the expenditures involved are proper for this day and generation as they are primarily for the creation and improvement of permanent property for the production of direct service to the people for their material welfare…when the bridge has been built the historian will record that in no other place in the world could the facilities it affords have possibilities of beneficially affecting the lives of so many people. Yet America's metropolis is even now so great in population and industry and its future so assured that its need for such facilities will continue to be unprecedented…"

***Baltimore and Ohio* magazine, January 1923**

In Round Figures

"…The estimated cost of the bridge itself in round figures is 100 million dollars; the freight classification yard in New Jersey, 25 million dollars; the Union passenger station, accommodating the trains of all the roads that come in from the west and north, 30 million dollars; the double-deck elevated railroad down West Street to the Battery, 30 million dollars. The cost of the electrification and the equipment of the whole system is set down at 25 million dollars, making a total cost of 210 million dollars for the whole scheme…"

***Popular Science,* April 1921**

"…The yearly traffic across the Hudson River in round figures for the year 1920 was as follows: Passengers, 200 million; draft vehicles, 10 million; freight; coal, 12 million tons, miscellaneous freight, 8 million tons. The present rate of increase indicates that by 1930, or about two years after the bridge is completed, the total traffic across the river will be 250 million passengers, 22 million vehicles and 25 million tons of freight: and it is estimated that of this total, something over one-half will be diverted to the bridge…"

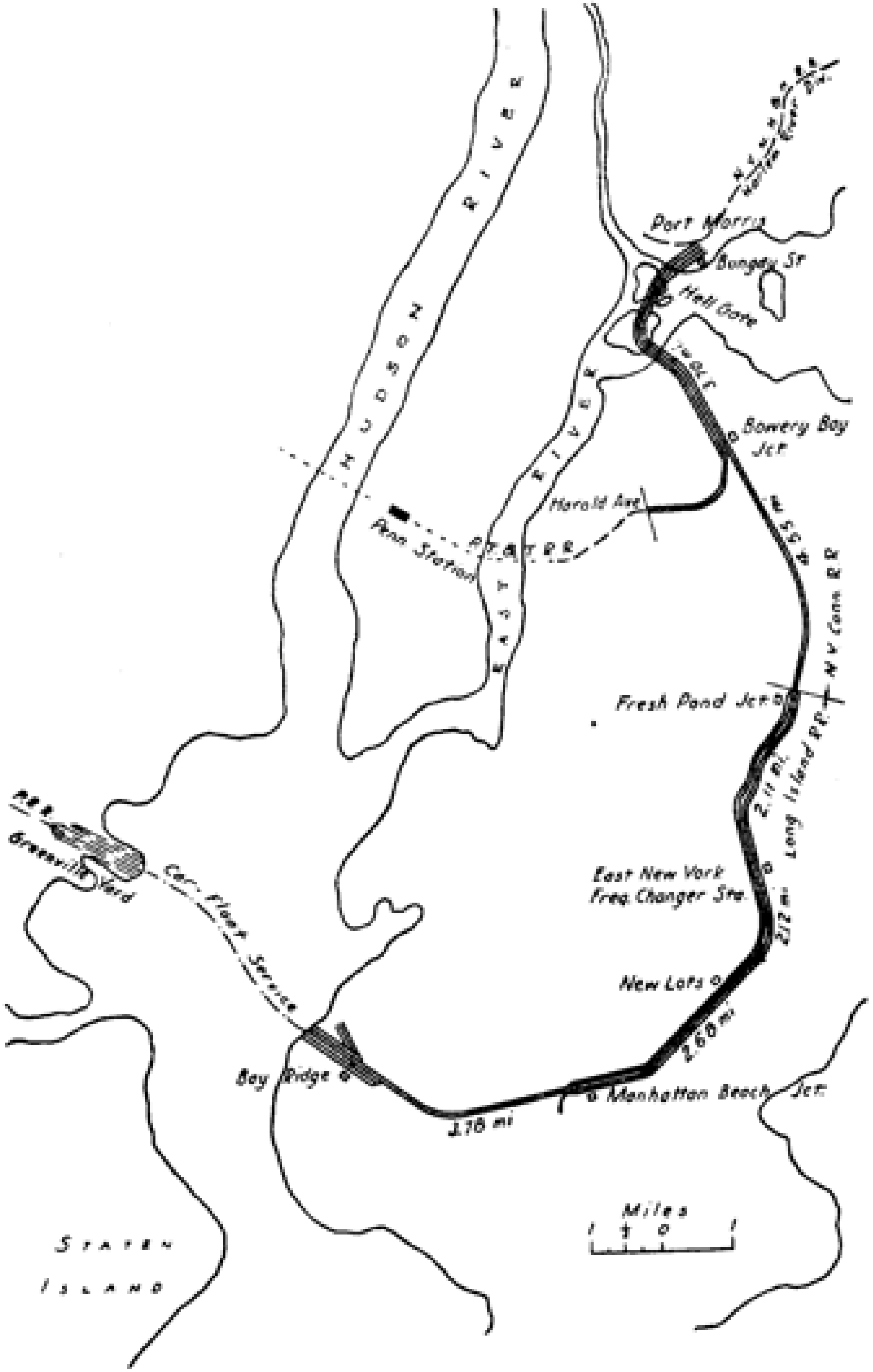
***Popular Science,* April 1921**

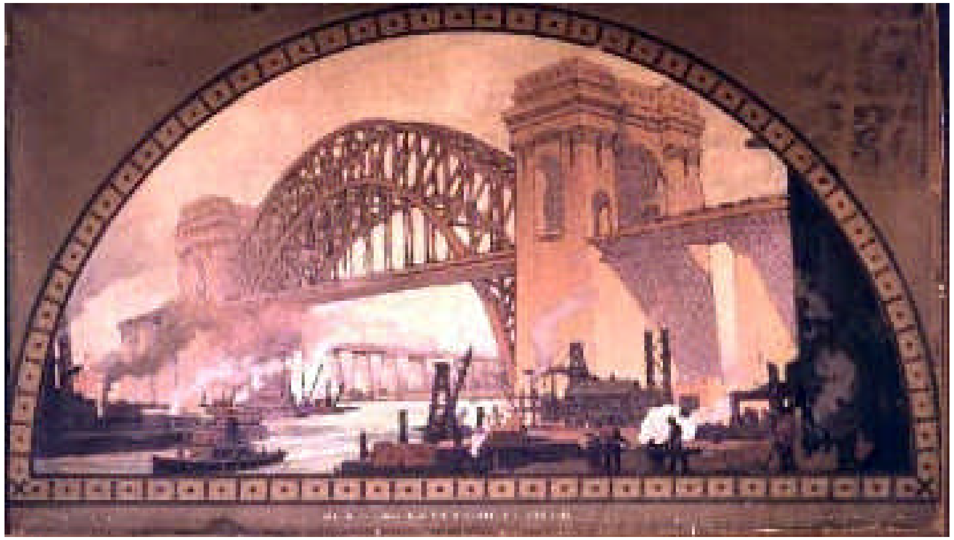
A Vision of Thirty Years

"…But how is the money to be raised for such an enterprise? That is the question that has been the chief concern during the thirty years since the idea was realized to be a mechanical possibility. Mr. Lindnethal's scheme is as unique as it is feasible. It overcomes what he considers to be the greatest obstacle in the way of accomplishing the actual building of the huge suspended roadway across the river. 'The communities on each side can pay their share in the form of yearly rentals,' says Mr. Lindenthal; 'so also can the railroads. The respective shares can be adequately determined to cover operation, interest, cost of maintenance, and taxes.' A separate terminal organization would act as agent and trustee for the Federal Government, while private capital, realizing the advantages to be conferred, can be relied upon to come forward with the required funds for building, equipping, and operating the vast project. Cooperation between the railroads, the City of New York, and the communities on the New Jersey side, and the Federal Government, will assure this method of bringing to life the vision of thirty years."

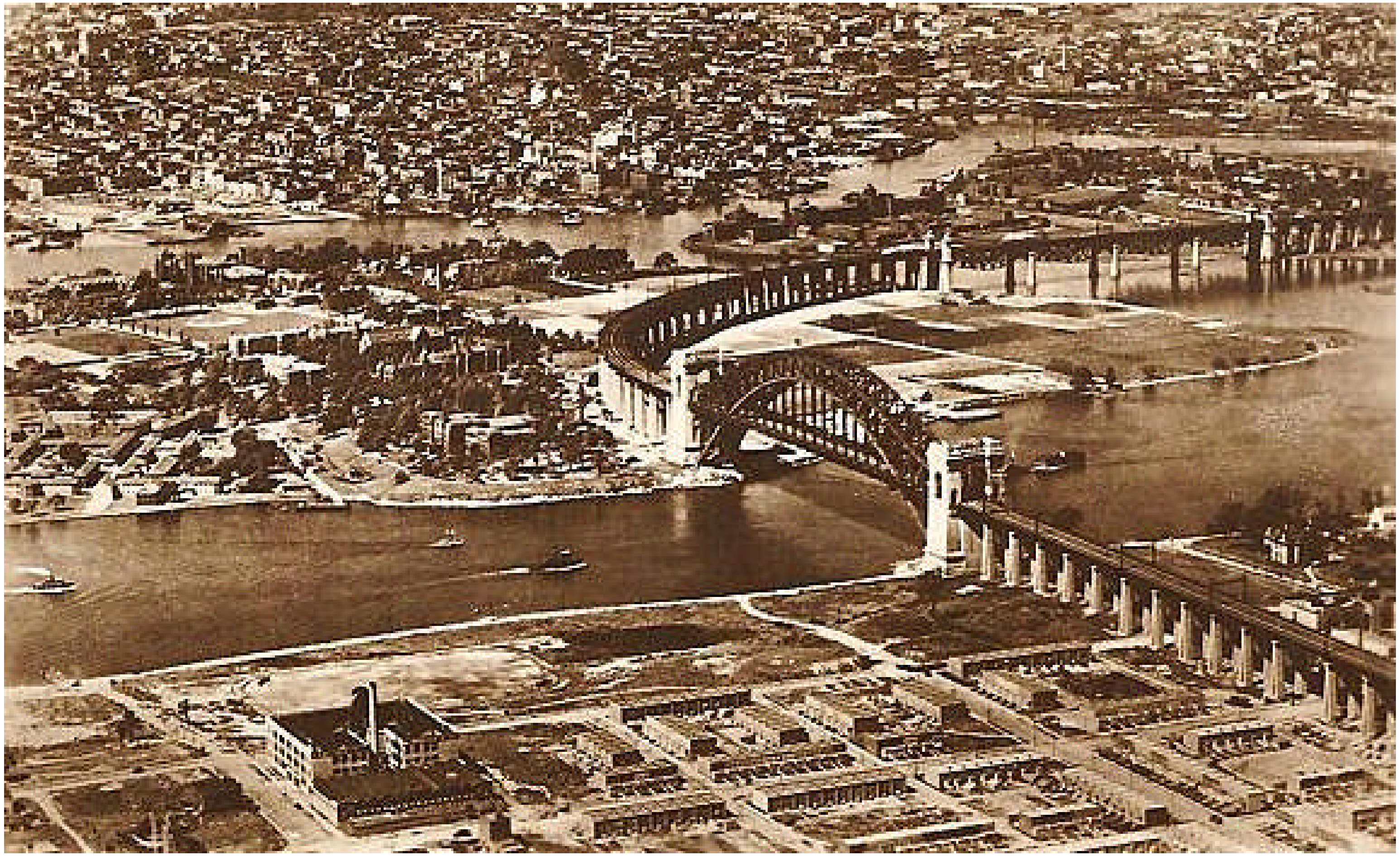
***Popular Science,* December 1920**

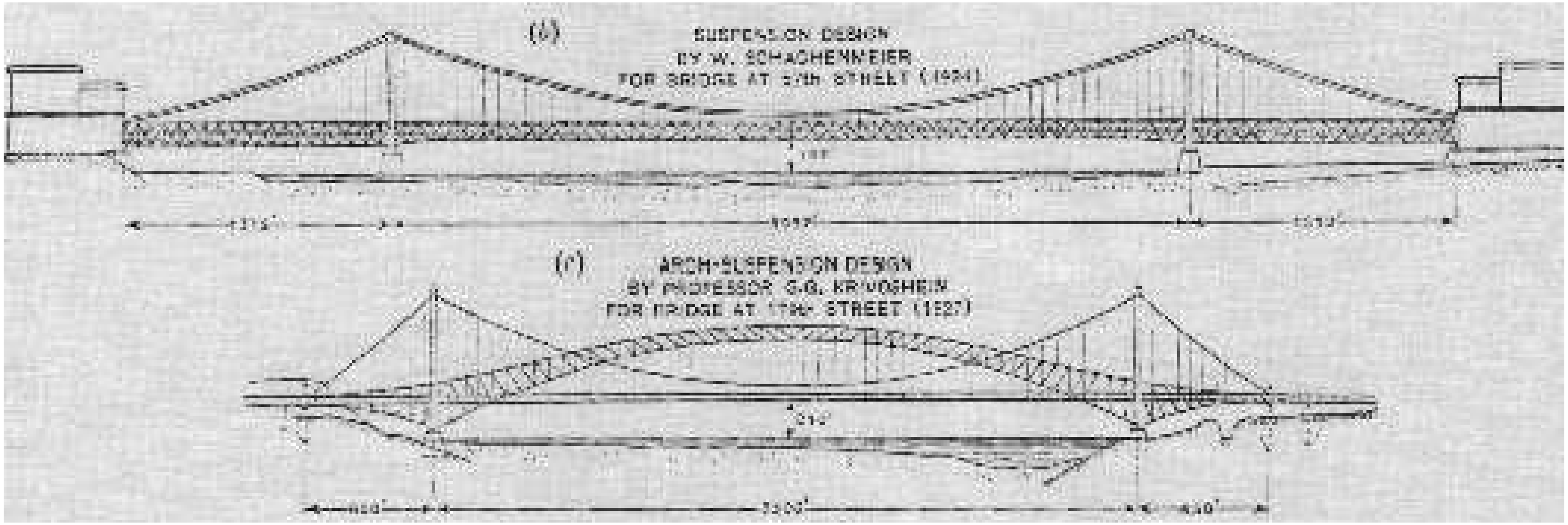
May the Best Bridge Win





Gustav Lindenthal's dream of constructing a *Hudson River* bridge from midtown *Manhattan* to *New Jersey* was designed to connect rail lines in New Jersey with those in *New York City* and *New England*. Part of this rail link was completed in 1917, when his *Hell Gate Arch* (above) – a component of a larger scheme known as the *New York Connecting Railroad* (left), opened for business.





<u>Above T&B</u>: caption: “Top (b): Suspension design by W. Schachenmeier for a bridge at West 57th Street (1924). The design featured a 3,937-foot-long main span, two 1,312-foot-long side spans, and a clearance of 164 feet. Bottom (c): Arch-suspension design by G.G. Krivoshein for a bridge at West 179th Street (1927). The design featured a 3,500-foot-long main span, two 650-foot-long side spans, and a clearance of 210 feet.”

"…Through all of this, Lindenthal's dream for a span over the Hudson continued. But what was grand in 1888 had, through decades of deferment, become fantastical. By 1923, Lindenthal's plan called for a bridge more than 200 feet wide, with two decks, one for 12 railroad tracks, the other for 20 vehicle lanes, including two for trolleys. Its massive concrete towers, at 825 feet high, would rise above even the ten-year-old Woolworth Building, then the world's tallest skyscraper. The price: at least a cool $200 million (nearly two billion in today's dollars). Ammann deferentially warned Lindenthal that such a costly project would never be realized. But the old master sharply rebuked his assistant…"

Smithsonian **magazine, October 1999**

“G.L. rebuked me for my ‘timidity’ and ‘shortsightedness’ in not looking ahead for 1,000 years”

O.H. Ammann

RE: with opposition to the North River Bridge Company’s scheme growing, Lindenthal withdrew into a world of militant self-assurance. During WWI, without any engineering work available, Ammann took a position as manager of a clay mine in *South Amboy, N.J*. of which Lindenthal and future *New Jersey* Governor *George Silzer* were stock-holders (Lindenthal recommended him). The mine was losing money but Ammann turned the situation around, impressing Silzer greatly. After three years, he resigned his industrial management position for the *Just Such Clay Company* in 1920 with the long-desired intention of returning with his family to his native *Switzerland* for a position with the *Swiss Federal Railway Department*. Lindenthal persuaded Ammann, albeit reluctantly, to return to his office to work on the *Hudson River* bridge project in early 1921. Ammann – and others in Lindenthal’s office, were awakening to the fact that the course set by their captain would lead them all to disastrous ruin.

"…In order for you to understand my situation for many months, in fact for the whole year, I will no longer conceal from you that the giant project for which I have been sacrificing time and money for the past three years, today lies in ruin. In vain I as well as others have been fighting against the unlimited ambition of a genius that is obsessed with illusions of grandeur. He has the power in his hands and refuses to bring moderation into his gigantic plan. Instead, his illusions lead him to enlarge his plans more and more, until he has reached the unheard of sum of half a billion dollars – an impossibility even in America…"

O.H. Ammann

RE: excerpt from a letter to his mother in *Switzerland* dated December 14th 1923. Forty-five years old, on March 21st 1923, Ammann left the employ of *Gustav Lindenthal* and set up an office in a loft building at *470 Fourth Avenue*, NYC. It was there – among spools of cloth, that he developed his own plan to bridge the *Hudson River*.

A protege to Lindenthal, *Othmar Ammann* opposed his mentor's ideas concerning a *Hudson River* bridge. Ammann argued that the Lindenthal plan would require expensive approaches in already congested midtown *Manhattan*, which would be politically controversial (to say the least). As well, many midtown businessmen were opposed to Lindenthal's grand scheme. Instead, Ammann pushed for a Hudson River bridge between *179th Street* in upper Manhattan and *Fort Lee, New Jersey* (rendering above), which would accommodate both motor vehicles and light rail. The location of the bridge would be at high points in Manhattan and New Jersey, allowing enough clearance for tall ships without extensive approaches. Furthermore, the location was at a relatively narrow point on the lower Hudson River, simplifying construction greatly. Ammann believed that the crossing would be an easier political sell since it would require neither the approval of influential business leaders in midtown Manhattan nor the necessity of persuading railroads to use the bridge.

"…Slight in stature, with a quiet demeanor that hid a steely core, Othmar Ammann seemed the opposite of the large, bluff, practically educated Lindenthal. Ammann's degree, unlike any that Lindenthal might occasionally claim, was from a Swiss institute of technology considered one of the most prestigious in the world. Ammann was impressed by his mentor, one of the world's pre-eminent bridge builders - and the favor was returned…"

Smithsonian **magazine, October 1999**

Left: *Othmar H. Ammann* - ca. 1904, the year he arrived in *America* to participate in the design of long span bridges

"My first serious interest in the problem of bridging the Hudson was awakened shortly after my arrival in New York on a visit to the top of the Palisades Cliffs from where I obtained a splendid view of the majestic river. For the first time I could envisage the bold undertaking, the spanning of the broad waterway with a with a single leap of 3,000 feet from shore to shore, nearly twice the longest span in existence. This visit came at that time as near to a dream to see the ambitious effort materialized. Nevertheless, for a young engineer it was a thrill to contemplate its possibility, and from that moment as my interest in great bridges grew, I followed all developments with respect to the bridging of the Hudson River with keenest interest."

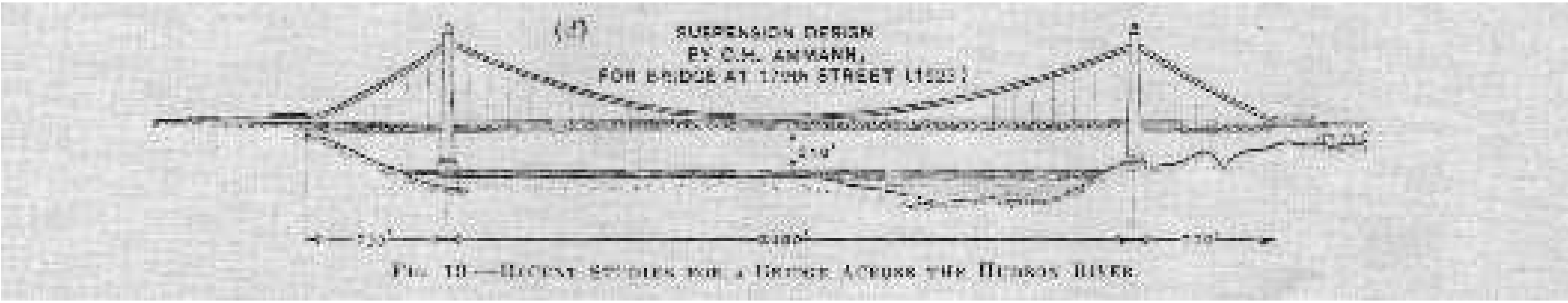
O.H. Ammann

On a More Moderate Scale

"…However, I have gained a rich experience and have decided to build anew on the ruins with fresh hopes and courage – and, at that, on my own initiative and with my own plans, on a more moderate scale. It is a hard battle that I have already been fighting for six months now, but the possibility of success is constantly increasing, so that I do not allow myself to be frightened in spite of the great hardships and my shrinking finances. I wait and hope that the New Year will finally bring my work to fruition."

O.H. Ammann

RE: excerpt from a letter to his mother in *Switzerland* dated December 14th 1923. Facing internal opposition while working for Lindenthal, Ammann struck out on his own, joining forces with newly elected Governor *George Silzer* of *New Jersey* (who knew him, and his abilities, well from the days when Ammann successfully managed the failing clay mine). Ammann officially unveiled his proposal on February 19th 1924 at a meeting of the *Connecticut Society of Engineers*.



"…Working on his own, Ammann had developed another scheme. Quietly, he wrote to the governor of New Jersey with suggestions for a smaller, cheaper suspension bridge to be built across the Hudson at 179th Street. The newly formed Port of New York Authority, which enjoyed both states' cooperation and had a short time before rejected Lindenthal's expensive monstrosity, was immediately interested - to Lindenthal's understandable dismay…"

Smithsonian **magazine, October 1999**

<u>Above</u>: caption: "Suspension design by Othmar Ammann for a bridge at West 179th Street (1923). The design featured a 3,400-foot-long main span, two 700-foot-long side spans, and a clearance of 210 feet. With some modifications, this was the design adopted for the George Washington Bridge."

“Mr. Ammann has been my trusted assistant and friend for ten years, trained up in my office and acquainted with all my papers and methods. But I know his limitations. He never was necessary or indispensable to me…Now it appears that Ammann used his position of trust, the knowledge acquired in my service and the data and records in my office, to compete with me in plans for a bridge over the Hudson and to discredit my work on which I had employed him. He does not seem to see that his action is unethical and dishonorable.”

Gustav Lindenthal

RE: excerpt from a letter to Governor Silzer of *New Jersey* (in response to his request that Lindenthal review a copy of Ammann’s prospectus). It was the discreet backing and encouragement from Silzer that had prompted Ammann to break from Lindenthal and pursue his own design. A Wilsonian Democrat elected Governor in 1923 previously, as a state senator, Silzer had backed the North River Bridge Company’s plans in the past, but as Governor he discontinued that support in favor of Ammann’s more practical scheme. In favor of large public works projects, Silzer needed to appease the Republican dominated legislature. Lindenthal’s scheme held no particular benefit for Republicans whereas Ammann’s bridge would connect to rural *Bergen County* – a Republican stronghold, and open it for development. Prior to his public announcement endorsing the Ammann proposal, Silzer sought to appease Lindenthal - his long-time friend and colleague, by asking him to review Ammann’s proposal.

Eminently Doable

"…By the degree to which Lindenthal's scheme seemed over-ambitious and overblown, Ammann's seemed disarmingly restrained and eminently doable. The younger engineer's proposal emphasized vehicular traffic, envisioning a wide roadway that would accommodate eight lanes of traffic and two pedestrian walkways on the upper deck, and four light rail lines on a lower deck that would be constructed in the future when capacity was reached on the original deck. The estimated price tag was a modest $40 million (the estimate for Lindenthal's structure had grown by this time to $500 million); and, with a location at the northern end of Manhattan connecting with a sparsely populated section of Bergen County, New Jersey, Ammann's site avoided the pitfalls of developing approaches and anchorages on land where real estate prices – and emotions – ran high…"

Darl Rastorfer, **Author**

"…By 1925, Ammann was bridge engineer for the Port Authority, charged with designing not only the 179th Street bridge (then known as the Hudson River Bridge) but also a bridge between Staten Island and New Jersey - both mainly for cars. Construction of the Hudson bridge began in the fall of 1927, with more than 100,000 miles of cable wire strung across the river by John Roebling's company. By any standard, the bridge was monumental. With a 3,500-foot main span - nearly twice that of the next largest suspension bridge, built just two years before - its slender deck was to arch gracefully more than 200 feet above the Hudson. Its twin 604-foot towers would stand nearly 50 feet taller than the Washington Monument. And each of its four cables could support more than 90,000 tons - ten times more than each Brooklyn Bridge cable. For his design, Ammann owed as much to material advances since that 1883 wonder as he did to his own ingenuity. Improved steel ensured that when drawn to only 0.196 inch in diameter, each of the 26,474 wires that made one cable had a strength of at least 240,000 pounds per square inch - more than one and a half times that of the cable wires in the Brooklyn Bridge. And better machinery allowed the wires to be hung from the towers (a process called spinning) sixteen times faster than in 1883…"

Smithsonian **magazine, October 1999**

RE: the new bi-state *Port of New York Authority* had given lukewarm reception to motor vehicle projects, but thanks to the persuasiveness of Ammann and Silzer, there was enough support on both sides of the Hudson to construct the proposed bridge. In 1925, the Port Authority agreed to take responsibility for constructing the bridge, and employed Ammann as Master Bridge Designer and Chief Engineer. *Cass Gilbert*, the designer of the *Woolworth Building*, would consult on the bridge's architectural treatment.

Keeping Faith

"The U.S. War Department recently had under consideration a plan, submitted by the North River Bridge Company of New York City, to build a railroad and highway suspension bridge across the Hudson River from Fifty-seventh Street in Manhattan to the New Jersey shore. It called for a double-deck structure with a single span of 3,240 feet, to be connected on the New York side with a great union passenger station. The new bridge would accommodate at least 40,000,000 vehicles, 400,000,000 passengers, and 25,000,000 tons of freight per year. Its cost is estimated at about $200,000,000. The designer of this gigantic project, who originated it some thirty-five years ago and has been working for its realization ever since, started his career in this country as a stone mason in the grounds of the Philadelphia Centennial Exposition at $2.50 a day. He is Gustav Lindemthal, who was 79 years old in May and says he expects to cross his beloved Hudson Bridge. In robust health, there seems to be no reason why this expectation should not be fulfilled…"

Popular Science, **August 1929**

RE: ***Gustav Lindenthal*** **(left) died in 1935**

"…In the relentless Great Depression, the bridge became a sort of savior in steel. Completed six months ahead of schedule, it cost less than the $60 million originally allocated. 'Fulfilling a dream of three-quarters of a century,' ran the ecstatic headline in the New York Times. On October 24, 1931, in front of thousands of spectators, New York governor (and soon to be President) Franklin Roosevelt and New Jersey governor Morgan Larson opened the bridge, newly named in honor of George Washington. In tribute to his mentor, Ammann drove with Gustav Lindenthal onto the bridge that the older man had spent his lifetime fruitlessly dreaming of…"

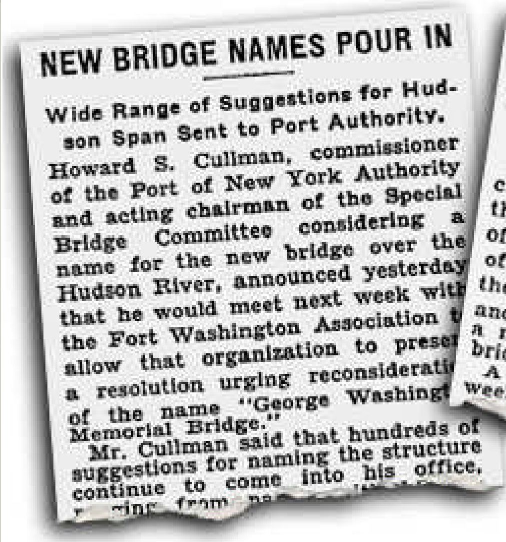
***Smithsonian* magazine, October 1999**

Left: October 24th 1931

“In every patriotic sanctuary, there is at least one figure so serenely certain of enduring honor that the scrutiny of centuries can never shake its permanence. In dedicating the George Washington Bridge, we pay tribute not so much to the military triumphs of a great general, not to the attainments of a great executive, but to a more precious heritage. We offer homage to great ideals, exemplified in Washington’s career and stamped indelibly upon our national thought. Out of the wealth of vital principles demonstrated by his deeds, I feel that three are peculiarly significant and especially appropriate to this occasion. They are the worth of integrity, the need for intelligence and the fact of our independence…”

Franklin D. Roosevelt,* Governor of the *State of New York

RE: excerpt from his dedication speech. The six-lane *George Washington Bridge* was completed on October 25th 1931, eight months ahead of schedule, at a cost of $59 million and twelve lives. Officials on both side of the Hudson praised the bridge as the realization of a long-sought dream. More than 30K people witnessed the opening of the bridge and many more listened to the opening ceremonies on the radio. Governor *Franklin Delano Roosevelt* of *New York*, standing alongside Governor *Morgan F. Larson* of *New Jersey*, dedicated the bridge in honor of the first President.



NEW BRIDGE NAMES POUR IN

Wide Range of Suggestions for Hudson Span Sent to Port Authority.

Howard S. Cullman, commissioner of the Port of New York Authority and acting chairman of the Special Bridge Committee considering a name for the new bridge over the Hudson River, announced yesterday that he would meet next week with the Fort Washington Association to allow that organization to present a resolution urging reconsideration of the name "George Washington Memorial Bridge."

Mr. Cullman said that hundreds of suggestions for naming the structure continue to come into his office,

'CLEVELAND BRIDGE' URGED.

Name of Ex-President Proposed for New Hudson Span.

In a telegram to John F. Galvin, chairman of the New York Port Authority, David Robinson, secretary of the Grover Cleveland Association of New York, last night suggested the name of the former President and Governor of New York State as a name for the new Hudson River bridge.

A controversy was started last week over the announced intention

First named the *Hudson River Bridge*, other names for the bridge had been considered, including the *Palisades Bridge*, *Fort Lee Bridge*, *Columbus Bridge* and *Verrazano Bridge*, before the Port Authority decided upon the *George Washington Memorial Bridge,* in 1930 (after school children voted it their favorite). Later, the name was shortened to "George Washington Bridge."

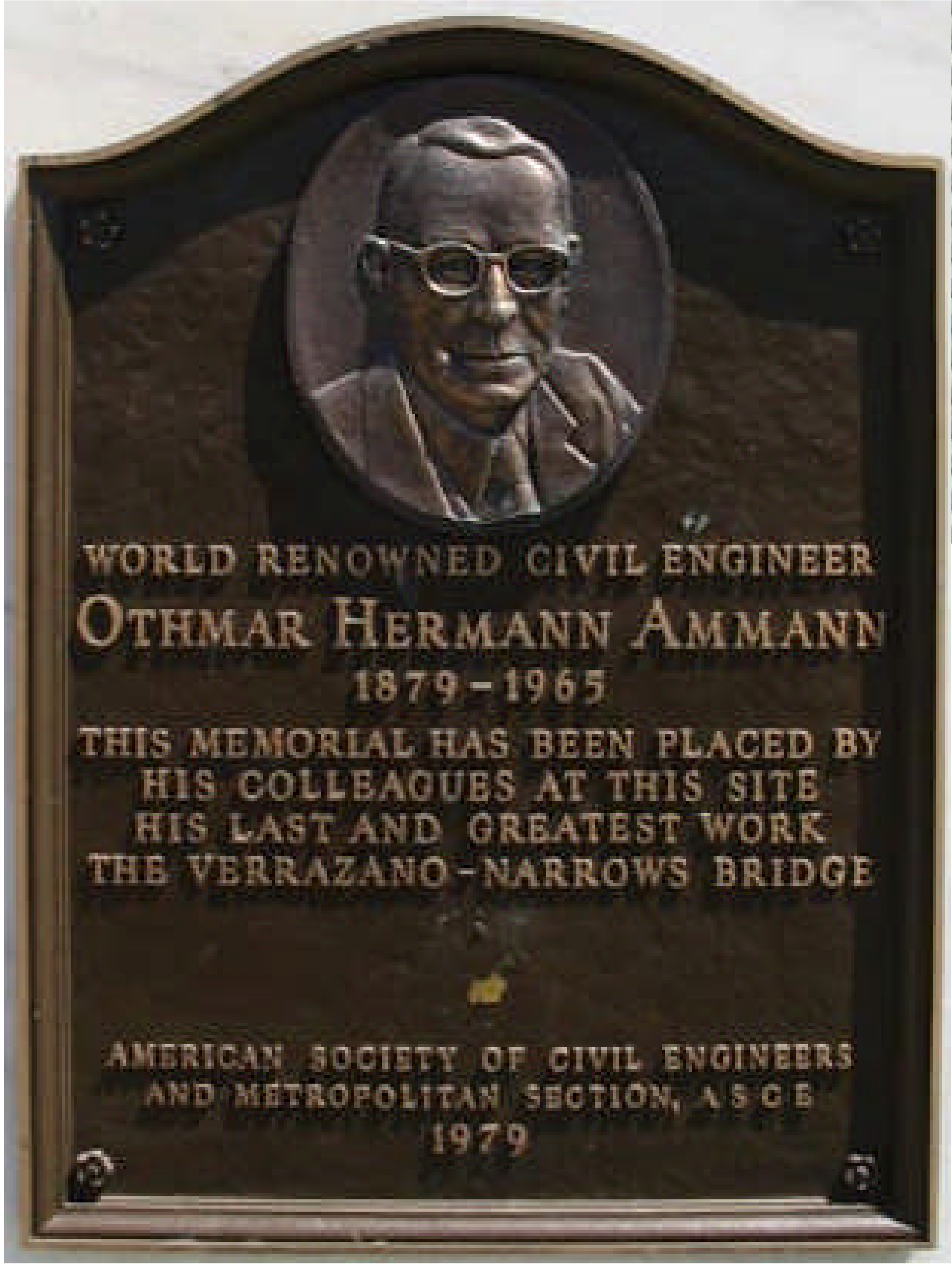
When it opened in 1931, the ***George Washington Bridge*** not only connected ***New York*** with ***New Jersey***, but also completed one of the earliest pieces of the tri-state arterial highway network recommended in 1929 by the ***Regional Plan Association***. In its first year of operation, it was forecast that sixty million vehicles would use the bridge. For six years, the ***Hudson River*** span held the title of the world's longest suspension bridge. It was eclipsed by San Francisco's ***Golden Gate Bridge*** (1937) which has a main span of 4,200-feet.

Left: caption: "USS Nautilus passes under the GWB in 1956"

"…By the early 1960s, when the George Washington's lower deck was added (as specified in the original plans), Ammann had all but eclipsed his mentor. Ammann's other 1931 creation, the Bayonne Bridge connecting Staten Island and New Jersey which was, until 1977, the world's largest steel arch bridge - more than 600 feet longer than the previous record holder, Lindenthal's Hell Gate Bridge. Months before his death in 1965, Ammann gazed through a telescope from his 32nd-floor Manhattan apartment. In his viewfinder was a brand-new sight some 12 miles away: his Verrazano-Narrows suspension bridge. As if in tribute to the engineering prowess that made Ammann's George Washington Bridge great, this equally slender, graceful span would not be surpassed in length for another 17 years."

***Smithsonian* magazine, Oct. 1999**

Left: *O.H. Ammann* (ca. 1963)

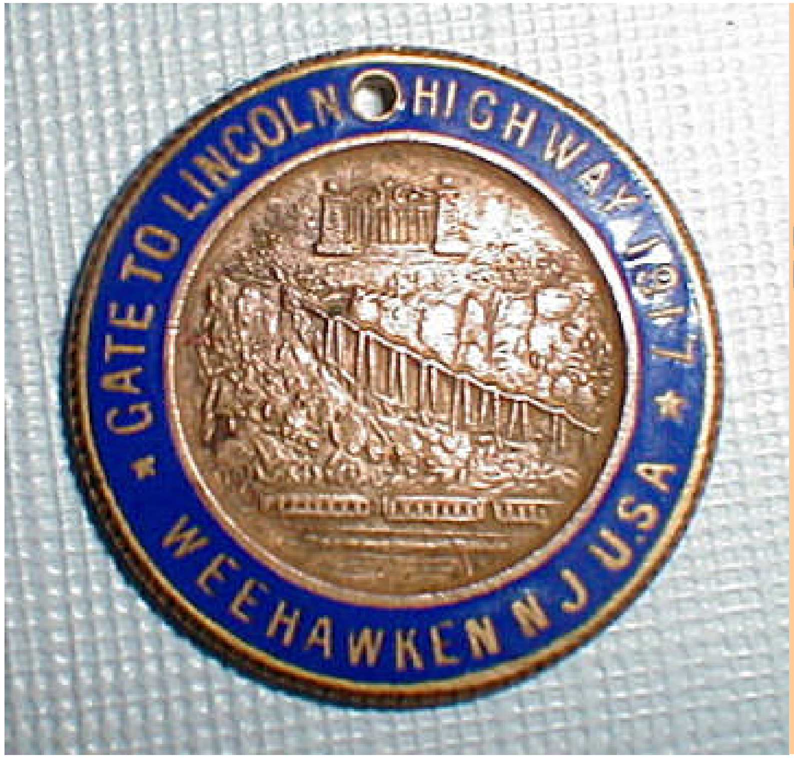


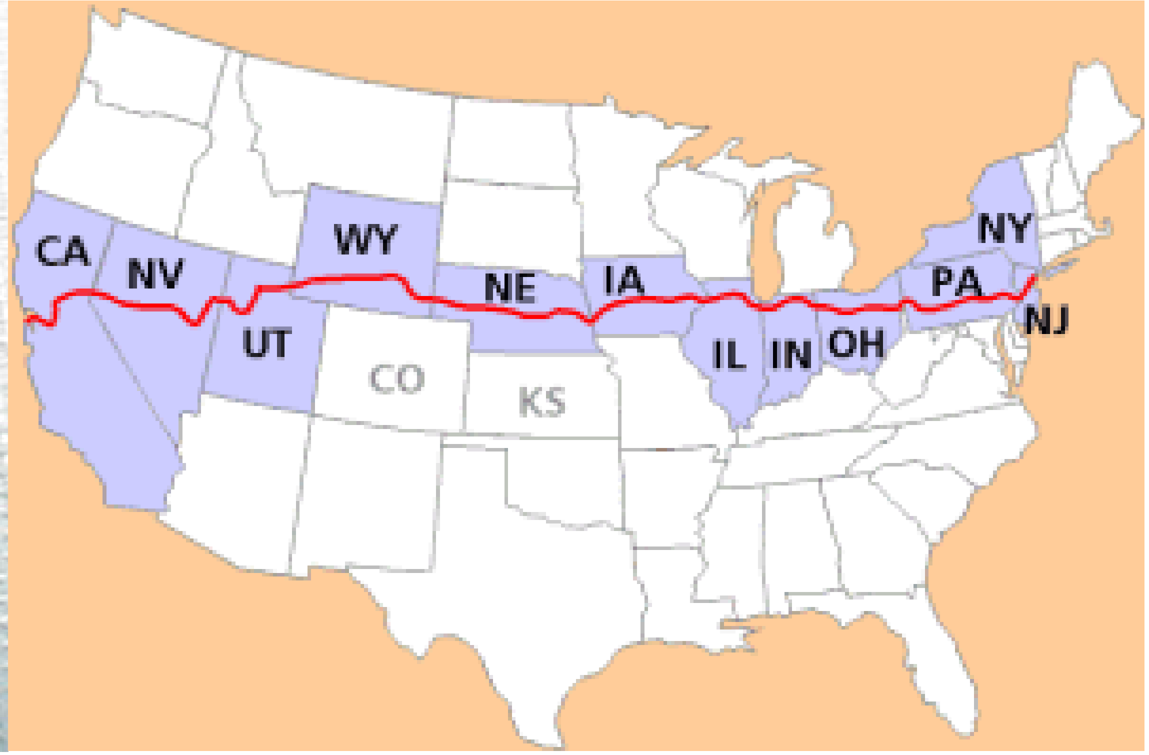
"In bridge designing, the aesthetics are quite as important as engineering details. It is a crime to build an ugly bridge."
O.H. Ammann

Part 10

Midtown-Hudson Tunnel

Namesake





In 1912, there were very few good roads in the *United States*. The relatively few miles of improved road were around towns and cities (a road was "improved" if it was graded). That year, *Carl Fisher* (developer of *Miami Beach* and the *Indianapolis Speedway*, among other things) conceived a trans-continental highway. He called it the "Coast-to-Coast Rock Highway." It would be finished in time for the 1915 *Panama-Pacific Exposition* and would run from the exposition's host city; *San Francisco*, to *New York City*. Two auto industry tycoons played major roles in the highway's development: *Frank Seiberling* - president of *Goodyear Tire & Rubber Co.*, and *Henry Joy* - president of the *Packard Motor Car Company.* It was Henry Joy who came up with the idea of naming the highway after POTUS *Abraham Lincoln.* On July 1st 1913, the *Lincoln Highway Association* was officially incorporated. The highway started in *Times Square*, NYC. It passed through *New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Iowa, Nebraska, Wyoming, Utah, Nevada* and *California* (see map at right), ending in San Francisco's *Lincoln Park*. *Weehawken, NJ* became known as the "Gate to the Lincoln Highway" (see 1917 medal at left). For the Port of New York Authority's new *Midtown-Hudson Tunnel*, whose western portal was in Weehawken, it only made sense to honor the fact that the late president and the highway which honored him also be named in his honor.

A Mighty Natural Barrier

“The Lincoln Tunnel has been built to meet the urgent needs of trans-Hudson vehicular traffic of the midtown Manhattan area and the adjacent New Jersey communities. The broad Hudson River, while it carries the water-borne commerce which has made this great Metropolitan area the trade center of the world, at the same time interposes a mighty natural barrier to the intercommunication and growth of the communities that line its shores. Their development is directly dependent on the adequate solution of the problems of vehicular transportation…”

RE: excerpt from the Port of New York Authority’s *Midtown Hudson Tunnel* dedication ceremony booklet (December 21st 1937)

Reaching Capacity

"…The Holland Tunnel, completed in 1927, and the George Washington Bridge, opened for traffic in 1931, were built in answer to this pressing traffic need and together they have carried 155 million vehicles. Indeed, since the first of these crossings was put in service vehicular traffic across the Hudson River in the Metropolitan area has more than doubled in volume. However, neither the Holland Tunnel, three miles to the south and now carrying its capacity load, nor the George Washington Bridge, located seven miles to the north, can meet all traffic needs of midtown Manhattan and opposite New Jersey communities. Immediately after the Holland Tunnel was opened, the rapid growth of motor traffic made it evident that before many years another similar tunnel would be needed to serve the midtown area, and studies for the midtown tunnel were begun simultaneously by the joint Bridge and Tunnel Commissions, builders of the Holland Tunnel, and by the Port of New York Authority…"

RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* dedication ceremony booklet (December 21st 1937)

"As early as 1929, it was indicated that there would be a demand for additional Hudson River vehicular crossings to keep pace with the large increase in traffic between the many New Jersey and New York communities. During the past six years, trans-Hudson traffic has increased from 16,000,000 to 29,000,000 vehicles annually. The Holland Tunnel is now operating at better than seventy-five per cent of annual capacity and on Sundays and holidays, during periods of peak traffic, its capacity has been reached. During the last three years, it has averaged about 11,600,000 vehicles annually…"

RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* ground breaking ceremony booklet (May 17th 1934). By allowing for more car and bus traffic, the new midtown tunnel (along with the *Holland Tunnel* (1927) and the *George Washington Bridge* (1931) reduced dependency on commuter railroads and/or ferries and promoted the automobile as a central factor in the region's economic growth. It would also provide much needed employment for hundreds of men during the depression. The tunnel was designed by *Ole Singstad*.

LINCOLN TUNNEL

UNDER THE HUDSON RIVER

BETWEEN NEW YORK AND NEW JERSEY

"…In 1930 the legislatures of the two states appropriated $200,000 each and directed the Port Authority to study and submit a report on the proposed Midtown Hudson Tunnel. The report on the preliminary investigation was submitted on January 1, 1931, advising that the construction of a two-tube tunnel, similar to the Holland Tunnel, between Midtown Manhattan and Weehawken, New Jersey, was practical and economically feasible. Shortly thereafter the Port Authority was authorized to proceed with the financing and construction of the project…"

RE: excerpt from the Port of NY Authority's *Midtown Hudson Tunnel* ground breaking ceremony booklet (May 17th 1934)

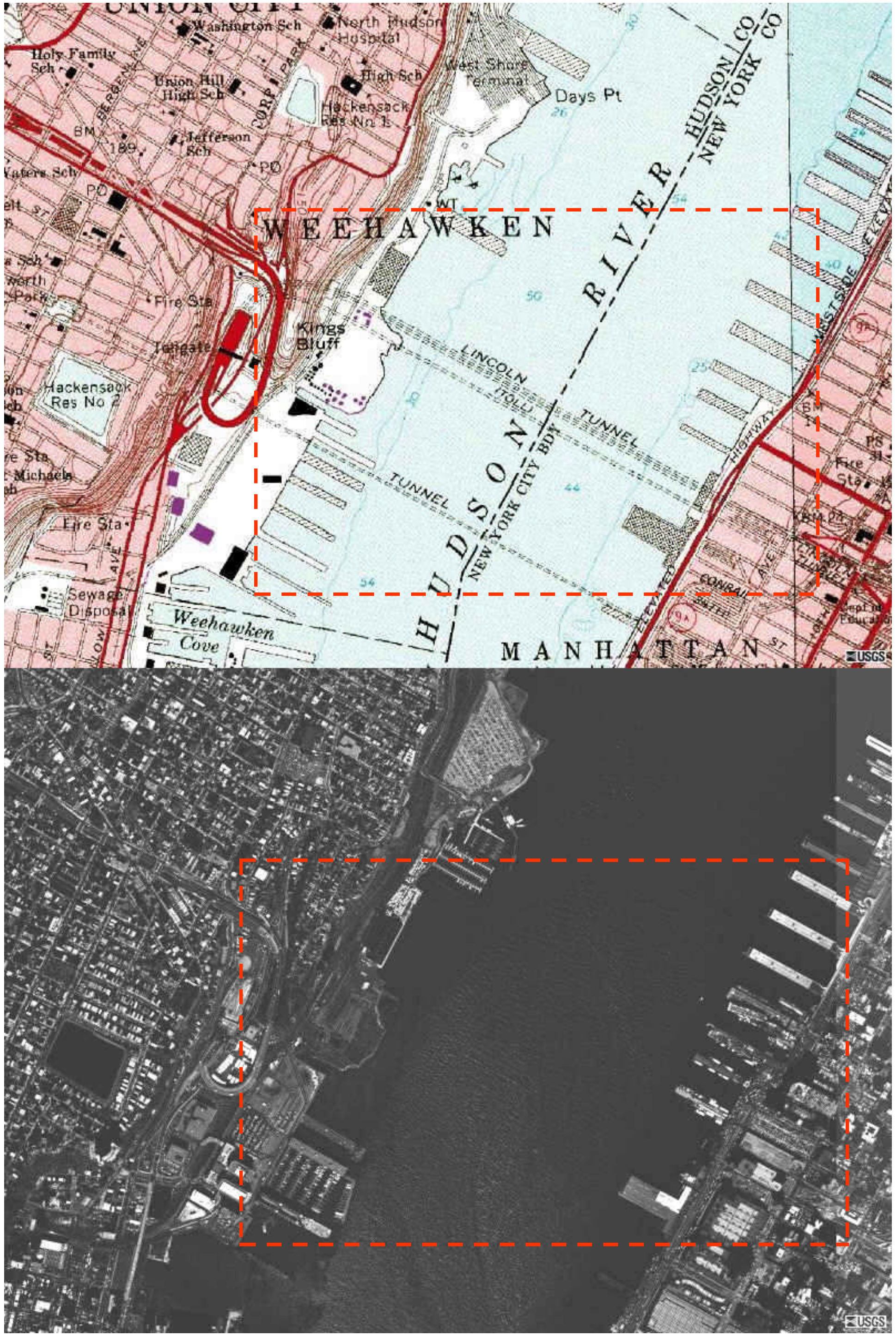
Old Man Depression

“…Early in 1931 the joint Bridge and Tunnel Commissions were merged with The Port of New York Authority and the States of New York and New Jersey authorized the reconstituted Authority to proceed with the construction of the new tunnel. However, by the end of 1931, when plans for the tunnel had been developed to the stage where construction could be started, the general economic situation had become such as to make it impracticable for the Authority to market its bonds, and activities were suspended…”

RE: excerpt from the Port of New York Authority’s *Midtown Hudson Tunnel* dedication ceremony booklet (December 21st 1937)

"…In the summer of 1932 the federal government embarked upon its program for the relief of unemployment through the financing of projects of a self-liquidating character, and the Authority at once entered into negotiations for the advancement of federal funds for construction of the tunnel. In the course of these negotiations the Authority made a study which indicated the feasibility of building the tunnel in essentially two stages, the first of which would provide a single tube with approaches and facilities for two-way traffic operation. The initial investment would thus be reduced to accord with the then existing economic conditions…"

RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* dedication ceremony booklet (December 21st 1937)



"…When first opened, the Midtown Hudson Tunnel will consist of a single tube carrying two lanes of traffic in opposite directions, between West Thirty-Eighth Street, in New York City, and Weehawken, N.J. Eventually, a second tube will be pushed through alongside the first, and each will then become a one-way tunnel. Funds advanced by the Public Works Administration, under Administrator Harold L. Ickes, permitted the start of the ambitious project with the construction of the first tube, which in itself will help relieve traffic congestion at the George Washington Bridge to the north and the Holland Vehicular Tunnel to the south…"

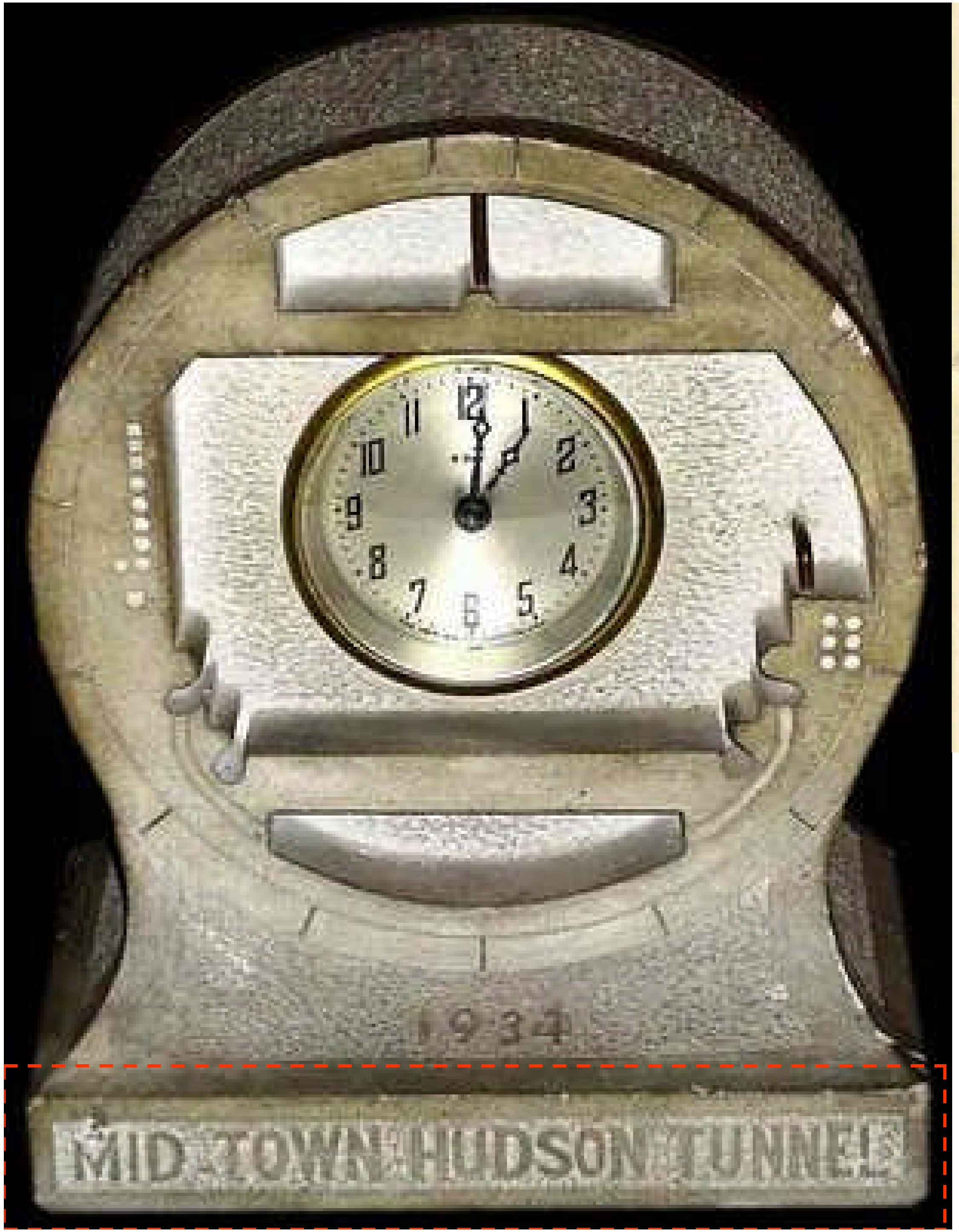
***Popular Science,* March 1936**

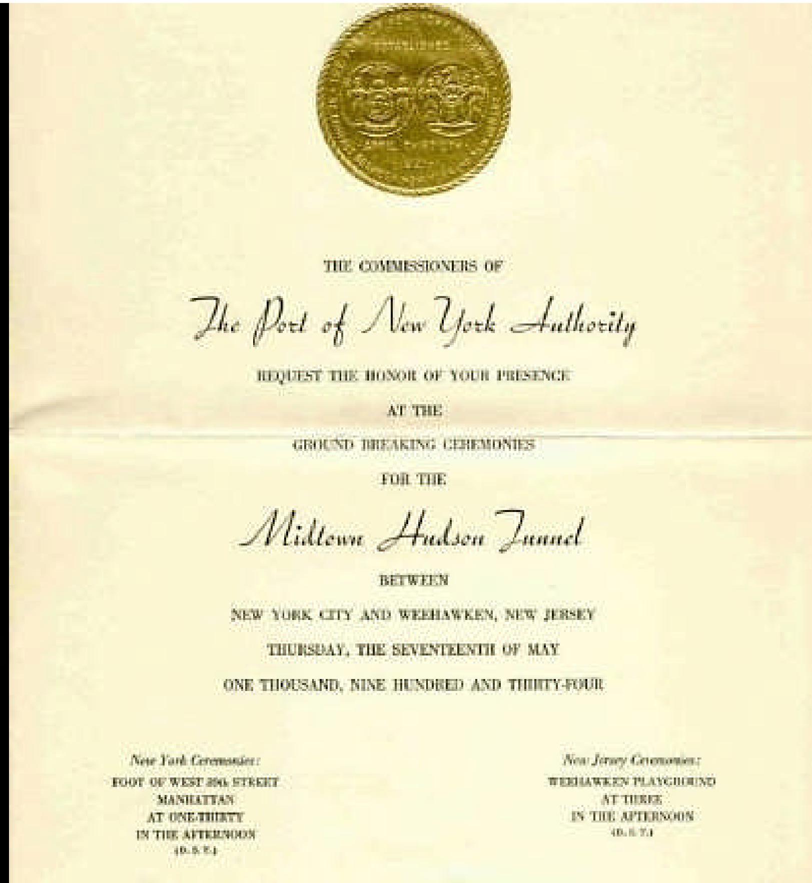
<u>Left</u>: topographical location map (top) and overhead photo (bottom)

"…An agreement for a federal credit of $37,500,000 for construction of the First Operating Unit was arranged through the Public Works Administration in September, 1933. Work was started promptly although official ground-breaking ceremonies were not held until May 17, 1934. Progress on shield tunneling was excellent and on August 2, 1935, the south tube was 'holed through' under the river. At the same time rock tunneling and construction of other parts of the project were going forward…"

RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* dedication ceremony booklet (December 21st 1937)

<u>Above</u>: caption: "May 17, 1934: The ground-breaking. It was a happy occasion. There isn't one in the scene not smiling."





THE COMMISSIONERS OF

The Port of New York Authority

REQUEST THE HONOR OF YOUR PRESENCE

AT THE

GROUND BREAKING CEREMONIES

FOR THE

Midtown Hudson Tunnel

BETWEEN

NEW YORK CITY AND WEEHAWKEN, NEW JERSEY

THURSDAY, THE SEVENTEENTH OF MAY

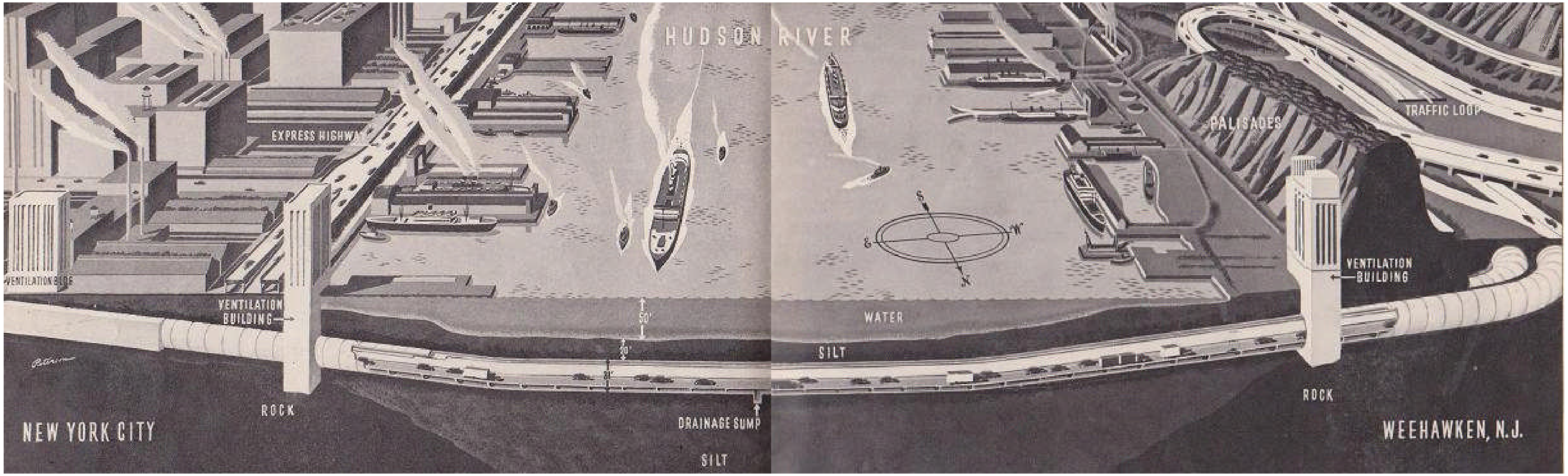
ONE THOUSAND, NINE HUNDRED AND THIRTY-FOUR

New York Ceremonies:
FOOT OF WEST 39th STREET
MANHATTAN
AT ONE-THIRTY
IN THE AFTERNOON
(D.S.T.)

New Jersey Ceremonies:
WEEHAWKEN PLAYGROUND
AT THREE
IN THE AFTERNOON
(D.S.T.)

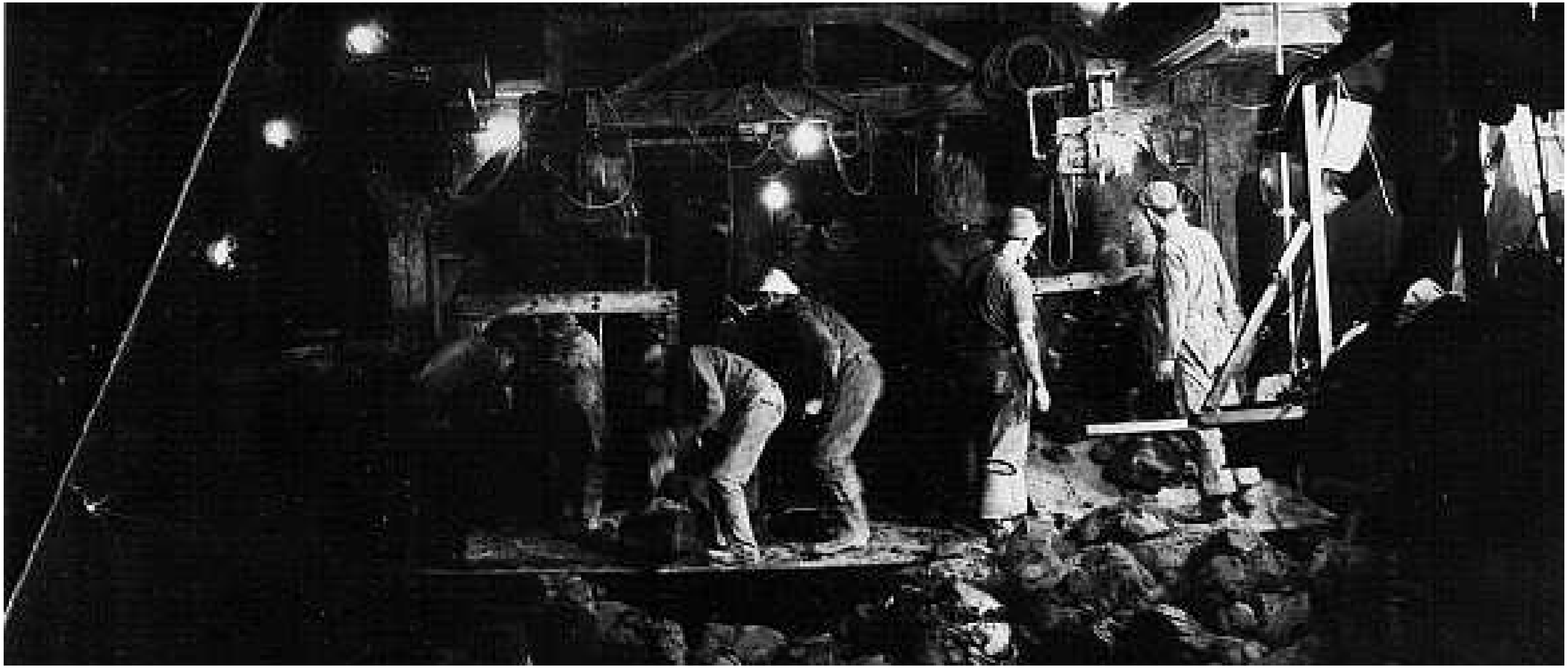
Above: invitation to attend the Ground Breaking Ceremonies to be held on May 17th 1934

Left: cast concrete clock showing tunnel cross-section given out to VIPs at the Ground Breaking Ceremony held on May 17th 1934 (note it has the initial name: "Mid-Town Hudson Tunnel" inscribed at its base)



"Up to Nov. 13, 1927 all vehicular traffic between New York City and New Jersey had to use ferry boats across the Hudson River. Then the great Holland Tunnel, a miracle of engineering in its day, was opened to motorists. A million cars a month are now congesting this interstate tunnel. To relieve this traffic jam, one tube of a second tunnel under the Hudson was opened to the public Dec. 22. Called the Lincoln Tunnel, it runs from West 39th Street in Midtown Manhattan to Weehawken, N.J. By Dec. 22, 1938, 5,000,000 of the 35,000,000 cars that annually pass between Manhattan and New Jersey will have dived through it. In 1941, the second tube will receive traffic, thus doubling the tunnel's capacity. A record of speedy construction, the 8,215-ft. tube was started in March, 1934 with a PWA loan, was holed through Aug. 2, 1935, completed in 3¾ years. The Port of New York Authority repaid the loan, expects the tunnel to pay for itself in 40 years or less. Charge will be $0.50 per passenger car. Above you see a profile drawing of the $85,000,000 Lincoln Tunnel looking south down the Hudson as it will appear when both tubes are completed. At present, with only one tube completed, cars going both ways will use it. When the project is completed each tube will carry one way traffic only…"

***LIFE* magazine, December 27th 1937**

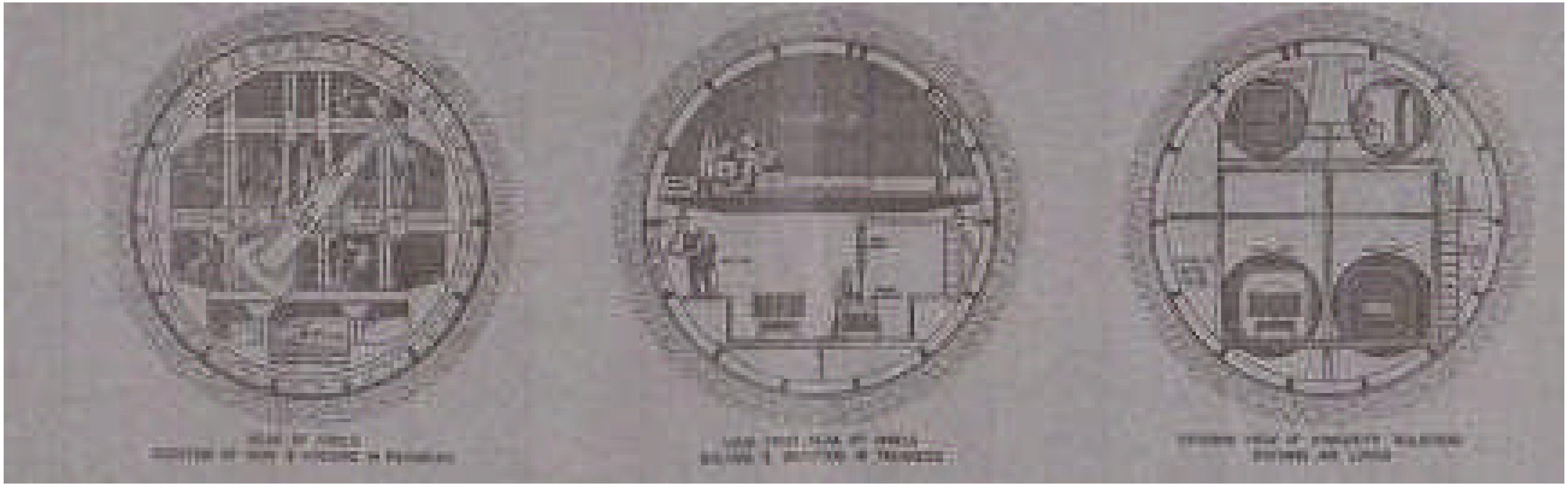


"…Early in 1935, business conditions had so far improved that it became practicable for the Authority to float a bond issue from the proceeds of which all federal government advances made up to that time ($12,300,000) were repaid, and funds in the amount of approximately $12,500,000 were made available to meet further construction costs of the First Operating Unit. The agreement with the federal government was modified to eliminate loan provisions and to make available instead a grant of $4,780,000…"

RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* dedication ceremony booklet (December 21st 1937)

Above: caption: "'Sand Hogs' bore through Hudson River Midtown Tunnel from Jersey side, 2/19/35"

Phasing



"…Subsequently it was determined to carry out construction in two stages. The First Operating Unit, which is now being financed by the Federal Administration of Public Works, will consist only of the south tube and will provide for one lane of vehicular traffic in each direction…Contracts were awarded during the latter part of 1933 for the manufacture of the cast iron and cast steel tunnel segments ($2,358,150) and the steel nuts, bolts and washers ($177,700). The manufacture of these materials is well under way. Contract MHT-4, covering the boring ($6,452,000), by the shield driven method, of the under water portion of the tunnel and two ventilation shafts has been awarded. Specifications for other contracts are being expedited in accordance with a construction program which provides for the completion and operation of the first operating unit in 1938…"

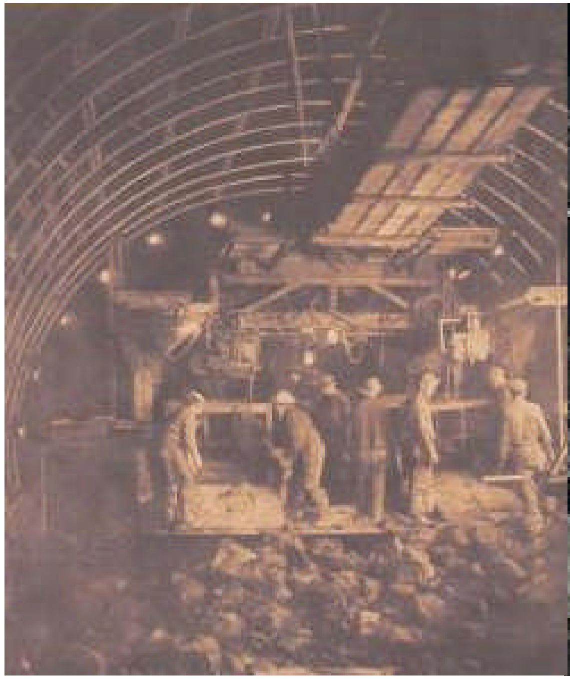
RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* ground breaking ceremony Booklet (May 17th 1934)

Above: caption: "Midtown-Hudson Tunnel – Tunneling Operations"

Top Left: caption: "North Tube, workers clearing bottom of rock tunnel at Weehawken, New Jersey, after completion of excavation"

Top Right: caption: "Sandhogs shovel grout between iron lining rings. The iron segments were bolted together and sealed to prevent the tunnel from leaking water or collapsing."

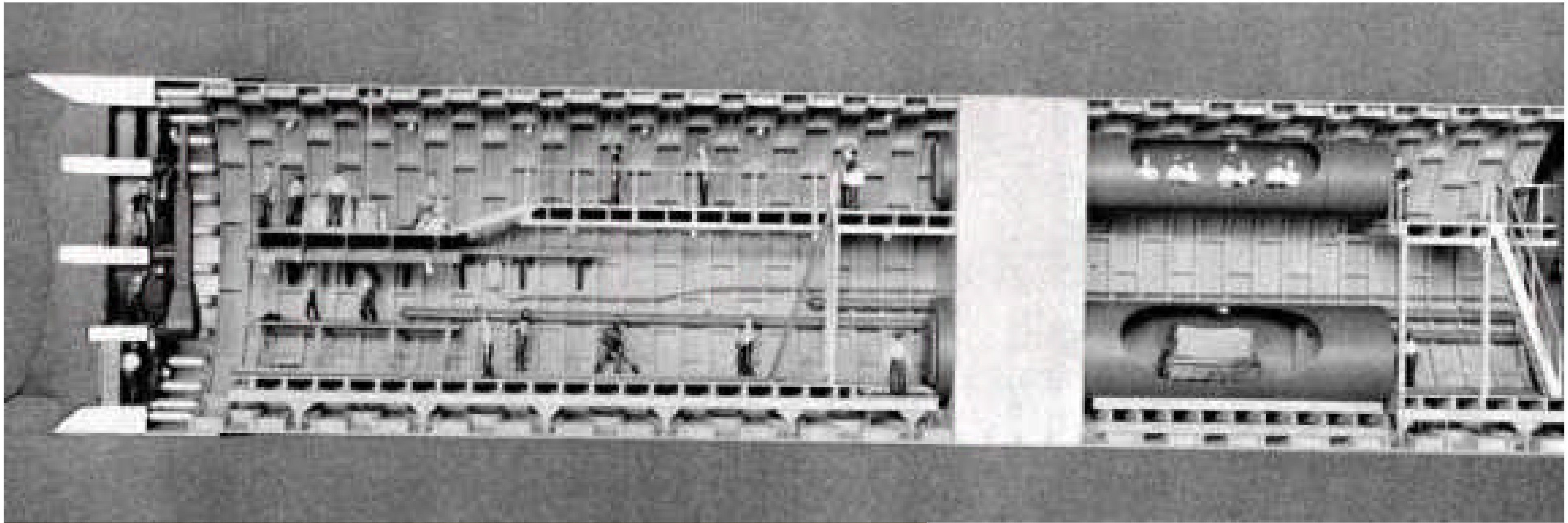
Left: caption: "Hemp Grommets being dried after treatment in red lead and oil"

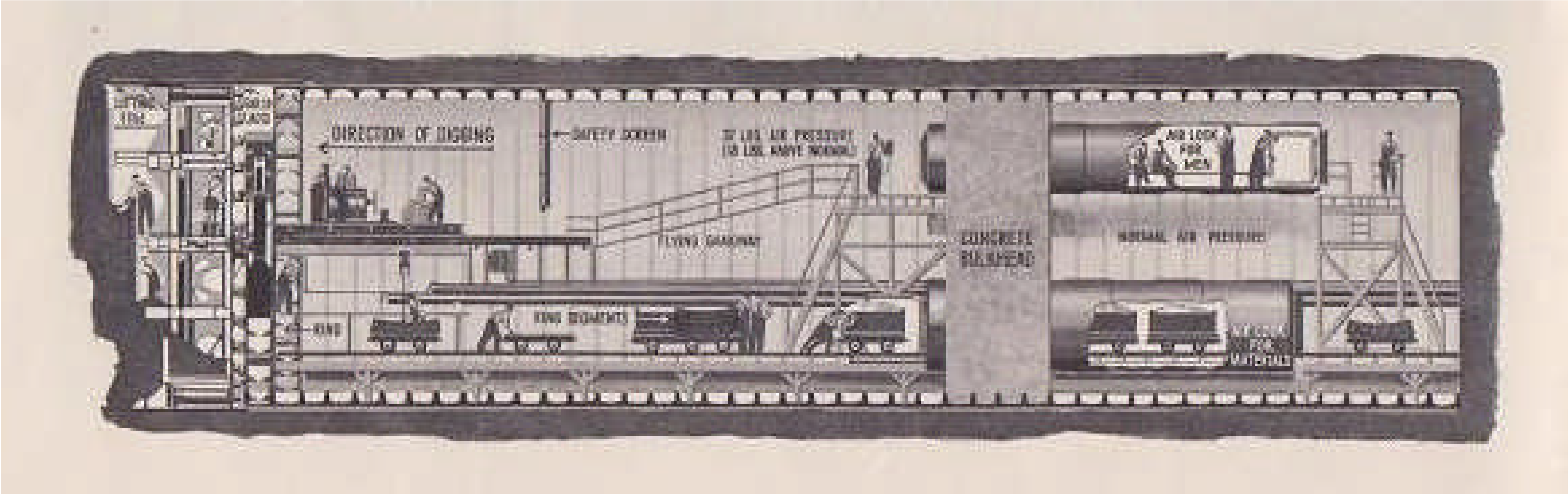
"…A circular metal shield, weighing 400 tons was advanced a few feet at a time by thirty hydraulic jacks of titanic power to punch a hole for the tunnel through the river bed, starting from the Jersey side. As it passed beneath a railroad, it added an amusing mishap to the annals of the tunnel, for its molelike trail upended the rails and a station platform as if an earthquake had hit them. Then, plunging down into the river ooze, it started its real work…"

***Popular Science,* March 1936**

<u>Above L&R</u>: caption: "Sandhogs shoveling river muck at face of shield"



<u>Above</u>: caption: “Tunnel Construction Model indicating driving of shield and air locks”
<u>Left</u>: caption: “Constructing concrete cradle for Shield, New York”



"…The diagram above shows how a tunnel is bored through rock and silt. Because work is carried on 20 ft. under the river bed, the sandhogs wage a continual battle to keep water from pouring into the tunnel. Only practical way of keeping it out is to use compressed air. Hence a massive concrete bulkhead is built near each end of the tube. Men passing through the bulkhead enter air locks in which air pressure is gradually raised to that prevailing on other side. At left is the working end of the shaft composed of a big circular shield and a row of hydraulic jacks. As the shield is jacked forward, silt is displaced and some is forced through shield apertures. After each shove a cast-iron ring forming outer jacket of the tunnel is brought in in segments and placed in position. Bull's eye of the two shields pushing from each end of the tube was a big steel caisson sunk in the New York edge of the Hudson River bed. When the shield reached this caisson they burned through its steel walls and the tunnel was holed through…" 805

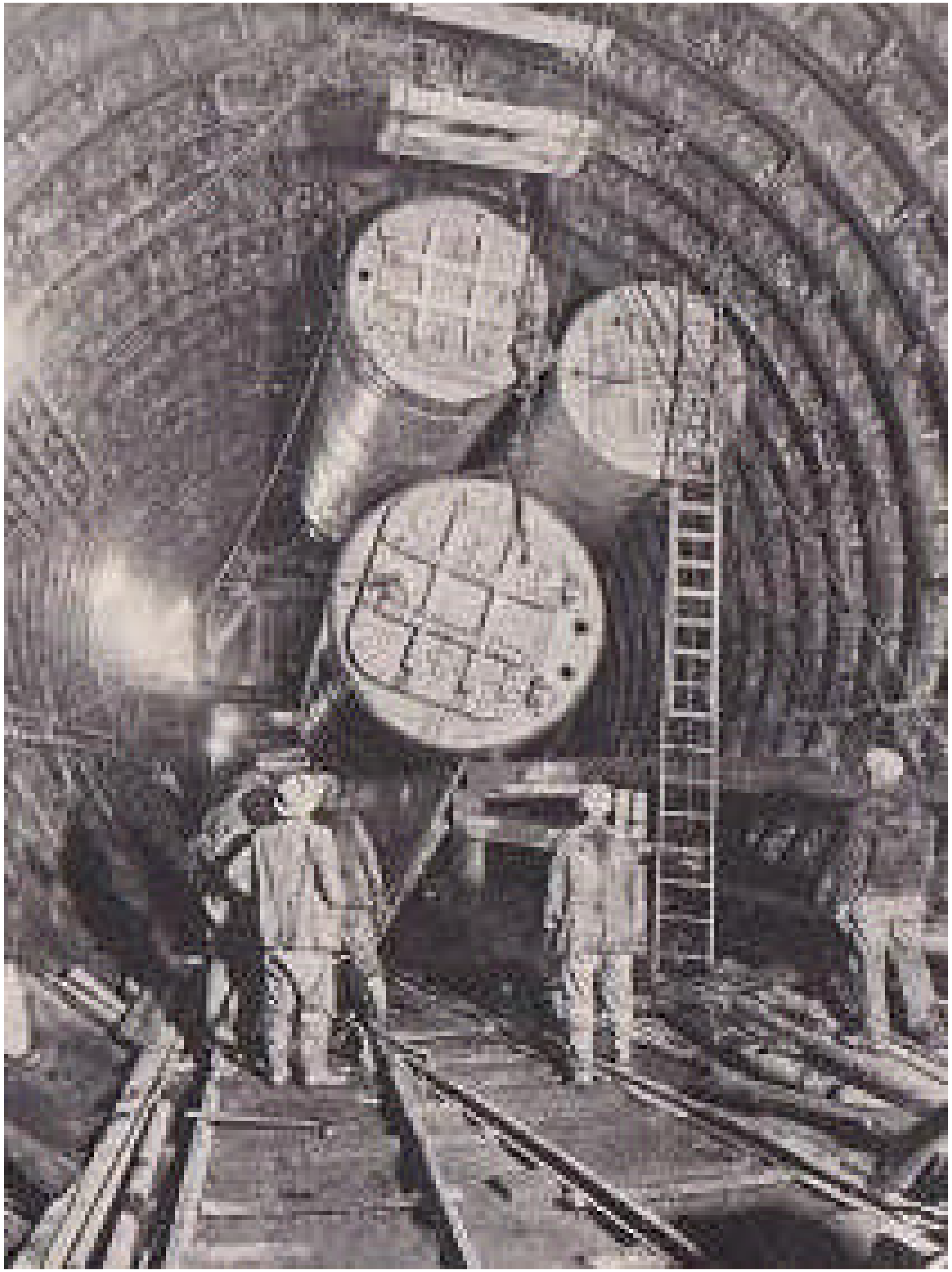
***LIFE* magazine, December 27th 1937**

<u>Above</u>: caption: "A great roadway for the motorist of 1938 begins to assume form in the mud and rock of the Hudson River bed: a view in the new Midtown Hudson Tunnel, which has advanced about 200 feet from the New Jersey side of the river and about 600 feet from the Weehawken Terminal Point. The daily movement toward the middle of the river is about twenty-five feet, and great rings of steel are set in place at regular distances for the frame of the tunnel."

<u>Top Left</u>: caption: “Making sure of their progress: a group of workmen placing and bolting a ring section on the roof of the tunnel”

<u>Top Right</u>: caption: “Heavy labor far beneath the surface: a group of sandhogs digging out the mud as the shield is moved forward”

<u>Left</u>: caption: “In limited working space: the hydraulic jack control, with this operator in charge of the shield and ring sector hoist”



"…Air pressures up to forty-five pounds to the square inch keep water out of the shaft as sand hogs toiled within the thimblelike trailing edge of the shield, erecting iron walls that consolidated their hard-won gains at every push of the giant mole. Bubbles rising to the surface of the river told of their constant peril lest a minor air leak should suddenly develop into a major 'blow,' or escape of air, which might shoot them through the river bed or let the river in upon them…"

Popular Science, **March 1936**

Left: caption: "Air Locks through which men and materials pass to enter or leave the compressed-air section of tunnel are placed in position in concrete bulkhead at back of the picture"

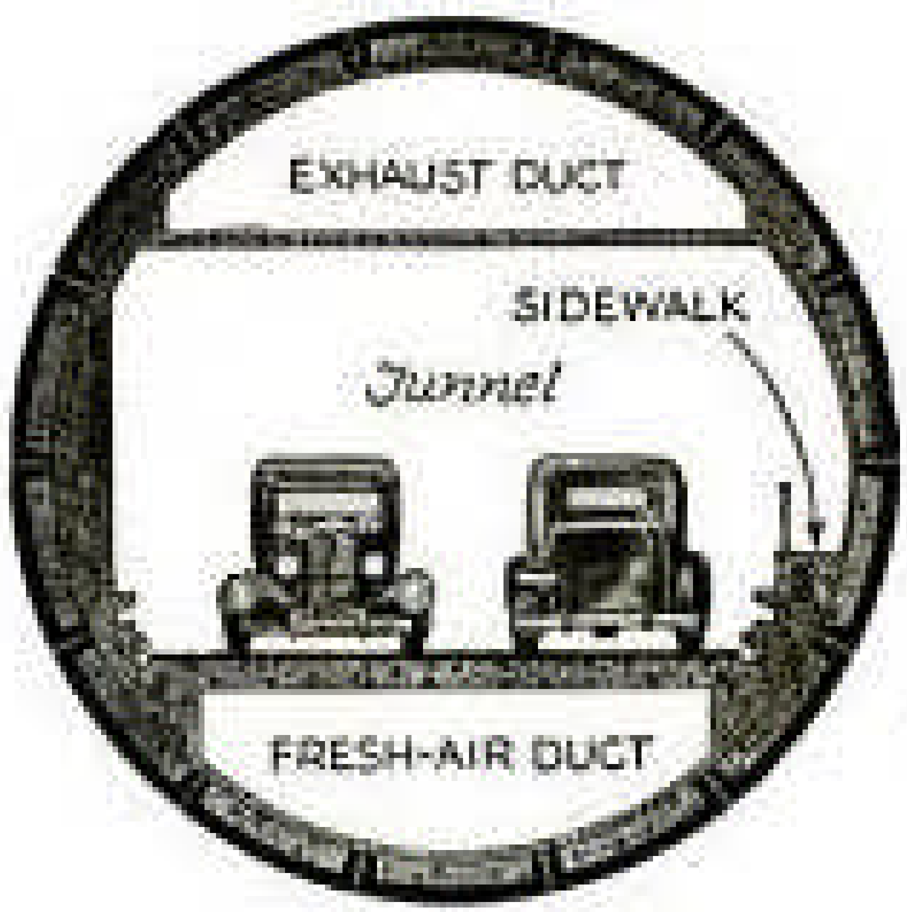
"…The work of the sandhogs was dangerous, claustrophobic and tedious. Just entering and exiting the tunnel took a long time. Crews entered air locks, one at a time, after which the doors at each end were sealed. An air pipe started hissing, and the men's ears would pop as the air pressure climbed until it equaled that of the adjoining lock. The workers were then able to safely open the connecting door and crowd into the next section, where the entire ordeal would be repeated. Once at the forward end of the tunnel, the men had to work swiftly because they could handle the pressure only briefly. Compression and decompression had to be reached in safe, short increments…"

RE: excerpt from: *Perpetual Motion: The Illustrated History of the Port Authority of New York and New Jersey*

Left: a PNYA "Compressed Air Employee" badge worn by all Sandhogs working in the *Lincoln Tunnel*

<u>Above</u>: a group of Sandhogs take a break from their difficult and dangerous work

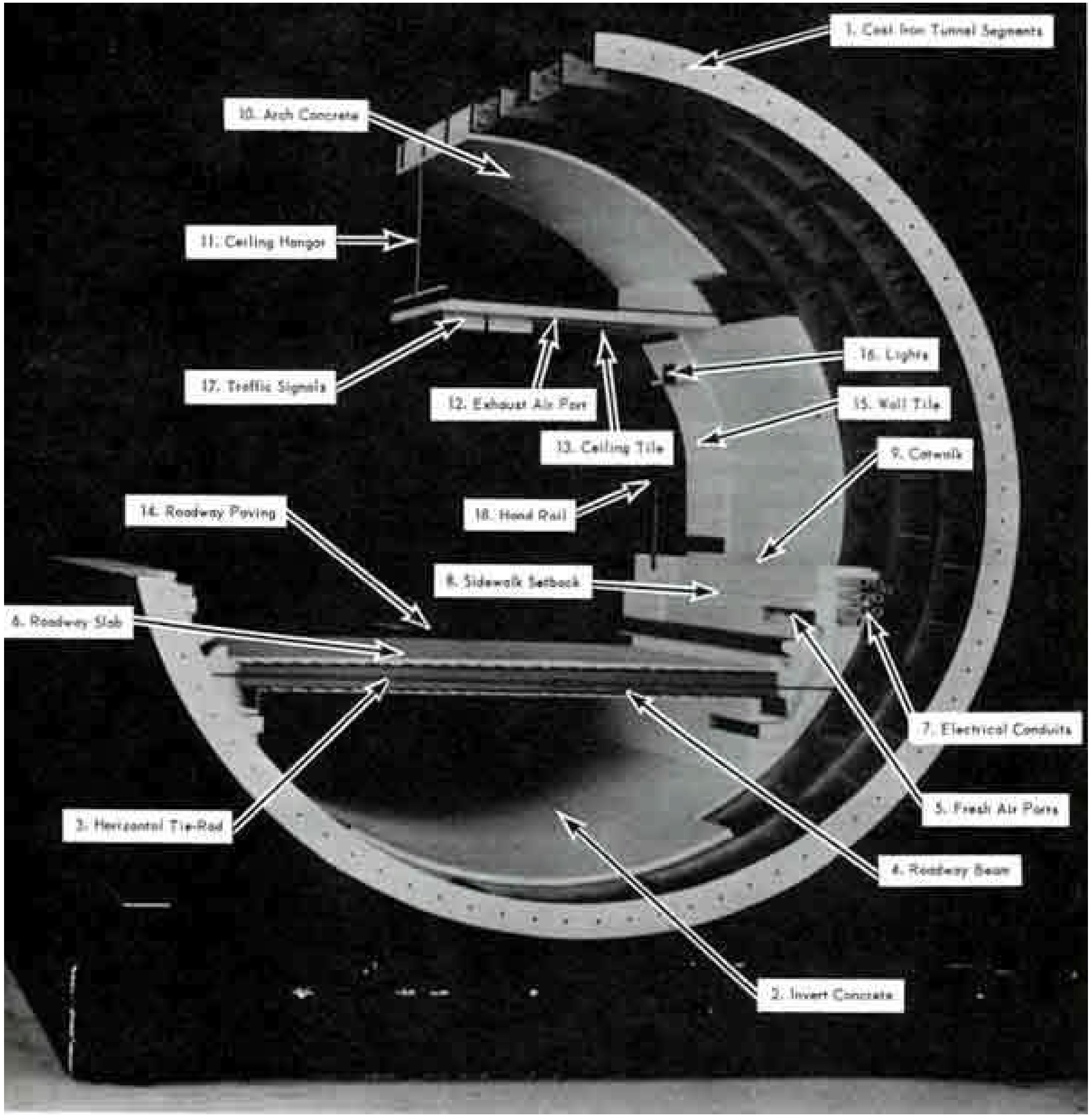
<u>Left</u>: according to this advertisement appearing in the January 17th 1938 issue of *TIME* magazine, the work of the Sandhogs and the drilling of the *Lincoln Tunnel* was made possible by printed forms from the *Hammermill Paper Company* of *Erie, PA.*



"…Completion of the ringed shell, as it was finally holed through into the connecting shaft from the New York end, enabled the abnormal pressure to be released. As this issue goes to press, workmen are placing the concrete that will line the finished tube, and erecting the roadway that will enable motorists to cover in a few minutes a journey that took sand hogs fourteen and a half months…"

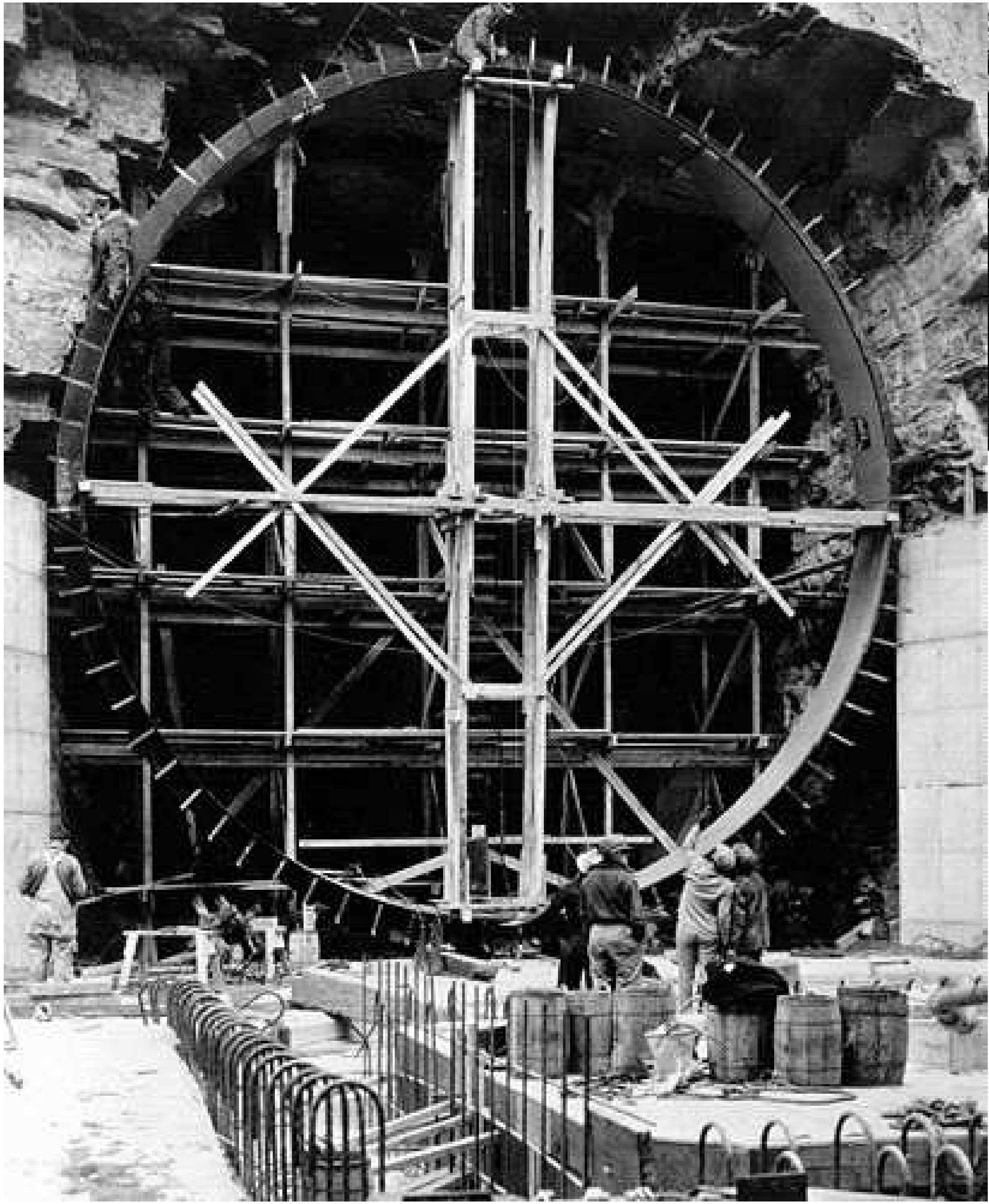
Popular Science, **March 1936**

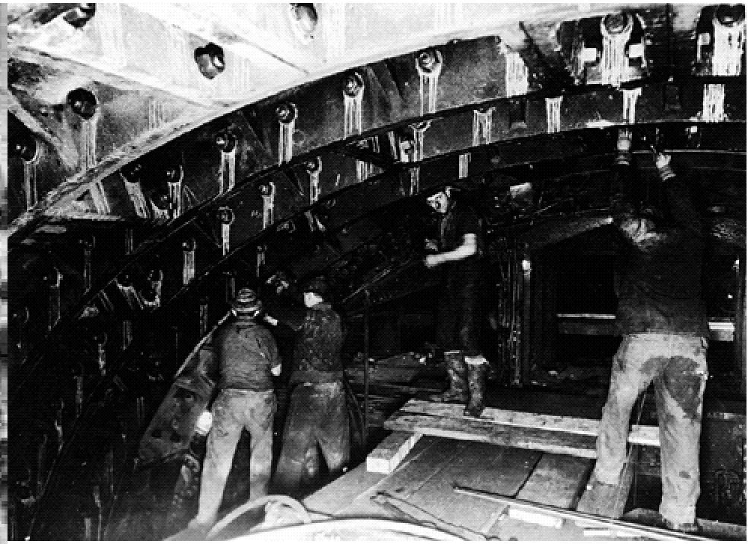
Left: caption: "Underwater Highway. Drawing shows cross-section of tunnel. Highway is laid in a tube thirty-one feet in diameter, made by bolting together curved iron segments to form rings."


1. Cast Iron Tunnel Segments
10. Arch Concrete
11. Ceiling Hanger
16. Lights
17. Traffic Signals
12. Exhaust Air Port
15. Wall Tile
13. Ceiling Tile
9. Catwalk
14. Roadway Paving
18. Hand Rail
8. Sidewalk Setback
6. Roadway Slab
7. Electrical Conduits
5. Fresh Air Ports
3. Horizontal Tie-Rod
4. Roadway Beam
2. Invert Concrete

<u>Above</u>: caption: "It takes a two-man four-handed wrench to set nuts on the Lincoln Midtown Tunnel job"

<u>Left</u>: caption: "The Midtown Hudson Tunnel comes up for air on the New Jersey side"





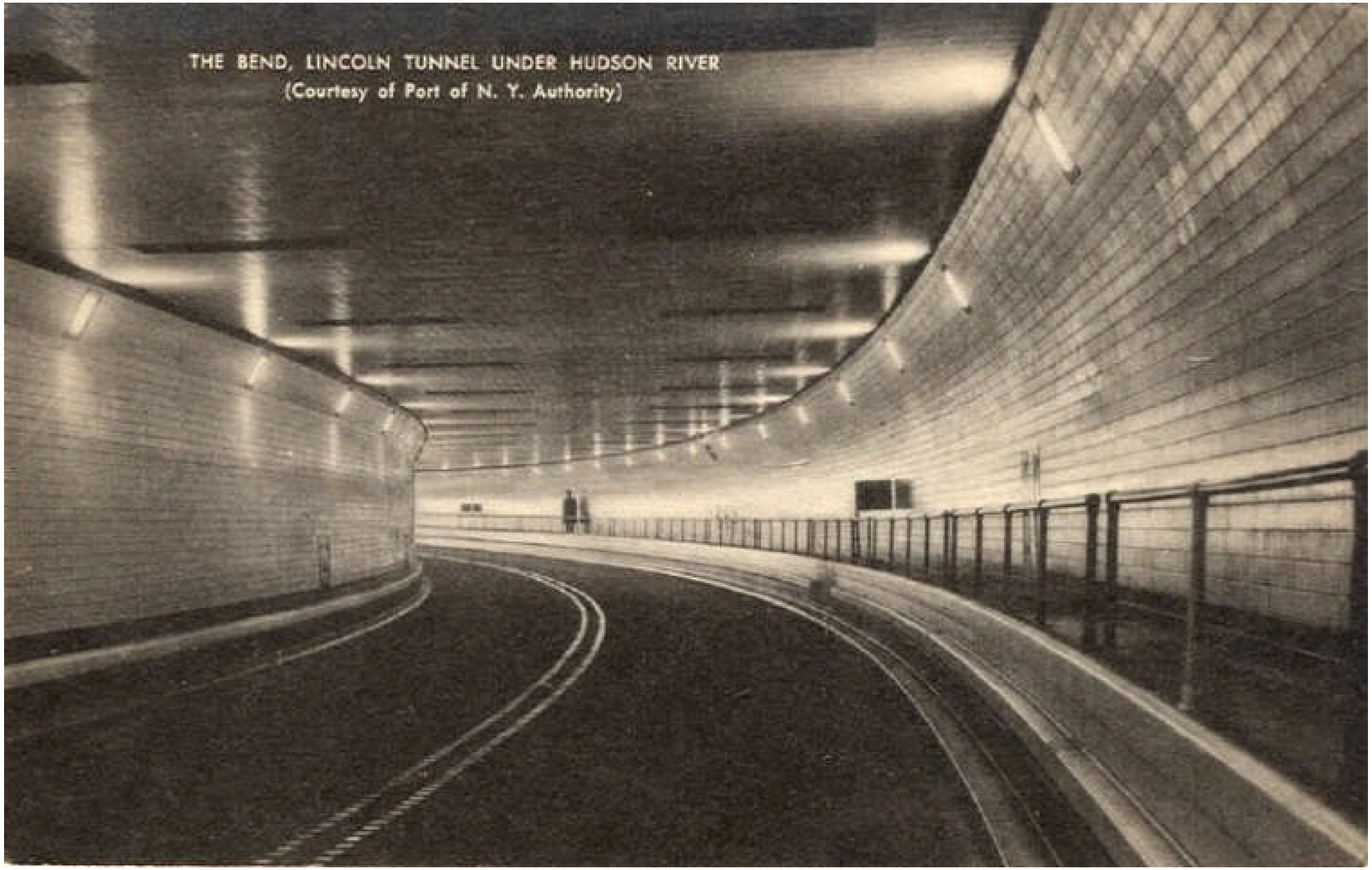
Above: caption: “Bolting Tunnel Wall Forms in Place”
Left: caption: “Setting a form for the walls of the tunnel”

<u>Top Left</u>: caption: "Lincoln Tunnel construction 1936"

<u>Top Right</u>: caption: "Lincoln Tunnel – North Tube – Interior of completed structural steel shell of rock tunnel at Weehawken, N.J., before lining with concrete"

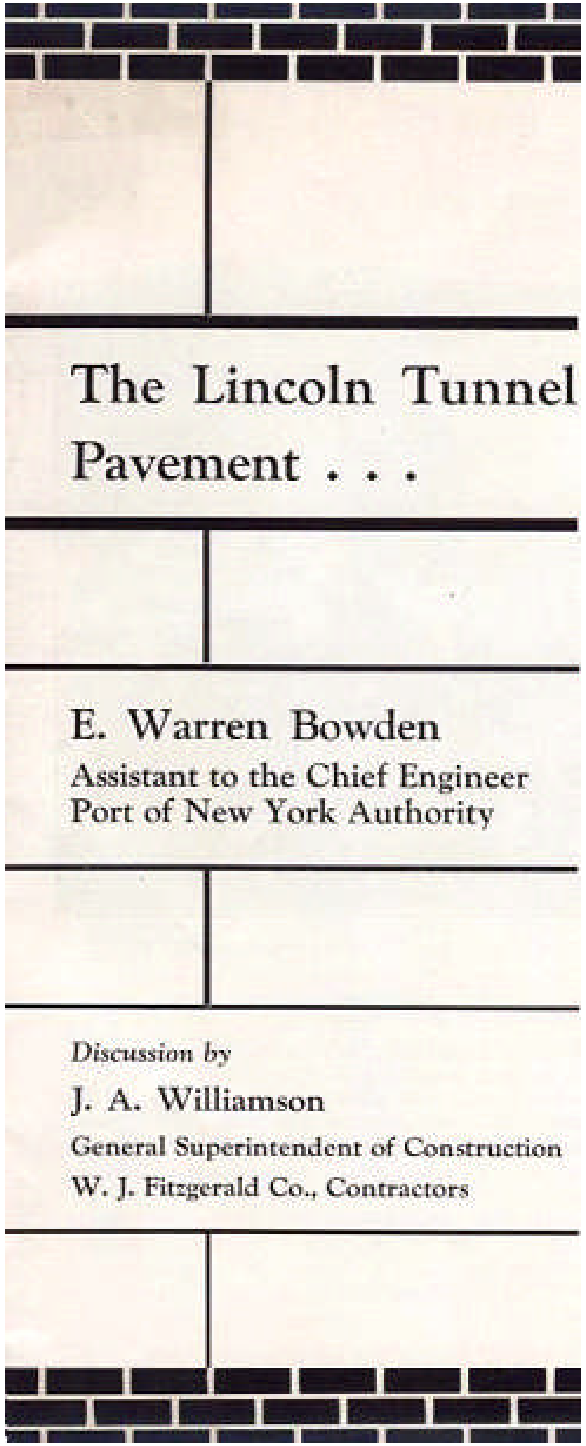
<u>Left</u>: caption: "Interior of Lincoln Tunnel under construction"

Top Left: caption: "The railroad track in the Lincoln Midtown Tunnel was taken up before the surface was laid for automobile traffic"
Top Right: caption: "Lincoln Tunnel – South Tube – Interior of tunnel showing first section of wall tiling in place"
Left: caption: "Entering the N.J. portal of Lincoln Tunnel on way to New York"


THE BEND, LINCOLN TUNNEL UNDER HUDSON RIVER
(Courtesy of Port of N. Y. Authority)


4349

Wearing Surface

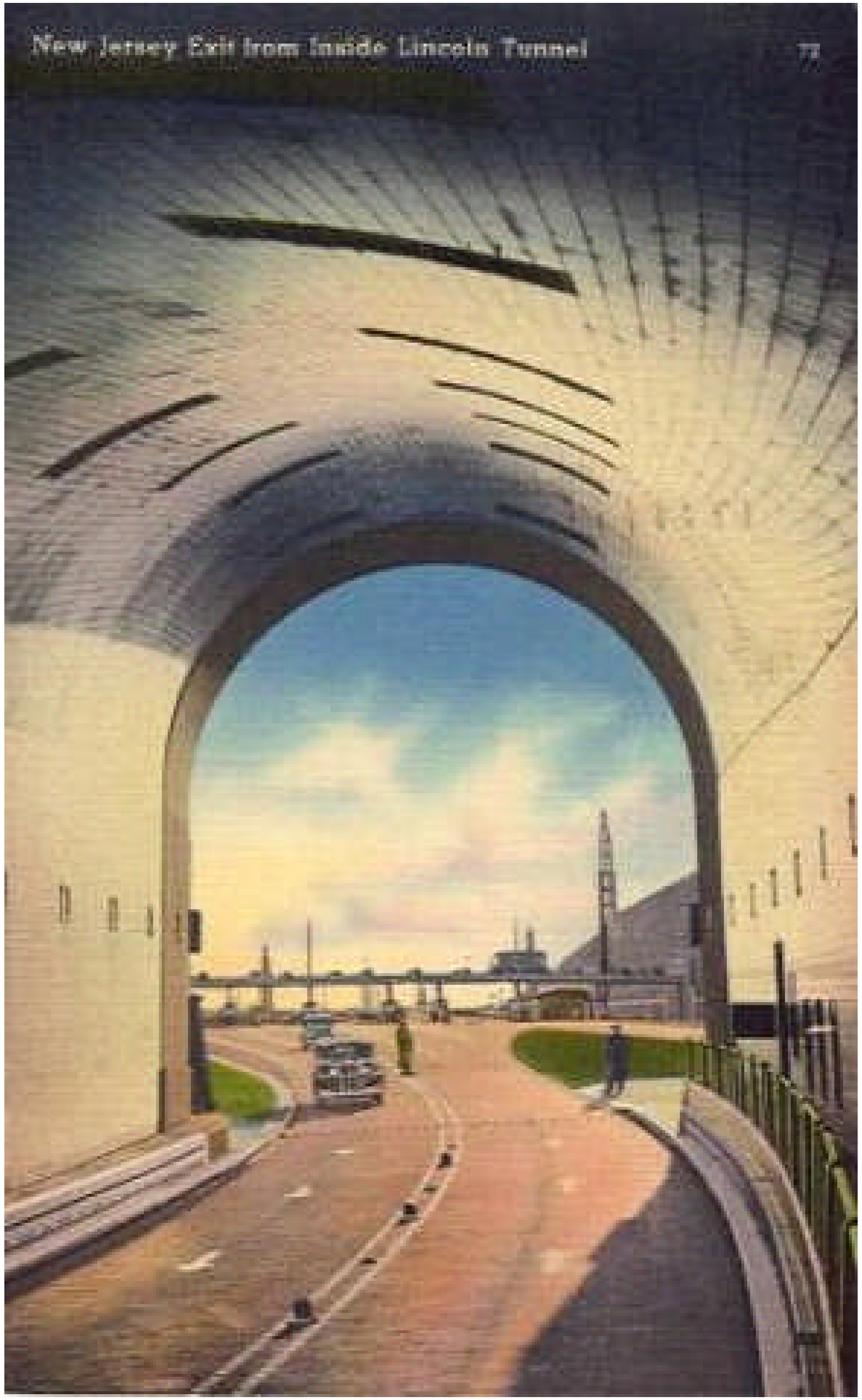

The Lincoln Tunnel Pavement . . .

E. Warren Bowden
Assistant to the Chief Engineer
Port of New York Authority

Discussion by
J. A. Williamson
General Superintendent of Construction
W. J. Fitzgerald Co., Contractors

"On December 22nd, just past, one of the most important stretches of brick pavement in the world, the Lincoln Tunnel at New York, was put in operation. Over this one and two-thirds mile length of two-lane roadway will pass more than four million vehicles during the first year of its use, a traffic later expected to become six or even seven million vehicles annually. No other stretch of brick surfaced roadway is so ideally situated to furnish an exact commentary on the development of present day paving brick to meet the requirements of modern traffic. Here an accurately counted never-ending stream of swiftly moving vehicles, confined to well defined traffic lanes and ranging from pleasure cars to 25-ton trucks will furnish a large scale demonstration of the qualities of paving brick…The importance of this project is such that every feature of its construction has been given the most careful consideration and, therefore, the choice of a de-aired vitrified brick pavement is an indication that to engineers intent on canvassing the entire field to find the product most suitable, vitrified brick appears to have valuable and outstanding characteristics for use in a modern vehicular facility…"

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**



"…At the time brick was chosen for the Lincoln Tunnel, there was no other important example of modern brick pavement in the Port area. The Holland Tunnel is paved with granite block and the George Washington Bridge with concrete. The decision to use a brick wearing surface was reached after careful studies and investigations had been made covering a dozen or more types of roadway surface, including concrete pavement, sheet concrete surface, armored concrete, cast iron paving units, steel plates or castings in treads, rubber pavement, granite block pavement, armored brick in wheel tracks and vitrified brick pavement. The decision was also based on the favorable impressions created by two sample sections of brick pavement laid in 1935 at the New Jersey entrance of the Holland Tunnel. The most important of these has carried over seven million cars to date…"

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**

Left: caption: "New Jersey exit from inside Lincoln Tunnel"

"…A tunnel roadway pavement should have certain essential characteristics, in keeping with those required in any good roadway pavement, no matter where located, namely, it should be non-slippery, durable, smooth riding and noise-less. In addition, the specialized conditions of a heavily traveled tunnel roadway require that the pavement surface be such that it can easily be repaired or renewed with a minimum of interference with traffic. And lastly, it should be economical when considered in terms of maintenance and replacement over a period of years…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

Skidding Characteristics

"…In the first place, the pavement must be non-slippery because, even though superior in many other respects, if slippery when wet or when coated with the oil dripping from passing motors, it would be un-satisfactory for a tunnel roadway. The first requisite for successful operation of a tunnel is the confidence of the public in it as a safe as well as expeditious travel facility. The most dependable sources of information that we could find with regard to skidding characteristics were the reports of studies of coefficients of friction of pneumatic tires on several types of pavement as developed by investigations at the Engineering Experiment Stations of Iowa and Ohio State Universities. At Iowa, experiments cov-ered both wet and dry road surface conditions and developed the fact that, when dry, the brick pavement on which the experiments were made had a somewhat higher coefficient of friction than the concrete pavement tested, while when wet, the coefficient of friction of the brick was slightly lower than that of concrete. The brick pavement was of the 'vertical fibre' type, filled by the squeegee method and had patches of filler on the surface…"

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**

“…The Ohio experiments brought out clearly the relatively high coefficients of friction developed by a ‘vertical fibre’ brick with no asphalt on top and the considerable loss of this valuable characteristic with increasing amounts of asphalt covering. It was quite clear to us that were it not for the recently developed method of completely removing excess asphalt joint material from the surface, consideration of brick for the tunnel pavement would have gone no further…”

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

“…To supplement the experimental data, the experience of those operating pavements of the type under consideration were sought. On Chestnut and Walnut Streets in Philadelphia where excellent brick pavements were in use, traffic officers and engineers reported no evidences of skidding on wet surfaces. The same statements were secured elsewhere. Our own observations on the operation of several million cars over the previously mentioned sample brick section laid at the New Jersey entrance ramp of the Holland Tunnel likewise attested quite satisfactory anti-skidding characteristics…”

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

Wear Resistance

"…As the second characteristic, the pavement must be durable under a traffic concentration more exacting than that usually found on open highways since a single traffic lane must carry from three to five million vehicles per year in sharply defined wheel tracks. The question was – how long could the various pavements be expected to remain in good condition. The answers were not easy to find because, although there is no dearth of testimony favorable to the several products, very little really scientific data is available. Granite block has served well in one location, concrete in another and brick in a third but in no case really comparable to our conditions have satisfactory data been determined for several kinds of pavement at once…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

"…It is true that we have the Connecticut Avenue experimental road in Chevy Chase, Maryland, built and maintained by the United States Bureau of Public Roads. The information secured, while valuable, is limited in its application to our problem chiefly because the traffic conditions there were not in any way analogous to those anticipated in the tunnel. In a single year the Lincoln Tunnel roadway will carry as many vehicles as the total carried during fifteen years of the experiment on Connecticut Avenue…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

<u>Above</u>: caption: "*Public Roads* has been exclusively an in-house research journal for engineers, scientists, and economists, fulfilling part of its original mission to publish the 'results or researches, experiments and studies of those connected with (the foreru- nner of the federal Highway Administration), and of highway officials of the various States'"

"…The accelerated traffic test made by the bureau on a circular brick test track at Arlington, Virginia, was also of much interest, but of very little help. One lane of our tunnel is estimated to carry in one year seventeen times the 326,500 tons total carried in the test. However, the test conditions were more severe than tunnel conditions, as, in all cases, trucks with solid rubber tires were used, and in 35 per cent of the trips the truck wheels were equipped with heavy non-skid chains…"

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**

"…A considerable amount of information was furnished by organizations interested in the several pavement types as to the costs of maintenance. Here again it was practically impossible to secure really comparable data. From our own experience with the wearing qualities of concrete under actually measured traffic movement on the Port Authority bridges and from our knowledge of the wearing qualities of the granite block pavement in the Holland Tunnel under similar conditions, we were able to make what we felt to be a conservative forecast of useful life for these two types of pavement. Our test sections of brick pavement, although in use for only a short time, had carried about five million vehicles in a single traffic lane without any signs of wear on the part of the brick at the time the point was reached when a decision must be made as to the pavement to be chosen for the Lincoln Tunnel…"

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**

Laboratory Investigation

"…Our final resort was to laboratory tests of the hardness, wear resistance and toughness of de-aired vitrified paving brick as compared to similar qualities of granite block. Granite was chosen as a standard of comparison because of its unquestionably high wearing qualities. In determining to make our own tests we had in mind recent developments in the process of brick manufacture, which had made possible an even more durable brick than any heretofore available…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

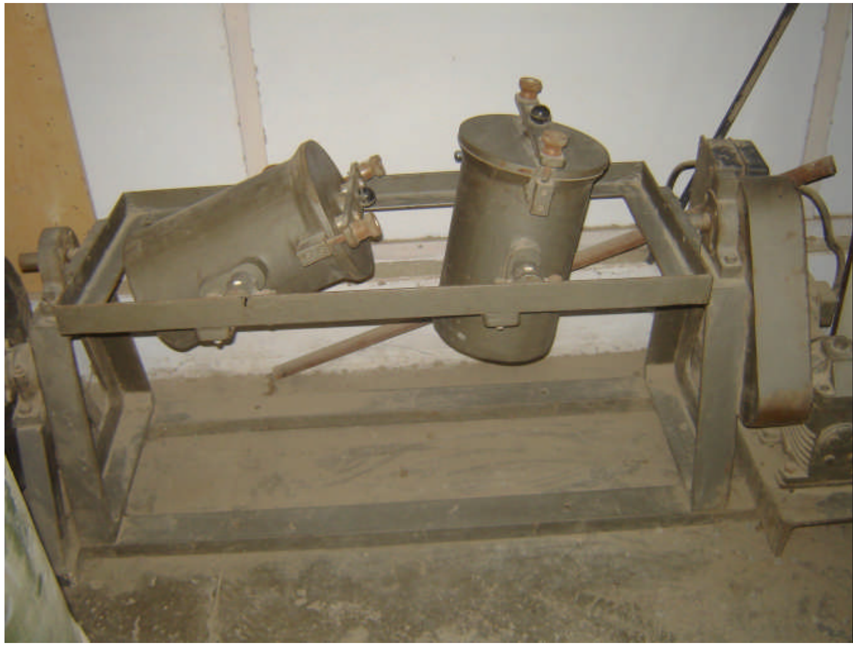
"…The laboratory tests were made under the supervision of Mr. G.M. Rapp, Assistant Engineer of the Port Authority, on samples of brick laid in the test section at the Holland Tunnel and manufactured by the Metropolitan Paving Brick Company. The conclusion reached was, briefly, that vitrified paving brick, manufactured by the de-aired process, can be produced equal in strength and durability qualities to the commercial, heavy traffic grade, granite block…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

"…The standard Dorry test for determining the surface hardness or resistance to abrasion consists of subjecting both end surfaces of small cylindrical specimens to the abrasion of quartz sand on a rotating disc machine. By this test, brick produced a coefficient of 19.09 as against 18.8 for granite block, showing the brick to be 10 per cent harder than the granite. A modification of the standard Dorry test was then run in order to more accurately simulate the actual service conditions of wear, and showed about 6 per cent less wear on the brick than on the granite…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

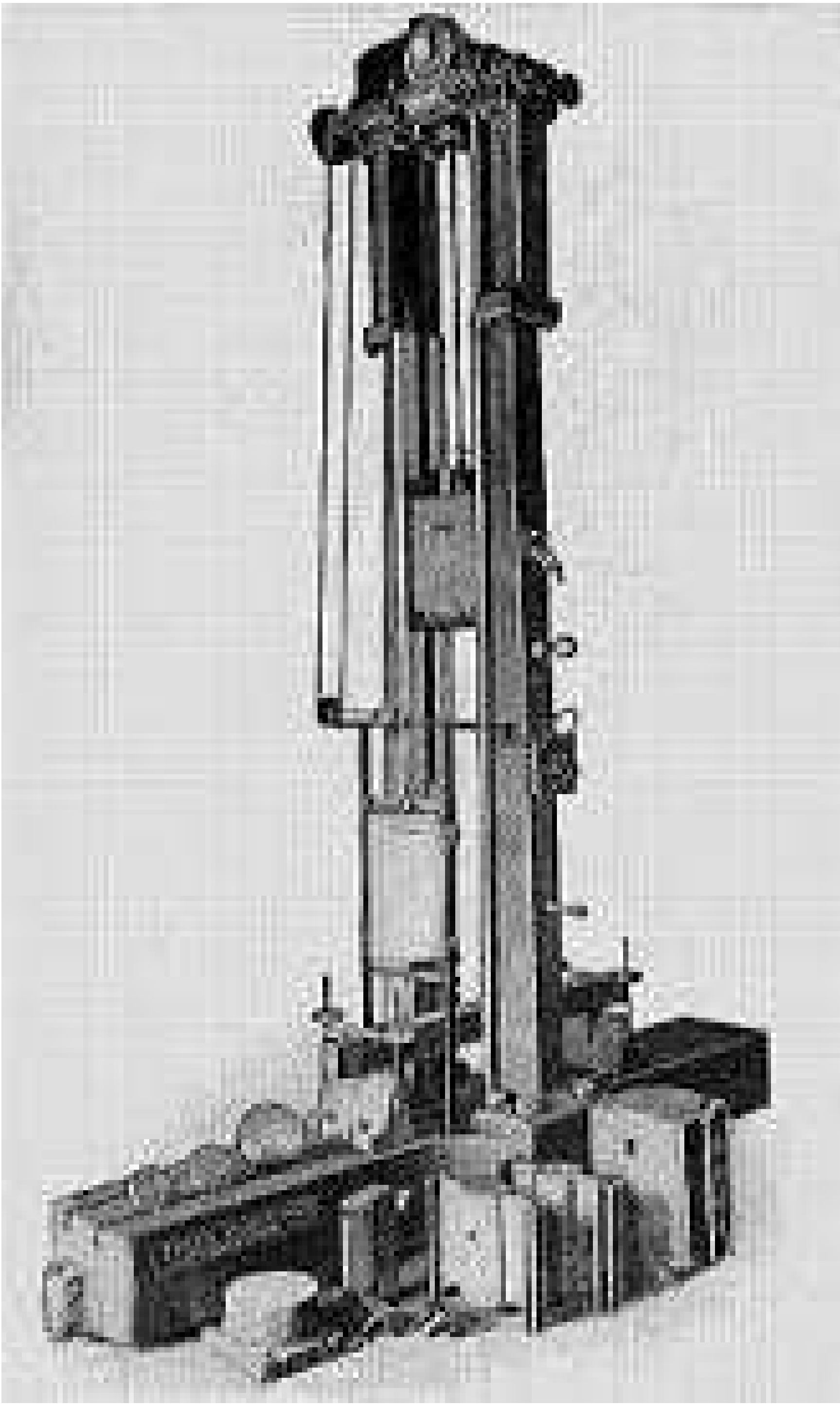
Left: caption: "Dorry Abrasion Testing Machine"



"…As a third test, samples of brick were subjected to abrasion in a Deval machine in accordance with standard methods. The test is designed to show the resistance to wear of rock aggregates used for road building and consists of subjecting a five kg. sample of coarsely broken fragments of the material to 10,000 revolutions in a steel cylinder inclined at 30 degrees with the horizontal and rotated about a horizontal axis. As applied to brick it differs from the rattler test by giving a truer picture of wear resistance itself, because the factors of toughness (or resistance to impact) and transverse strength are eliminated. It also tests the quality of surface wear predominating in the rattler test. The result of this test was to show for brick a French Coefficient of Wear of 12.1 as compared to 13.5 for granite block or in other words, the test showed the brick to be 10 per cent less resistant to wear…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

Above Left: caption: "Deval attrition testing machine (Deval attrition test). This equipment is used for testing the abrasion resistance of aggregates. The machine consists of a rotating frame to support two steel cylinders complete with covers and locking device. These cylinders are mounted on a shaft at an angle of 30 degrees with the axis of rotations of shaft. The shaft rotates at 30 - 33 rpm through a reduction gear operated by motor."



"…The apparent discrepancy between the results of this and the tests just described may be due to the fact that the interior structure of the brick, which is exposed to wear in the Deval test, is less hard than the surface, which is exposed in the Dorry test, or it may be due to the method of determining loss of weight by abrasion in the Deval test, since only detritus small enough to pass a 0.066 inch screen is recorded. Toughness or resistance to fracture was next considered and to determine it samples of brick were subjected to the standard drop impact test on a standard Page machine. This test records the height in centimeters of free fall of a 2 kg. hammer required to fracture a cylindrical specimen. Brick was found to have a coefficient of 19 as compared to 11.0 for granite block, indicating that the brick tested were considerably tougher than granite. In transverse strength the block was found to average 2,200 lbs. per sq. in. as against 2,700 lbs. per sq. in. for granite block, while for crushing strength the comparison was 23,100 lbs. per sq. in. for brick and 24,200 lbs. per sq. in. for granite block…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

Left: caption: "Impact Testing machine"

"…These tests certainly testified to the high qualities of paving brick now being manufactured and, although we realized that since the samples were taken from a lot furnished for a test road section, they would obviously be of relatively high quality, we were nevertheless satisfied that the question of durability had been satisfactorily answered…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

Other Factors

"…Our next two criteria – smooth riding qualities and noiselessness – were found to be fully met by brick pavement of the type used in the tunnel. Two factors, easy replaceability and cost, remained for consideration and of these the first named was felt to be at least as important as any other point considered. The requirement that the roadway surface be such that it can easily be repaired and returned immediately to service is peculiar to a tunnel roadway, where traffic operates twenty-four hours every day and where there can be no detours or extended closure of even a single lane without serious adverse effect on traffic and a resultant important loss of revenue. Certain types of surface, although satisfactory in other respects, would be quite undesirable from the replacement viewpoint. However, brick pavement with asphalt joints is admirably designed to meet this requirement. If and when repairs are necessary, it is possible to take up a short section of brick in a single lane and replace it immediately with a new brick surface. The whole operation can be performed during the night in the hours of least traffic and the pavement can be returned to operation immediately after the surface has been repaired…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

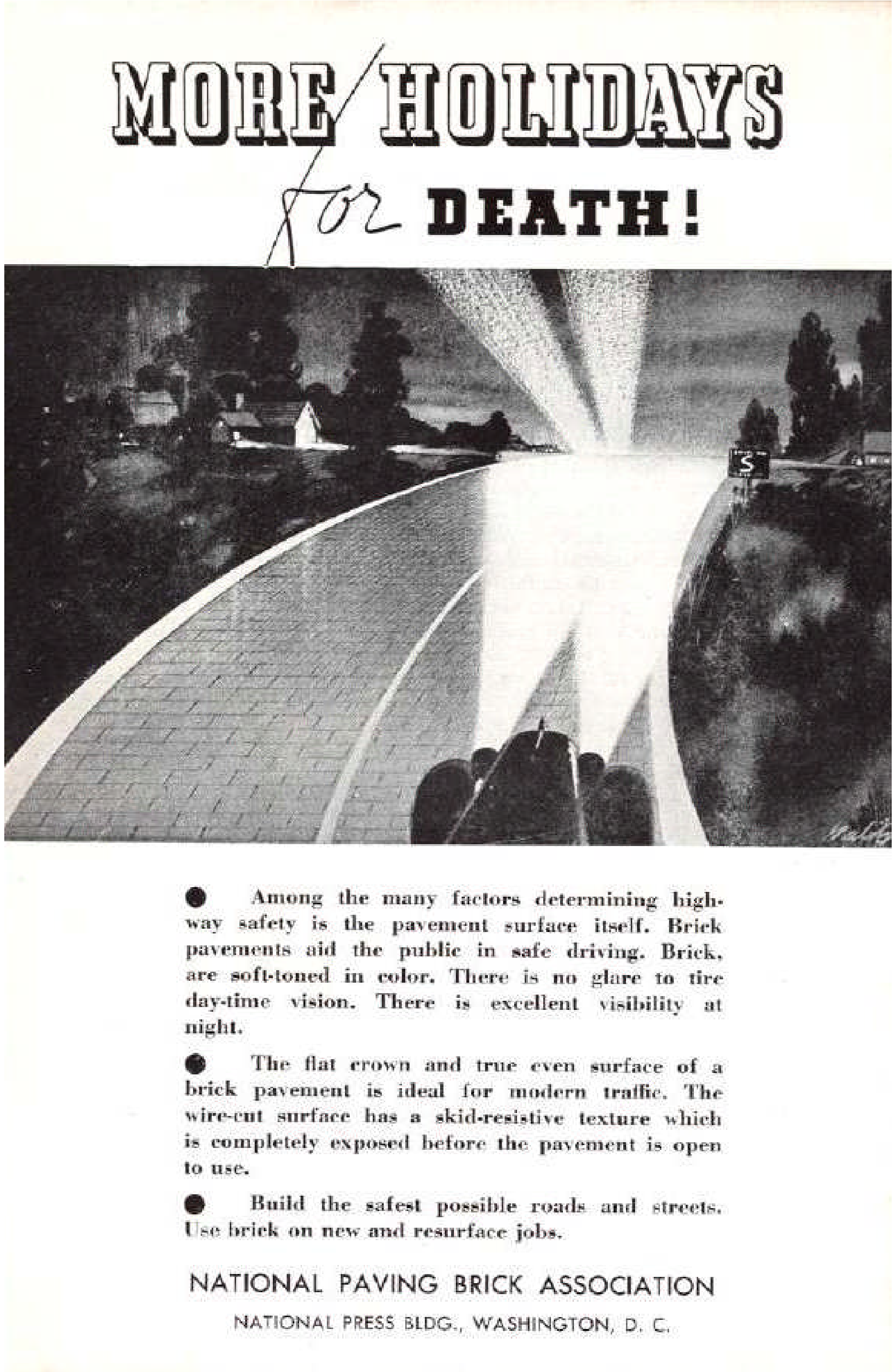
Ultimate Costs

"…The final factor in determining the choice of type of surface was the item of cost, and not only the initial cost but rather the ultimate cost as nearly as we were able to estimate it over a number of years. Thus all types of pavement were considered from the viewpoint of their ultimate utility. We have previously spoken of our studies to determine the probable length of useful life of the several pavement. It was necessary to make such an assumption in each case to determine the ultimate cost over a thirty year period, which was used for comparison. No matter what the length of useful life, every pavement sooner or later must undergo extensive repairs and replacements and to meet our requirements a block type of ultimate surface, which can be placed quickly and driven over as soon as placed, is indicated regardless of the initial pavement finish…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

"…Among the various materials proposed of meeting the pavement problem was the one of finishing the surface of the roadway slab initially as a concrete pavement and later placing over it a brick or granite pavement, or some other similar surface when necessary. This method of procedure offered economy in the initial investment but had certain very objectionable features from the practical viewpoint. In the first place, it would be necessary to provide adjustable curbs which would have to be moved to a higher elevation when the ultimate block surface was to be placed. Drainage details to accommodate the variable surface elevation would be awkward and difficulties would be found in relocating to new elevation the numerous manholes, air measurement boxes and other fixtures in the roadway pavement. Headroom, too, is an important factor and the inch or more added to the slab thickness to provide the concrete wearing surface would reduce the ultimate headroom by that amount unless taken initially from the lower air duct by lowering the entire roadway slab. In the latter case the restriction in duct area would cause a small but permanent annual increase in the cost of ventilation. In the end, this plan of procedure was rejected…"

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**



"…The estimated cost over a period of thirty years for each method of surface treatment included the initial cost, the cost of resurfacing, the cost of curb alteration where required by change in surface level, and interest on the investment. By this analysis it was found that among the reasonably acceptable plans, vitrified brick pavement resurfaced with brick would cost slightly more than an initial concrete pavement resurfaced with brick, but would cost considerably less than any other methods of treatment…"

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

<u>Left</u>: promotion for brick paving such as was used in the *Lincoln Tunnel* from the *National Paving Brick Association*

Specifications

"…Decision to use brick having been reached on the basis of the foregoing studies, specifications were prepared which called for a pavement of de-aired vertical fibre vitrified brick laid on a bituminous mastic cushion placed directly on the concrete base slabs, the joints between the brick to be filled with an asphalt filler. The brick were to be 3 in. thick and, of the various degrees of burning commonly classified as light, medium and dark, the medium and dark burned brick were to be preferred. The brick were to have lugs on one side and both ends. The standard rattler test was called for, the brick to show an abrasion loss of not more than 18 per cent…"

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**

Above: caption: "Laying brick pavement"

"…The current A.S.T.M. specifications base acceptance only on visual inspection and on the rattler test for brick. In addition to this our specifications provided for tests for transverse strength and toughness. For the transverse test, lots of five brick were to be tested according to the requirements of the Standard Methods of Testing Brick (Designation: C 67-31) of the American Society of Testing Materials. It was required that the average transverse strength should be not less than 2,000 lbs. per sq. in. and that the minimum value for any brick of a test lot should be not less than 1,800 lbs. per sq. in…"

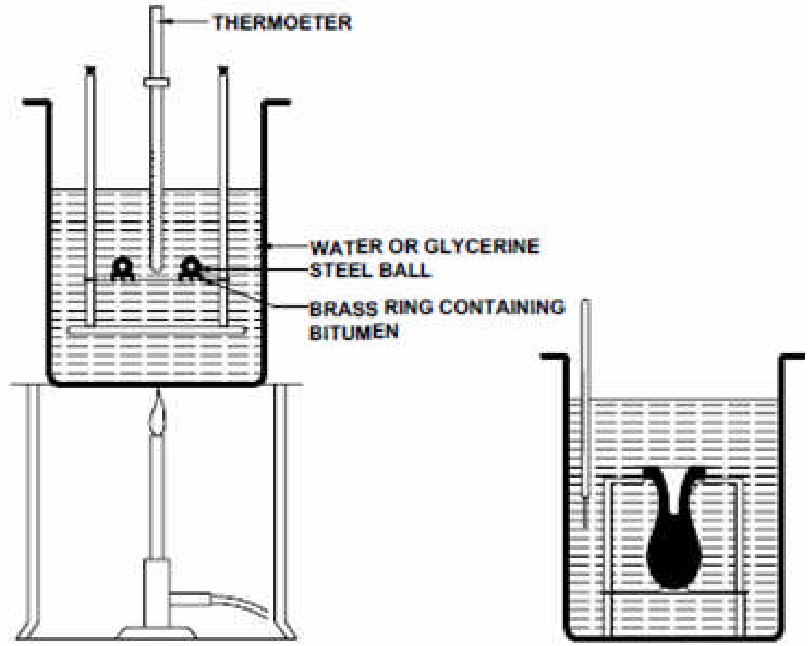
E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**

“…For the toughness test a modification of the Page Impact Test was set up by our engineers. In practice it was found that the results obtained from the toughness test were so erratic with regard to the qualities otherwise apparent that rigid application of the test was waived. However, it will be described as a matter of information. The method of performance is as follows: - the brick to be tested is placed horizontally in flat position on knife edges or rollers spaced 7 in. apart. Over the center of the brick is suspended a solid spherical a solid spherical steel ball weighing 2½ lbs., which is allowed to drop freely on the center of the top surface of the brick from successive heights, starting at 1 ft. from the top surface of the brick and increasing by intervals of exactly 1 ft. until fracture. The height of drop in feet at fracture gives the toughness value of the brick. It was specified that of the ten bricks constituting a test lot, the average toughness value should be not less than 4.5, that no specimen should have a toughness value less than 3 and that only one specimen should have a value as low as 3…”

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**

“…The joint filler was specified to be a blended asphalt with or without the addition of inert mineral flour filler. A great deal of study was devoted to this material because we were very anxious to avoid bleeding of the material on to the brick surface. Our specifications required that the filler should show no signs of foaming when heated to 445-degrees F.; should have a minimum flash point of 500-degrees F,; a softening point, Ring and Ball Test, minimum of 215-degrees F. and a maximum of 230-degrees F,; penetration at 32-degrees F., a minimum of 15; a penetration at 77-degrees F., a minimum of 23 and a maximum of 32; and at 115-degrees F., a maximum of 45; ductility of 77-degrees F. was to be a minimum of 1.4 cm. Toughness at 32-degrees F. was to be a minimum of 8 cm., when tested according to A.S.T.M. Designation D2-18. The foregoing figures were for asphalt filler without the mineral flour. The softening point and the penetrations were slightly modified for asphalt filler with mineral flour…”

E. Warren Bowden, **Assistant to the Chief Engineer – PNYA (January 1938)**



The temperature at which bitumen softens is determined by the “Bitumen Softening Point Test” (a.k.a. “Ring and Ball Test” - above L&R). A brass ring containing bitumen is suspended in a liquid medium (water or glycerin) and a steel ball is placed on the disc of bitumen. The liquid medium is then heated at a specified rate. The temperature at which the softened bitumen touches the bottom plate placed at a specified distance below the ring is recorded as the softening point.

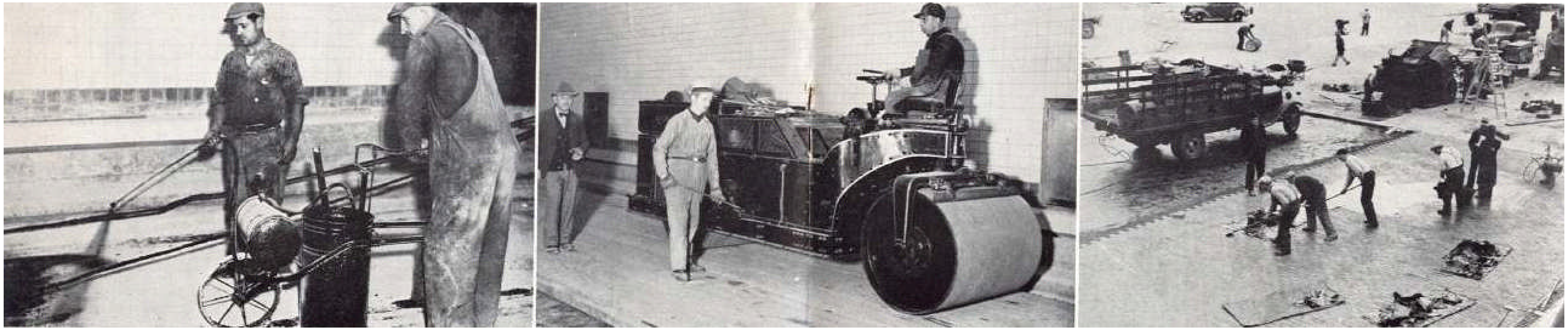
<u>Above</u>: caption: “(a) Diagram of Apparatus at Beginning of Test (b) Diagram Showing End of Test”

<u>Left</u>: caption: “Softening Point Ring and Ball Apparatus”

Construction

"…The paving contract was awarded to W.J. Fitzgerald Company in May, 1937. It provided for 26,100 sq. yds. within the tunnel proper, in the plazas near the portal, at the toll booth area of the Weehawken plaza and in a short underpass tunnel from the south end of the Weehawken plaza. The contractor bid $3.60 per sq. yd. For the brick pavement. Included in the contract were also white vitreous lane markers, illuminated lane markers and air measurement boxes to be installed in the pavement. The total cost of the contract was $135,000.00. Start of the field work was dependent upon the work of other contractors and it was not until the latter part of September that the contractor was ordered to begin his operations. The pavement was laid in one half the roadway at a time and progress was made at the rate of about 500 ft. of single lane per day. The contract was completed on December 21st, the date of the dedication ceremonies."

***E. Warren Bowden,* Assistant to the Chief Engineer – PNYA (January 1938)**



<u>Above Left-to-Right</u>: caption: “Pressure spraying base with bituminous prime coat before depositing mastic cushion material / Rolling brick on 1-inch surfaced boards with less than ten per cent renewal on entire job / Filler application and surface removal at Weehawken (N.J.) plaza, 180 by 286 feet”

<u>Above Left-to-Right</u>: caption: “Striking off asphaltic-sand mastic bed course with screed traveling on rollers and discs with compensating carriage / Close-up view of completed brick pavement showing clean wire-cut skid-resistant traffic surface / Kerosene fueled heating kettles in which ‘blended’ asphalt filler was heated to 450-degrees F”


CONTRACTORS

OSBORNE DRILLING CORPORATION
Land and River Borings

KENNEDY-RIEGGER DRILLING CO., INC.
Land and River Borings

PHILIP J. HEALEY, INC.
Land Borings—New York Approach

SPRAGUE & HENWOOD, INC.
Land Borings—New Jersey Approach

STANDARD DRILLING COMPANY
Borings—New Jersey Approach and New York River Shaft

BETHLEHEM STEEL COMPANY
Manufacture of Cast Iron and Cast Steel Tunnel Lining for Both Tunnels

OLIVER IRON AND STEEL CORPORATION
Manufacture of Bolts, Nuts and Washers for Tunnel Lining, South Tunnel

MASON & HANGER CO., INC.
Shield Driven Tunnels and Shafts for Both Tunnels and Rock Section of North Tunnel

UNDERPINNING & FOUNDATION CO., INC.
Rock Section in New Jersey—South Tunnel

GEORGE M. BREWSTER & SON, INC.
Steel Bent Sections of Both Tunnels in New Jersey, and Plaza Connections and Approach between Hudson County Boulevard East and Pleasant Avenue in Weehawken

CORNELL CONTRACTING CORPORATION
Steel Bent Section, Plaza and Approaches of South Tunnel in New York

GEORGE SCHOR
Demolition on New York Approach

BUFFALO FORGE COMPANY
Mechanical Equipment for Ventilation of South Tunnel

CAULDWELL-WINGATE COMPANY
New York River Ventilation Building

GEORGE COLON CONTRACTING CORP.
New York Land Ventilation Building

GEORGE SIEGLER COMPANY
Ventilation Building, Field Office Building, Toll Booths and Floodlight Towers in New Jersey

MACBETH-EVANS GLASS COMPANY
Manufacture of Ceiling Tile

J. LIVINGSTON & COMPANY
Electrical Equipment and Installation

DEL TURCO BROS., INC.
Side Wall Tile and Other Tunnel Finish

THE P. J. CARLIN CONSTRUCTION CO.
New York Approach Finish of South Tunnel

W. J. FITZGERALD
Tunnel and Plaza Brick Paving

A. DIERKS & COMPANY, INC.
Pumping Equipment

JOSEPH P. SCANLON, INC.
Marginal Roadways in Union City

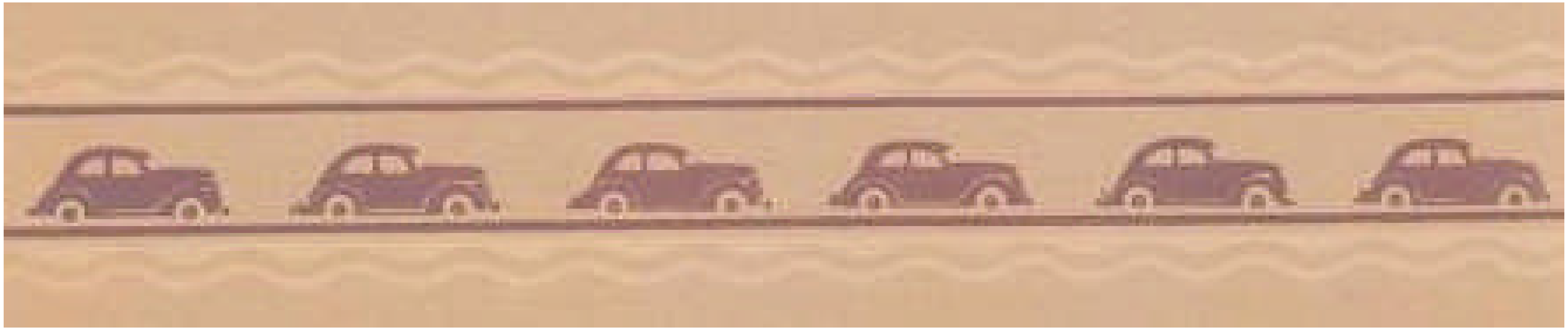
BEACH ELECTRIC COMPANY, INC.
Toll Signaling and Recording Equipment

CLINTON ASPHALT COMPANY
Widening and Paving 19th Street, Weehawken

TAYLOR-FICHTER STEEL CONSTRUCTION CO., INC.
Structural Steel for Steel Viaduct Section in Weehawken

POIRIER & McLANE CORPORATION
Concrete Viaducts and Concrete Deck and Piers for Steel Viaduct Section in Weehawken

L. P. O'CONNOR, INC.
Excavation and Foundations for Viaduct Sections in Weehawken



"…In November of last year, general business conditions were such as to justify the Authority in going forward with construction of the second tube and the remainder of the work on connections. Bonds in the amount of $10,000,000 were issued in December to initiate second tube financing. Other issues have been made as required by progress of construction on the entire project. Thus bonds aggregating approximately $62,600,000 for Lincoln Tunnel purposes are now in the hands of the public. While the Authority proposes to complete the financing of the project in this same manner, the federal government, through the Public Works Administration, has cooperated with the Authority by establishing a credit against which it may borrow for Lincoln Tunnel construction purposes if necessary, and also by agreeing to make an additional grant (not to exceed $3,100,000) contingent upon the amount of labor which may be taken from relief rolls…"

RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* dedication ceremony booklet (December 21st 1937)


NEW YORK

Access

"…The plaza for entrance and exit will be between 38th and 39th Streets and between 9th and 10th Avenues in New York; and adjacent to Park Avenue, south of King's Bluff, in New Jersey. From these plazas there will be appropriate connections to the various streets and highways so as to make access to the tunnel easy from all directions…In Manhattan, a new street eight blocks long will be opened between Ninth and Tenth Avenues as part of the approach system. On the New Jersey side connections will ultimately be made with all the main highways both east and west of the Palisades. Practically all grade crossings and left turns will be eliminated…"

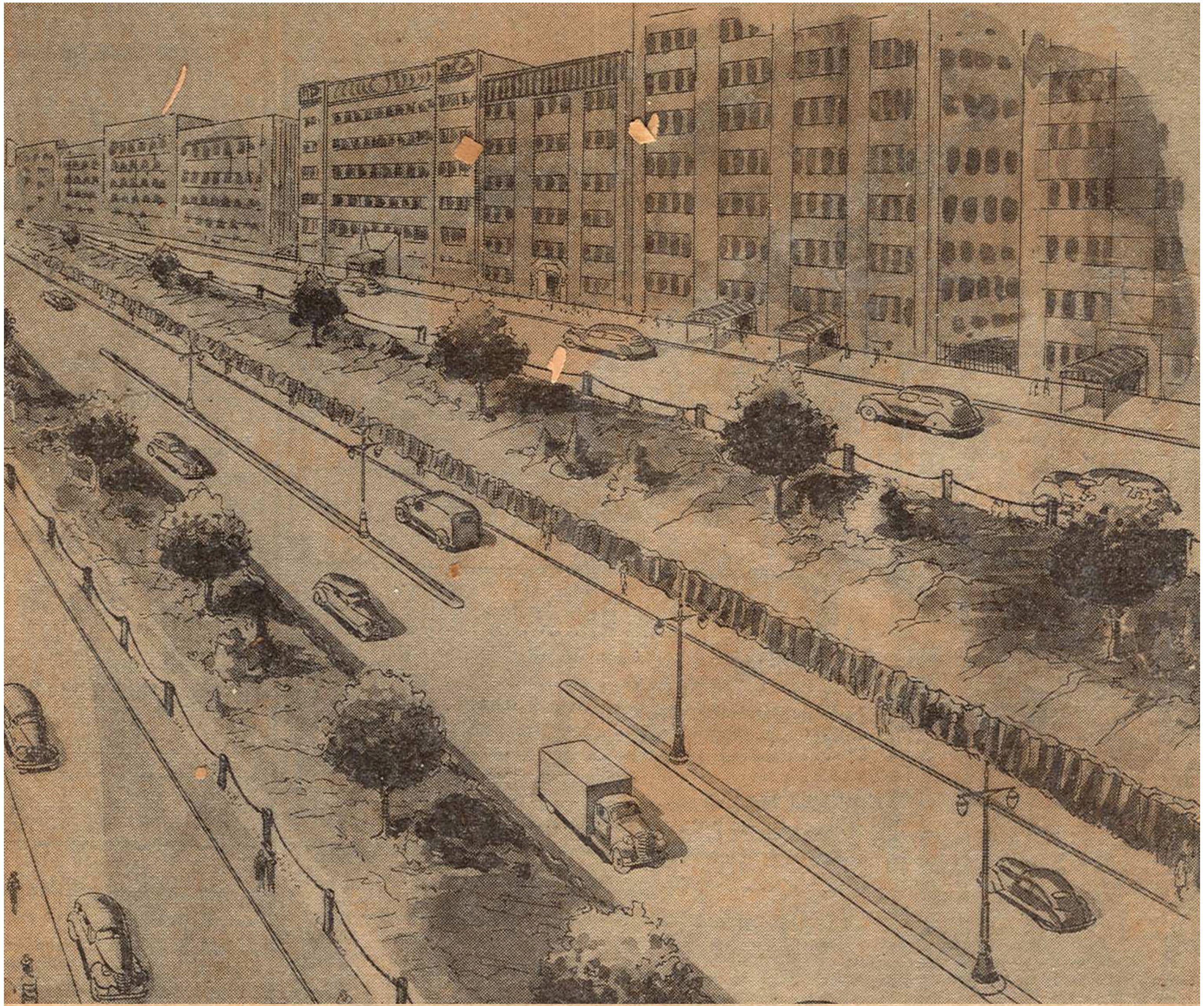
RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* ground breaking ceremony booklet (May 17th 1934). Plans for the *Hudson-Midtown Tunnel* and its approaches were first announced in 1930, when the PNYA proposed a $62 million, twin-tube tunnel under the *Hudson River* between *West 38th Street* in *Manhattan* and *Weehawken, New Jersey*. On the western shore of the Hudson, the tunnel was to connect to *New Jersey State Route 3* (NJ 3).

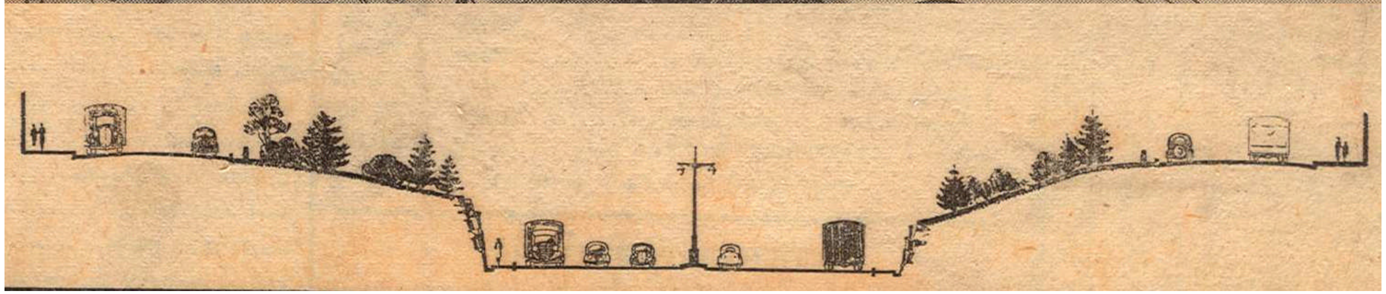
New Jersey

The original midtown tunnel proposal included a land tunnel extension from the toll plaza west through *Bergen Hill*, ending at *Tonnelle Avenue* (*US 1/9*) in *North Bergen*. Instead of constructing the land tunnel, the PNYA constructed a 360-degree, elevated "helix" that brought the six-lane highway from atop the palisades of *Weehawken* down to the tunnel's toll plaza. The 2.6-mile-long connecting freeway through *North Bergen, Union City* and Weehawken (designated *NJ 3*) was opened by the PNYA in December 1937. With its six 11-foot wide lanes, lack of shoulders and inadequate acceleration and deceleration lanes, the road reflects pre-Interstate highway design standards including Robert Moses' trademark stone-arch overpasses.

Left: caption: "Lincoln Tunnel Approach Viaduct (a.k.a. NJ 495), locally known as "The Helix." Upon exiting the tunnel, NJ 495 makes a helical incline to the top of the Weehawken Palisades."

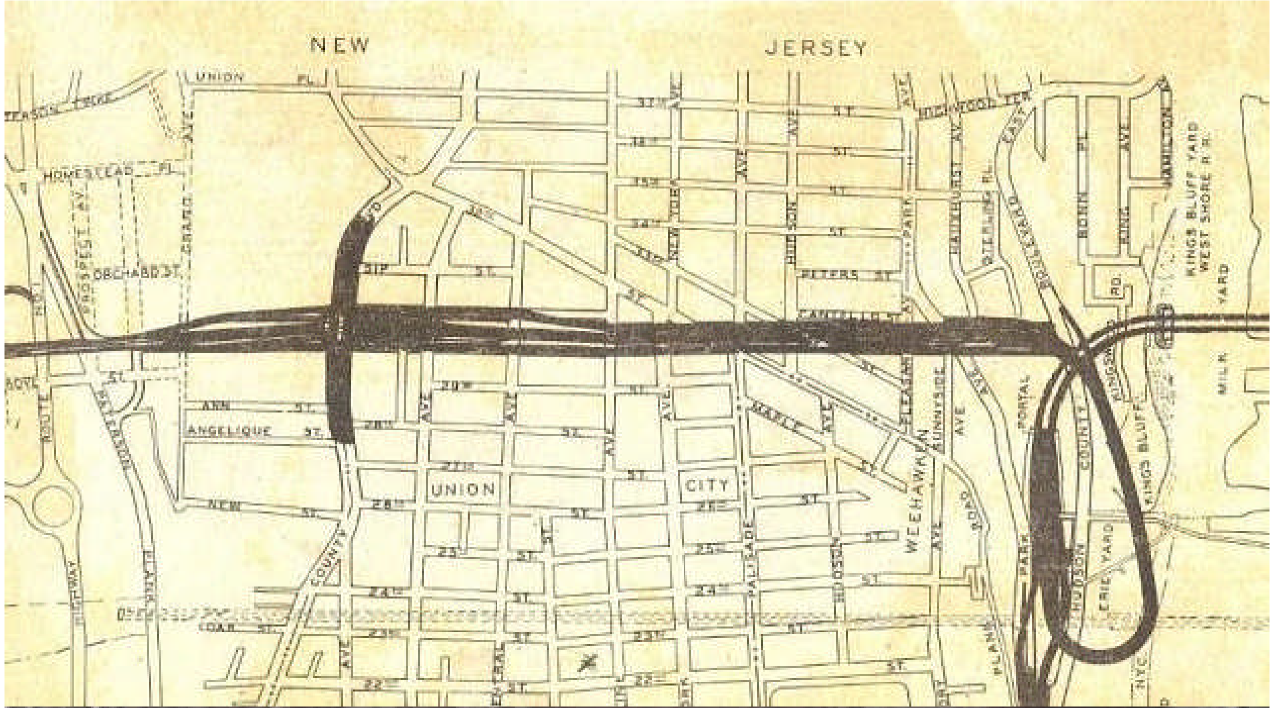
Right: caption: "Westbound NJ 495 in Union City, NJ"

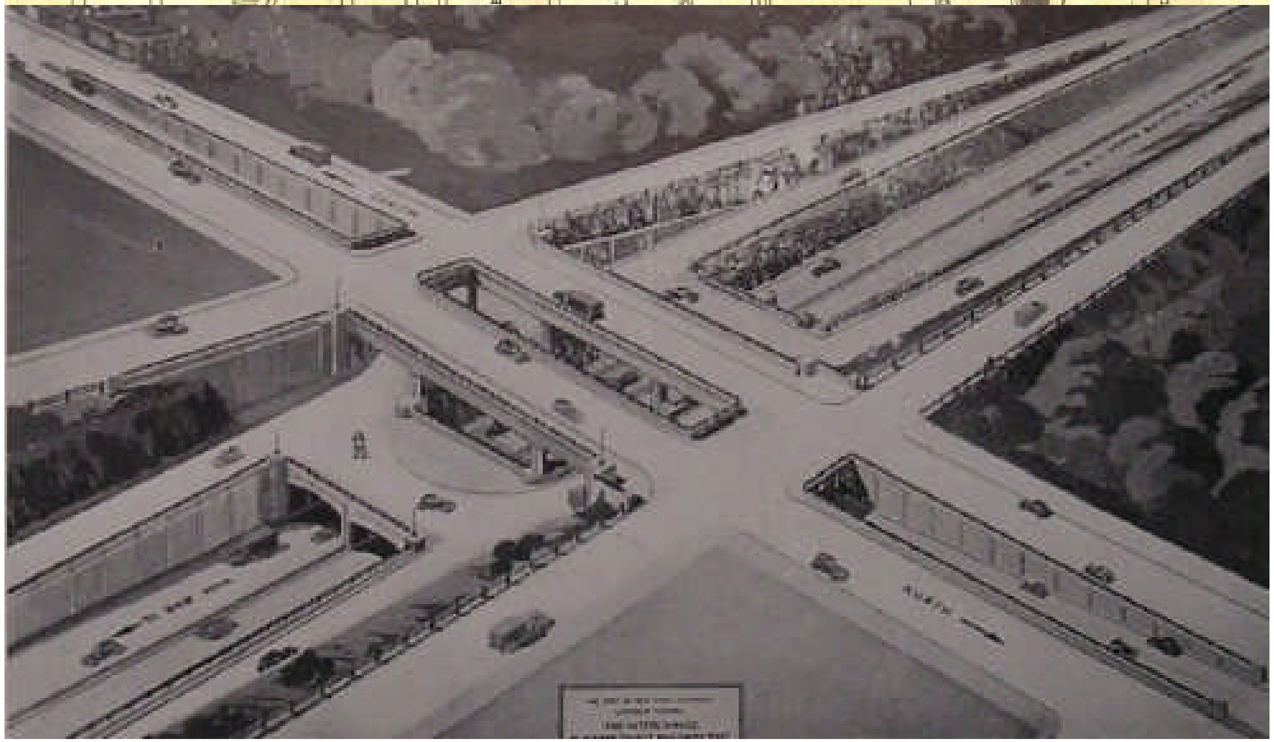




Top: caption: "Here is how Kay envisions the Weehawken-Midtown Tunnel approach. The drawing, which shows a section of the highway, lays stress on the highway development from the real estate angle. Here you will see the beautiful apartment houses that will in all likelihood rise on both sides of the highway. Residents of these modern apartments will look down upon a scene of beauty and charm in the parkways flanking the highway."

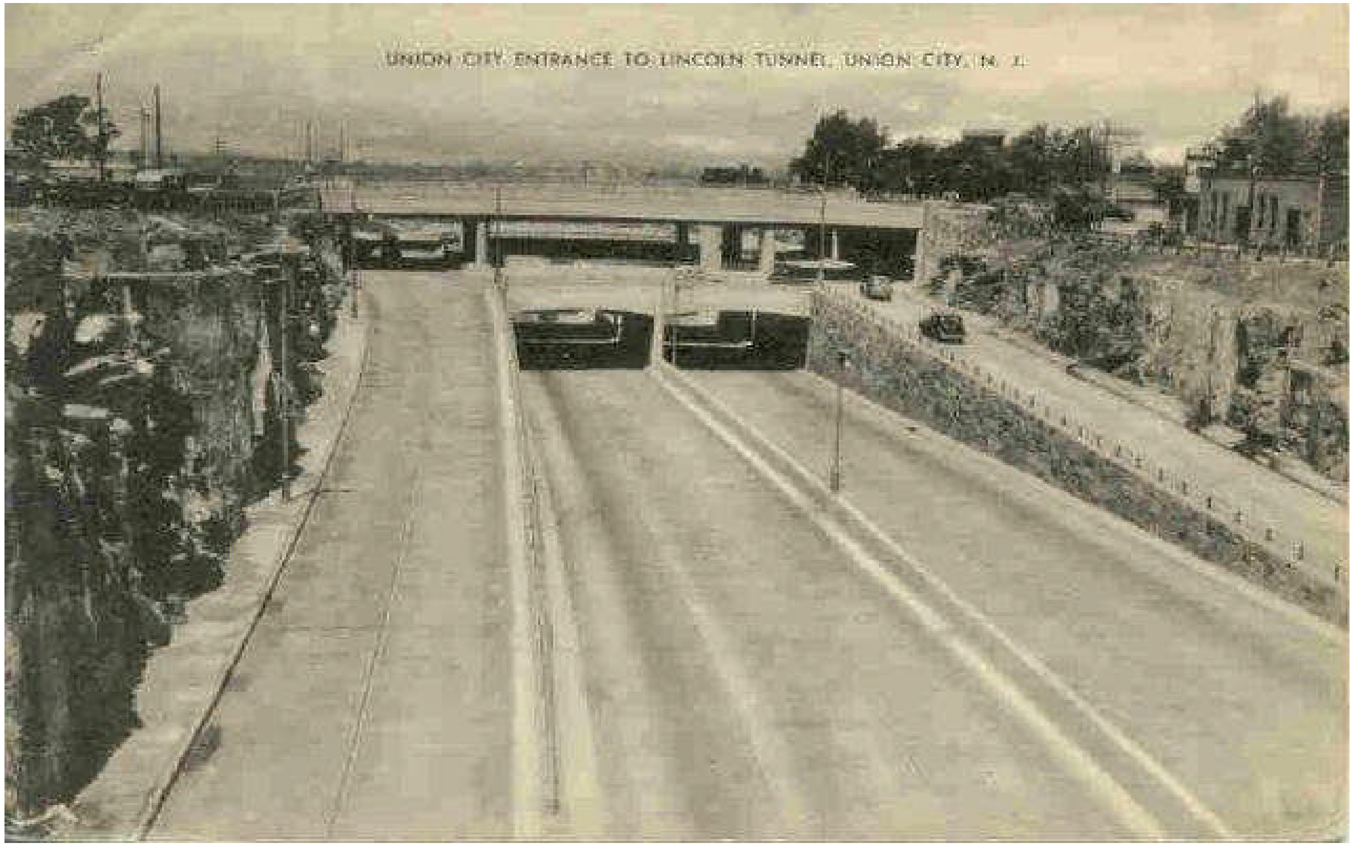
Bottom: caption: "A cross-section view of the depressed highway approach to the Weehawken-Midtown Tunnel, flanked by parkways rising to the level of the marginal highways on each side."

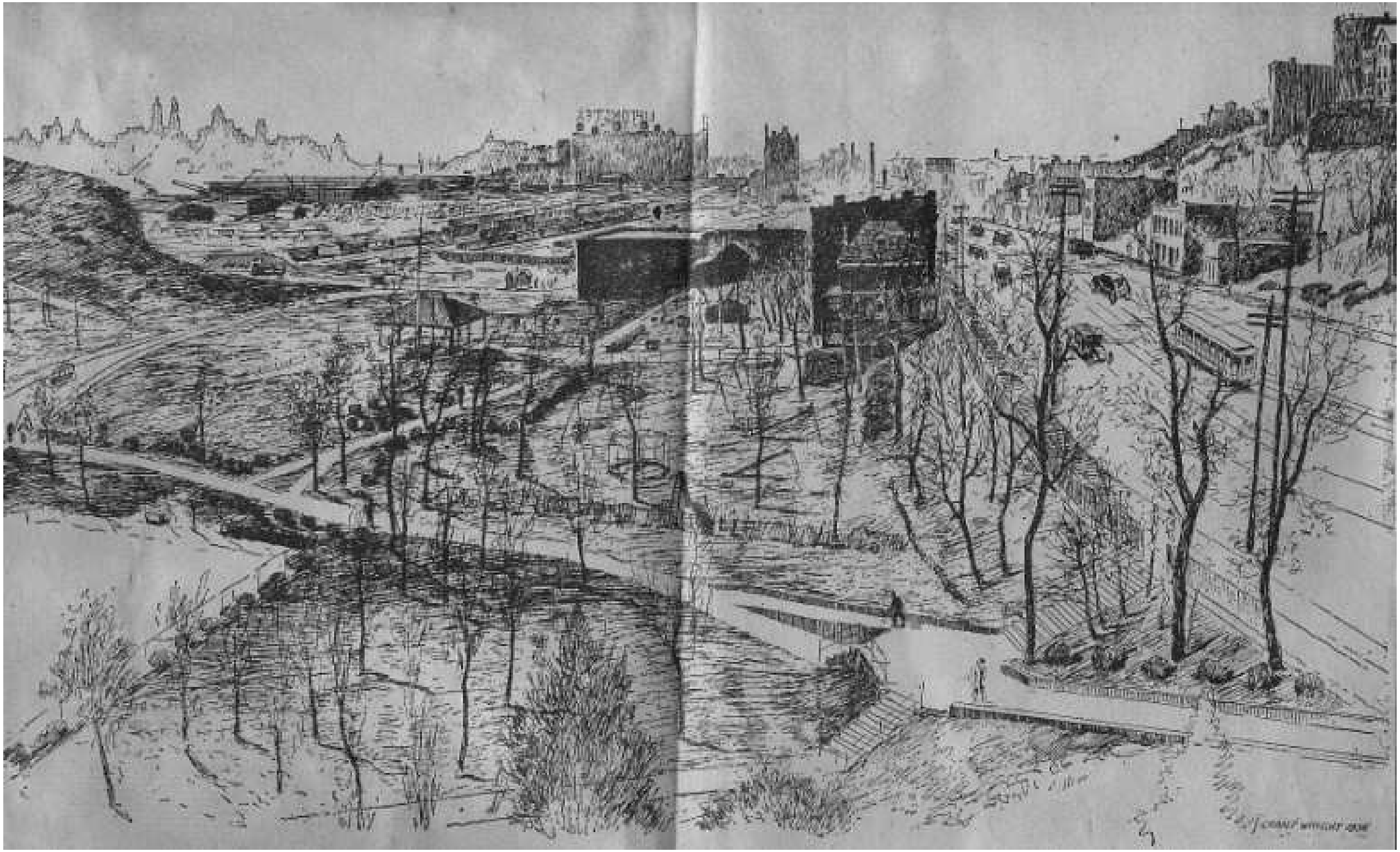




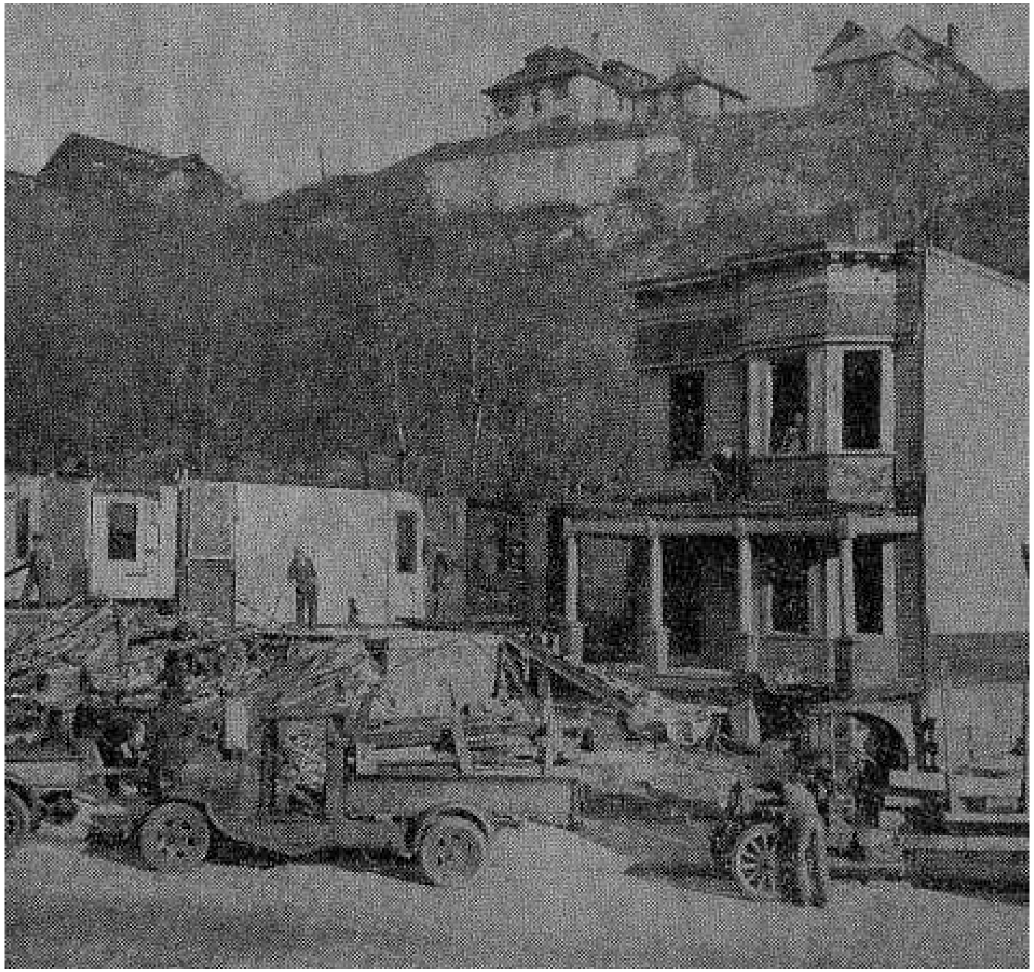
<u>Top</u>: caption: "The above diagram shows how the depressed highway of the Weehawken-Midtown Tunnel will cut through Union City and Weehawken. From the tunnel mouth in Weehawken the highway forms a loop around Boulevard East and swings up to begin its course across Union City at Pleasant av. The three sections forming the black area indicate the depressed highway and marginal surface highways. Where they pass New York av. At 32nd st., a plaza will be built, and continuing to the Hudson Boulevard, further developments will be made. The depressed highway will go under the Boulevard and remain depressed until it reaches Route 1 in North Bergen." (*Hudson Dispatch*, April 23rd 1937)

<u>Bottom</u>: caption: " A Triple 'Layer-Cake' of Cross-Overs. A Lincoln Tunnel approach in Northern Hudson County."

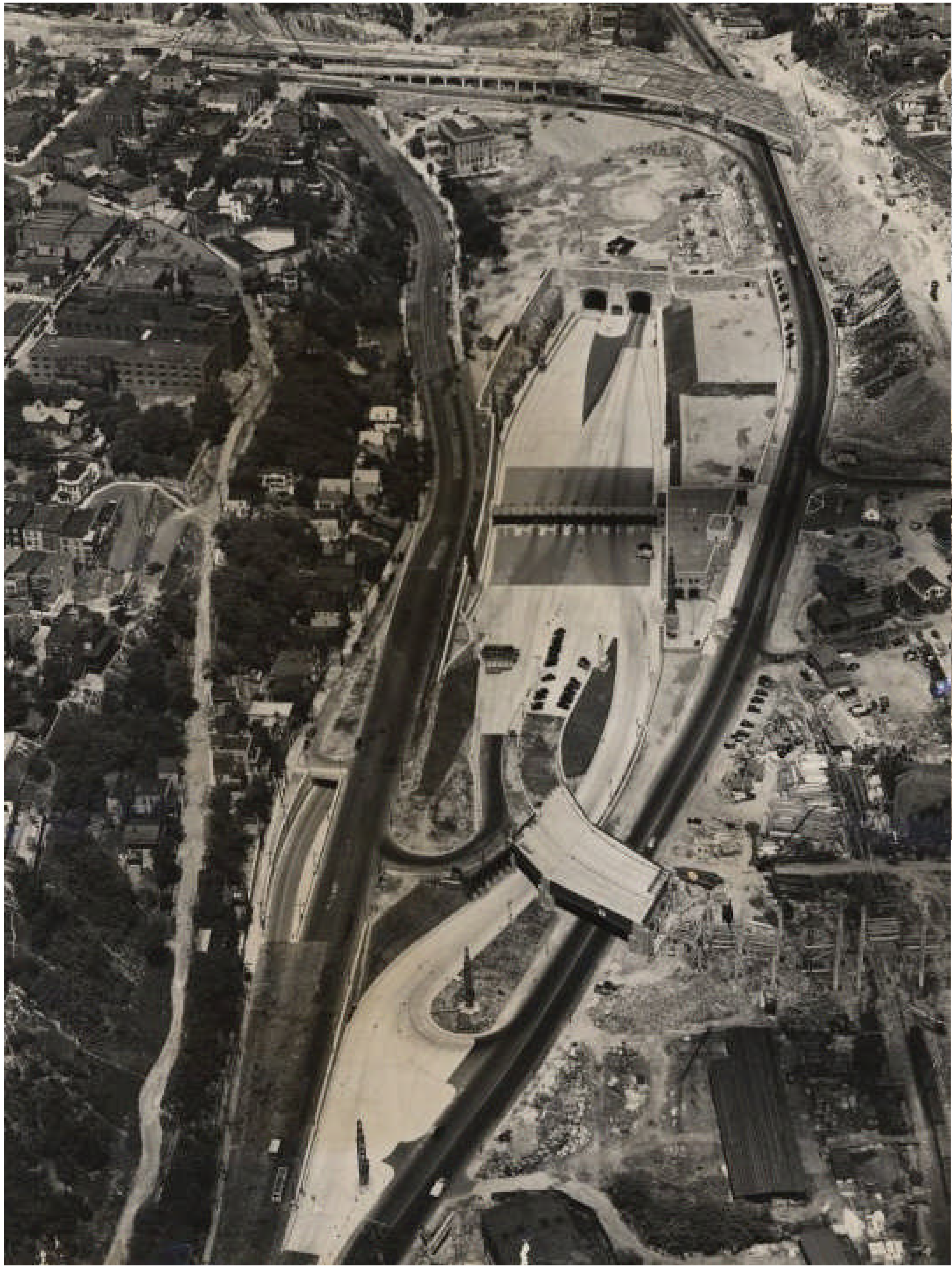

UNION CITY ENTRANCE TO LINCOLN TUNNEL, UNION CITY, N. J.



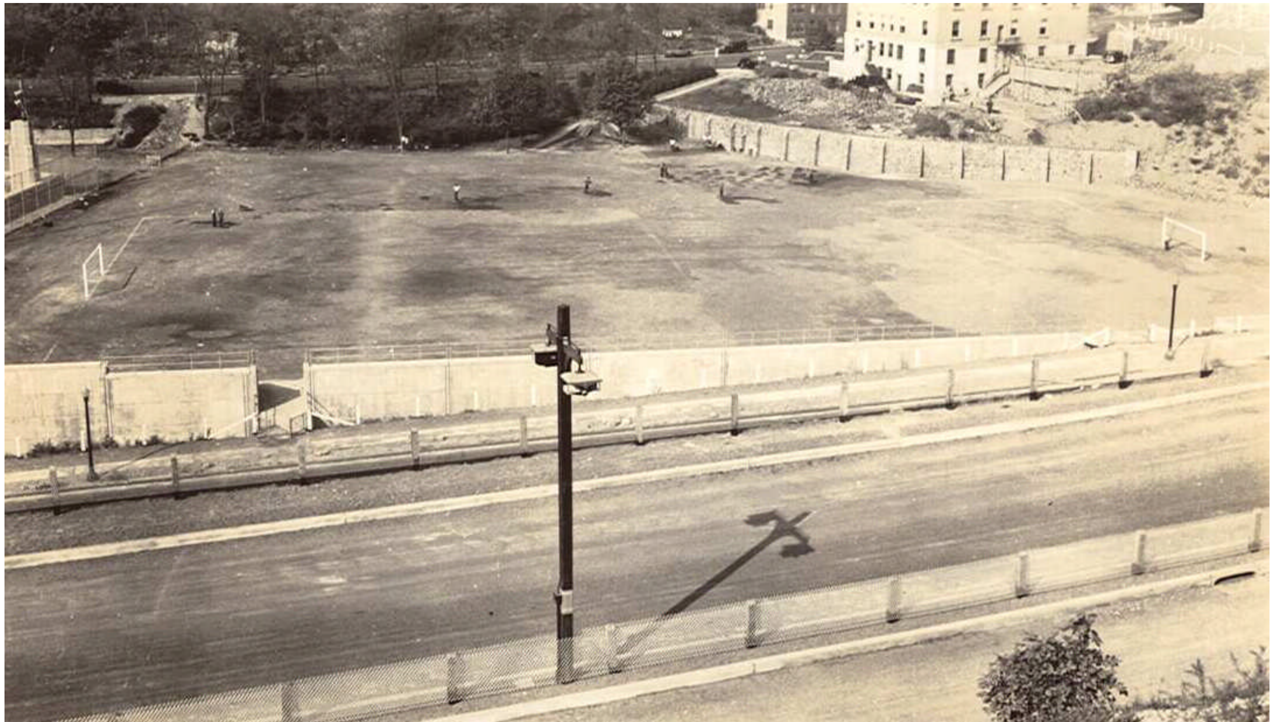
Above: caption: “This sketch by Grant Wright shows the area of the Weehawken side of the Lincoln Tunnel before construction began”

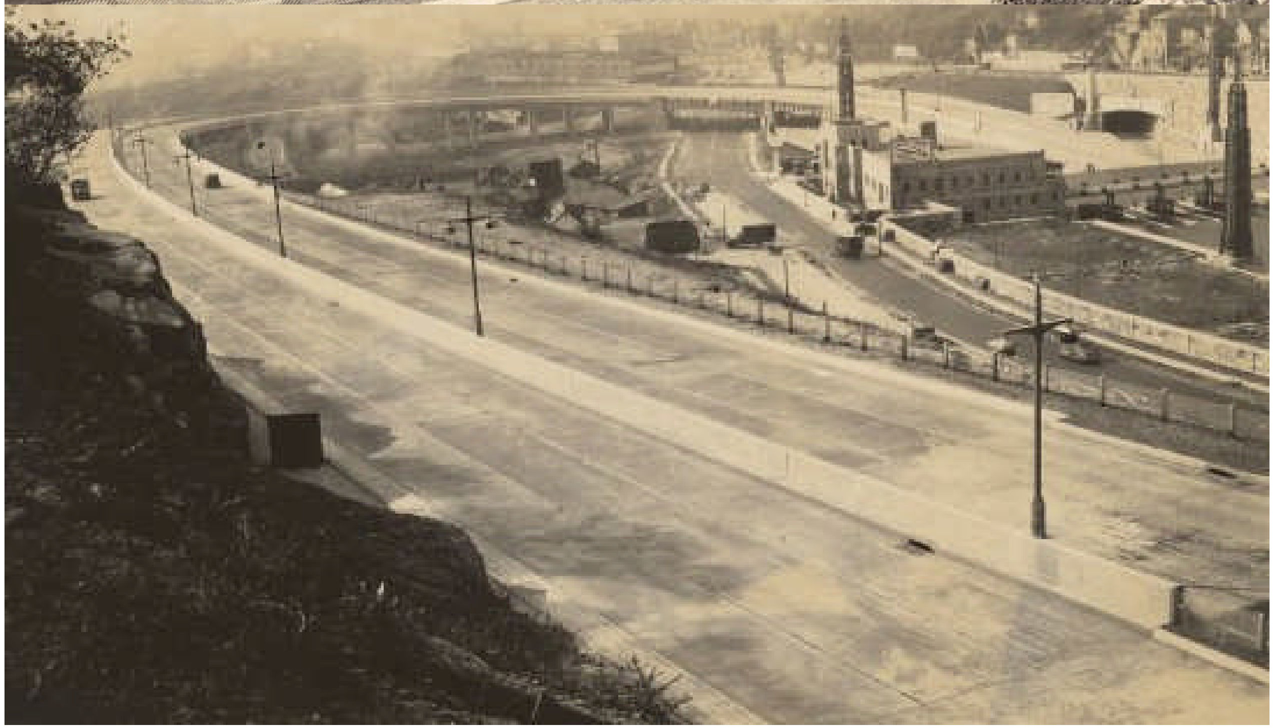


<u>Left</u>: caption: "November 1935: The job of wrecking is under way. Here is almost completed the task of tearing down 24 frame houses in the 'Valley' on Boulevard East, Weehawken, in preparation for building the approaches to the tunnel. One of the buildings is in process of demolition. Another is being readied for the spike and rope. This is in vicinity of new playground. King's Bluff is in background. This is a section in what was once Weehawken's 'Valley Park,' years ago the scene of busy industries and shad fishing. The setting is looking east toward the famous 'Bluff' where the Kings and other famous families lived in 19th Century exclusiveness. The houses to go were among the township's oldest privately owned dwellings."



<u>Above Top</u>: caption: “The Helix being constructed; looking west along express highway from top of King’s Bluff”
<u>Above Bottom</u>: caption: “The Helix after its opening in October 1938 - with no traffic”
<u>Left</u>: caption: “Aerial view of the Helix being constructed, 1938”

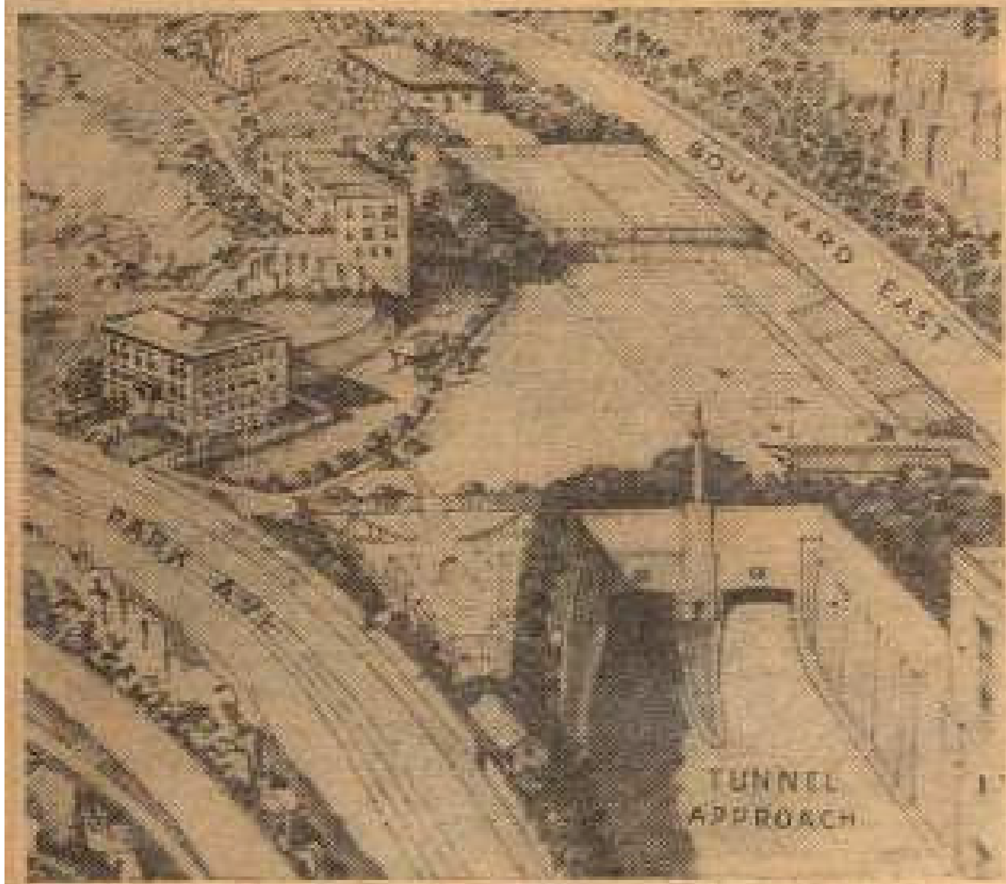




Above: caption: “Installation of the bridge carrying the Lincoln Tunnel approach over Park Avenue. Placing 55-ton steel to complete the ramp on Park Av.”

<u>Above</u>: **caption: "Initial Arrangement of New Jersey Approach. Weehawken toll plaza with its initial to Hudson County Boulevard East and Park Avenue as completed to form part of the First Operating Unit of Lincoln Tunnel. The uncompleted structure at Hudson County Boulevard East will form part of the viaduct loop which is now under construct-Ion." (as of December 1937)**

NEW YORK TIMES, SUNDAY, OCTOBER 21, 1934.



SKETCH OF THE NEW WEEHAWKEN PLAN.

The tunnel entrance and exit are at the lower right, and the Municipal Building at the left. Boulevard East is drawn in accordance with the new proposal. The approach plaza and hairpin loop across Park Avenue are not included in this sketch.

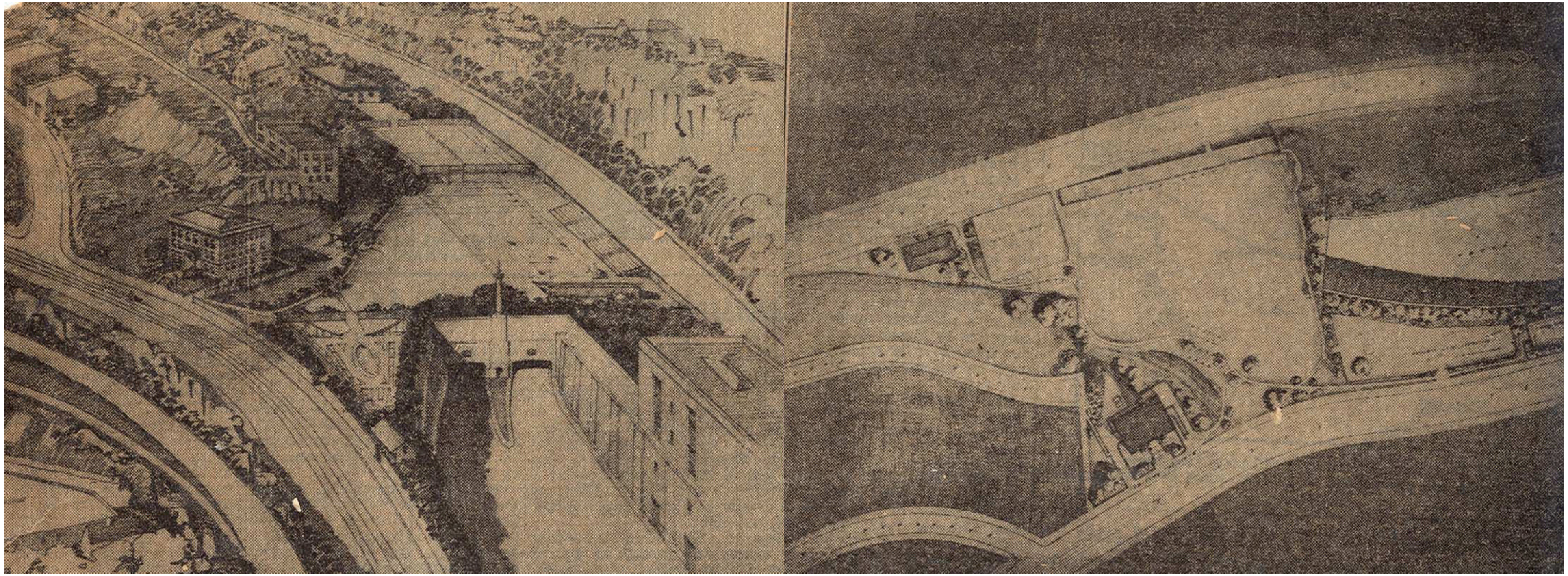
WEEHAWKEN GETS NEW TUNNEL PLAN

148th Proposal of Port Board Is Offered to Satisfy Taxpayers' Demands.

BOULEVARD EAST SHIFTED

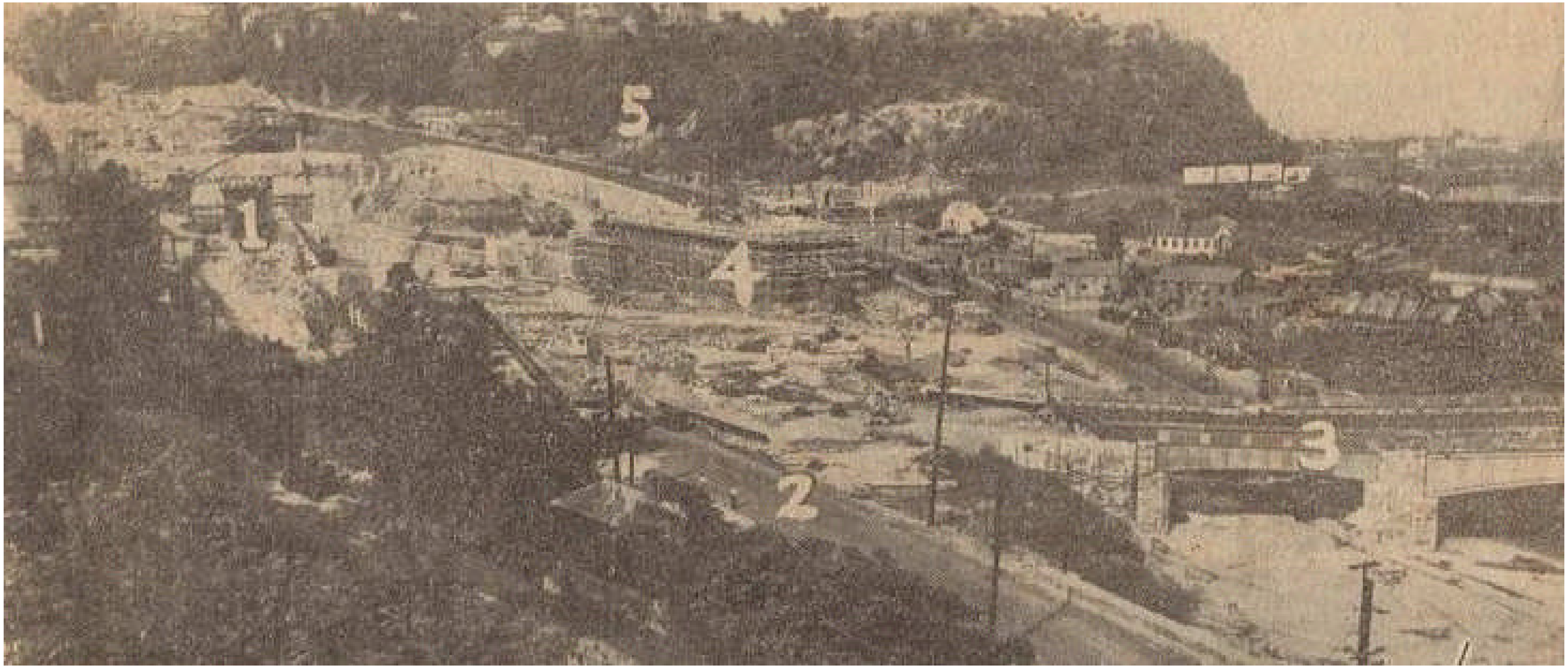
Further Playground Development Is Provided—Assessment Problem Is Unsettled.

A new plan for the approach to the Midtown Vehicular Tunnel in Weehawken, N. J., was proposed last week by the Port of New York Authority at a public meeting called by Mayor John Meister of Weehawken. The plan was the 148th mapped by the Authority in an effort to meet its own requirements and to satisfy the demands of Weehawken taxpayers and township officials.

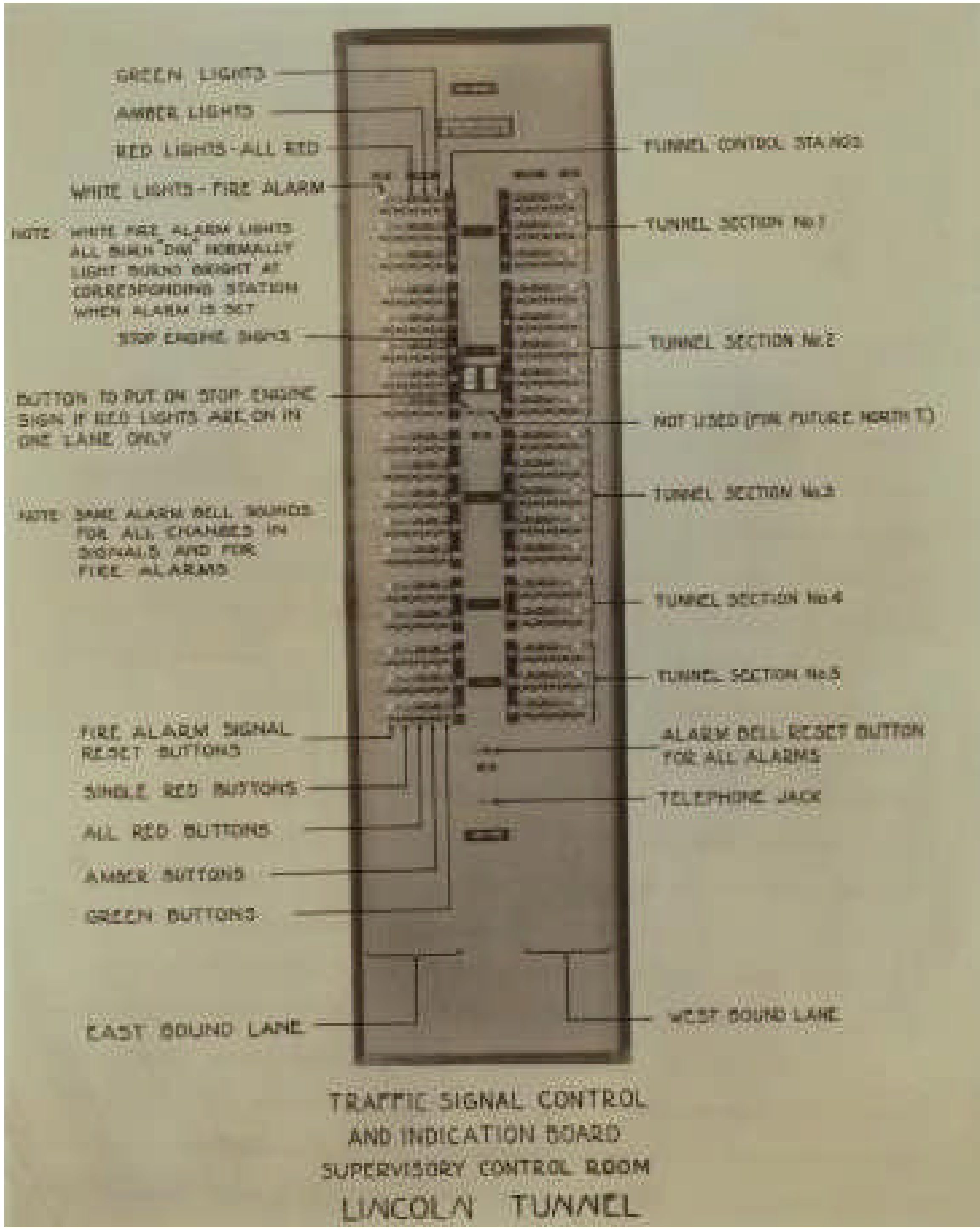


<u>Left</u>: caption: The above sketch discloses latest proposed plan for location of entrance and exit to new Mid-Town Tunnel at its Weehawken end. Road to right is Boulevard East (Valley Road) and at left Park avenue. Picture is drawn looking north from Eighteenth street with new town play field directly above tunnel entrance.”

<u>Right</u>: caption: “Air View of Weehawken Tube Plaza”

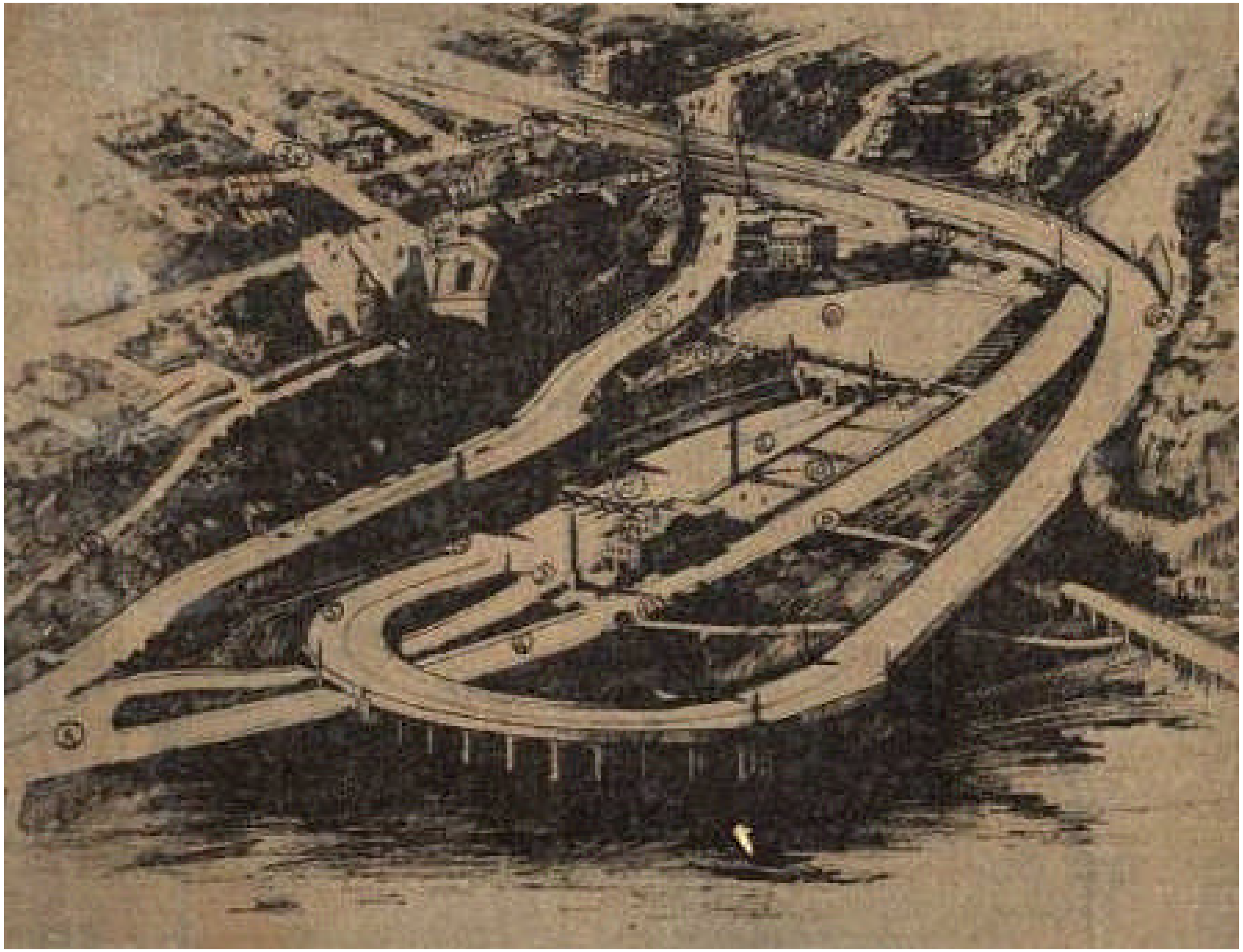


<u>Above</u>: caption: "Just as time marches on, so does construction work on the Weehawken Midtown Tunnel. Here is a view taken of the latest advancements made on the approaches. No. 1 shows the mouth of the tube crossing from the western to the eastern side of the Hudson River. No. 2 is Park av., widened. No. 3 is the first completed section of the overpass crossing Boulevard East. The pass will be built farther south and will circle back north alongside King's Bluff and west into Union City. The stretch of dirt road in the foreground is Hackensack av., better known as the 'High Road,' which will also be rebuilt. No. 4 is the administration building now in process of construction. This will house the business department of the Port of New York Authority who will concentrate on tunnel work. No. 5 is where the overpass will circle around and back into Union City. Workmen are busy constructing concrete pylons and blasting away the rock hills just north of the town hall." (*Hudson Dispatch*, August 19th 1937)



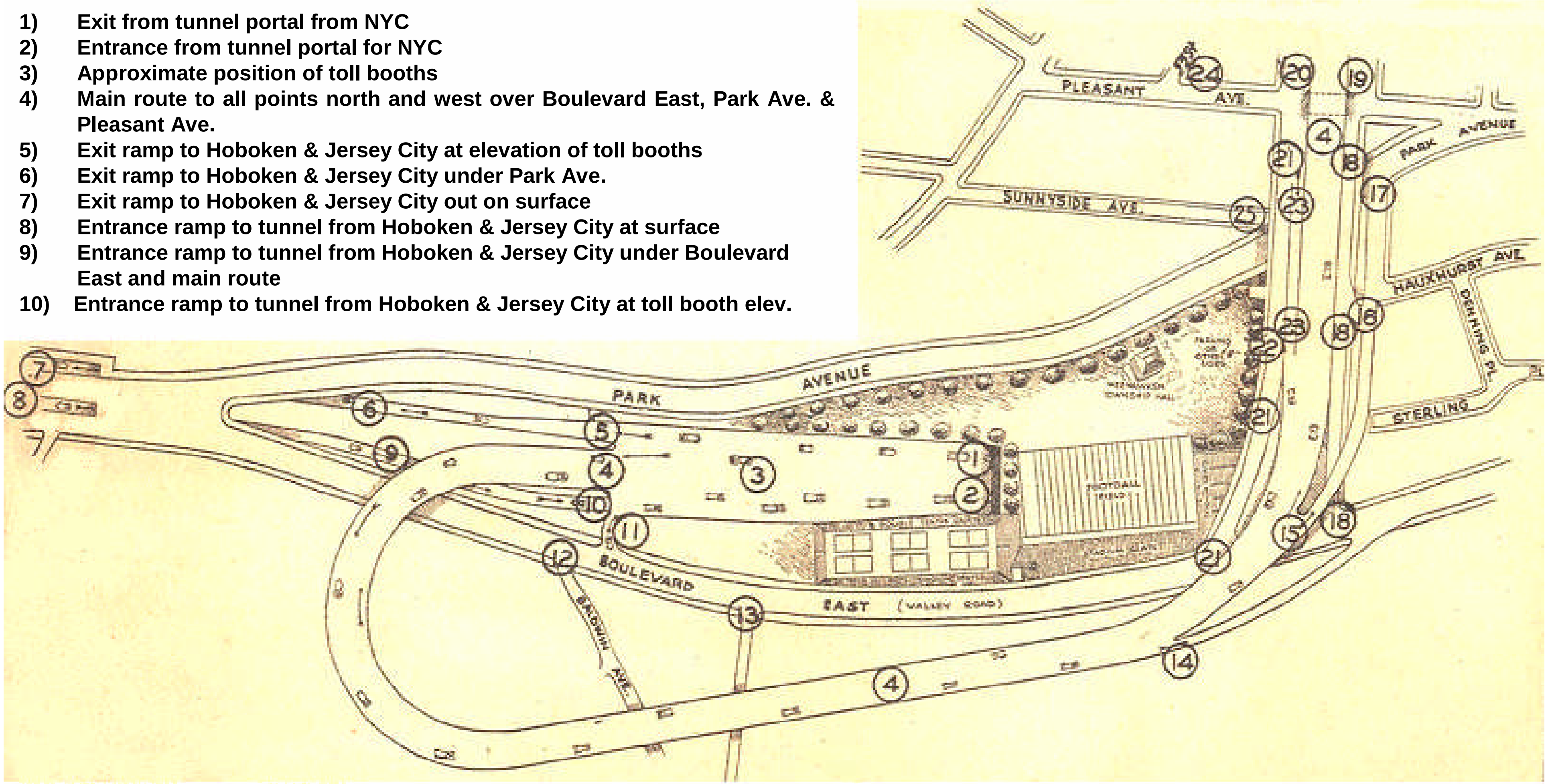
<u>Above</u>: caption: "Officer controlling traffic in the Traffic Control Building at the New Jersey Plaza"
<u>Left</u>: caption: "Traffic signal control and indication board – Supervisory control room"

<u>Above</u>: caption: "Ultimate Arrangement of New Jersey Approach. Weehawken toll plaza with its connections to Hudson County Boulevard East and Park Avenue, the viaduct loop structure, and the open-cut express highway through Union City. The latter will provide connection with Hudson County Boulevard and state highway routes in North Bergen. The toll plaza is practically complete, while the viaduct structure and depressed highway are now under construction." (as of December 1937)



<u>Above</u>: caption: "Picture shows two tunnels. Only one, however, will be opened for traffic in 1938. Should conditions warrant, the second tube will be constructed. (1) Entrance and exit to the tunnel; (2) Port Authority Administration Building; (3) road from Hoboken; (4) road to Hoboken; (5) main 'loop' route to Union City; (6) new Boulevard East; (6a) ramp to Boulevard East, going north; (7) Park Avenue with Municipal Building above; (8) main ball field and stadium; (9) children's playgrounds; (10) tennis and handball courts; (11) parking space; (12) Sunnyside Avenue; (13) Pleasant Avenue; (14) Hackensack plankroad. (A) The present intersection of Park and Willow Avenues; (B) the new Highroad, or Paterson plankroad extension; (C) Baldwin Avenue; (D) Electric Ferries; (E) fare booths."

1) Exit from tunnel portal from NYC
2) Entrance from tunnel portal for NYC
3) Approximate position of toll booths
4) Main route to all points north and west over Boulevard East, Park Ave. & Pleasant Ave.
5) Exit ramp to Hoboken & Jersey City at elevation of toll booths
6) Exit ramp to Hoboken & Jersey City under Park Ave.
7) Exit ramp to Hoboken & Jersey City out on surface
8) Entrance ramp to tunnel from Hoboken & Jersey City at surface
9) Entrance ramp to tunnel from Hoboken & Jersey City under Boulevard East and main route
10) Entrance ramp to tunnel from Hoboken & Jersey City at toll booth elev.

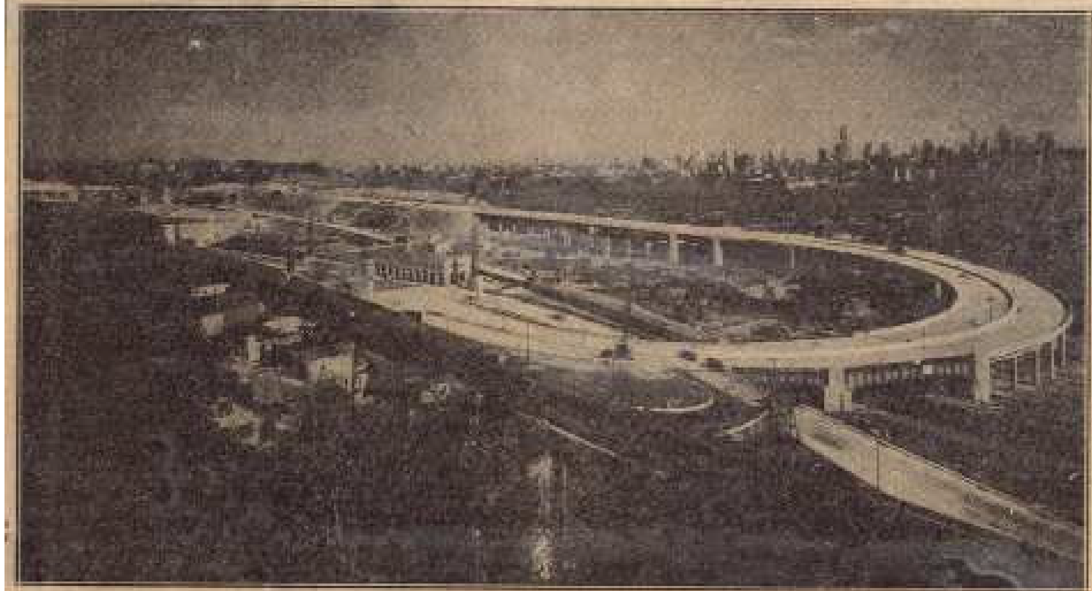


11) Entrance ramp to tunnel from Boulevard East (Valley Rd. section)
12) Relocation of connection between Boulevard East & Baldwin Ave.
13) Relocation of connection to Electric Ferry
14) Exit ramp from main route to Boulevard East (Valley Rd. section), for Weehawken Heights & points north
15) Exit ramp from main route to Hauxhurst Ave., Park Ave. & local points in Weehawken & Union City
16) Exit ramp at Hauxhurst Ave., showing connection with Marginal St.
17) Exit ramp at Park Ave. present grade
18) Marginal St. connecting East & West Boulevards
19) Connection of Marginal St. with main route for west bound traffic
20) Connection of main route traffic to Marginal St. which connects West & East Boulevards
21) Marginal St. connecting Boulevard West with Boulevard East
22) Marginal St. connection with Weehawken municipal center
23) Entrance ramp to main route for tunnel-bound traffic
24) Entrance to main route for tunnel bound traffic from Park Ave., which becomes Pleasant Ave. traffic when all right hand turns are necessary. Park Ave. traffic may also enter tunnel at point 8
25) Sunnyside Ave. to become entrance to Marginal highway

SATURDAY, OCTOBER 8, 1938

Weehawken Loop of Lincoln Tunnel Open to Traffic Next Saturday Noon

Panoramic View of Lincoln Tunnel Entrance and Loop



Approach Roadway Link as Far as Pleasant Av., Union City, Ready Considerably Ahead of Schedule — Depressed Highway to Be Opened Next Summer

DOES AWAY WITH TRIP TO 19TH ST.

The loop roadway approach to the Lincoln Tunnel in Weehawken will be opened to traffic next Saturday at noon, the Port of New York Authority announces. No formal ceremonies have been planned.

This construction, a notable departure from methods hitherto adopted for the handling of vehicular traffic, is a major phase in the construction of adequate approaches to the Lincoln Tunnel in New Jersey.

A curving concrete and steel structure dedicated solely to tunnel purposes will carry vehicles between the tunnel portal in Weehawken and Pleasant av., Union City. Its completion at this time is considerably ahead of schedule, and will be followed next summer by the opening of the depressed express highway through the Palisades connecting with State Highways 1 and 3. The depressed roadway will be a continuation of the loop roadway.

The latter is an outstandi
ample of construction where
increasing of distance lesse
grade of a roadway, as th
latter can be negotiated in
high gear. It is understood
the only construction of this
acter east of the Rockies.

Opened to Pleasant Av.

Starting at the southerly
the Weehawken Plaza, the
swings left as a viaduct over
vard East and runs along
"shelf" cut into the westerly
of King's Bluff. It then re-
Boulevard East and passes
of the Weehawken Townshi
It ends at Pleasant av., t
dividing line between Weeh
and Union City, at which p
finally has reached the plat
the Palisades.

The rather short section b
Park av., Weehawken, and
ant av., will not be opened
time. Ramp connections w
loop at Park av., will be us
clusively for the present.
ramps connect with m
streets flanking the main ap
to the tunnel.

The loop is about 4,000 fe
There are three traffic la
each direction. A wall wi
rate eastbound and we
traffic and act as a curtain
posing automobile lights. F
convenience of traffic d
along the north bank of th
son River, the loop will
Boulevard East by merging
bound lanes.

The temporary connecti
in use between the tunne
and Park av. will be disco
and similar service will b
formed north of the tunnel.
All other permanent conn
with existing highways w
maintained.

Ends Trip to 19th St.

"The opening of the l
'helix,' as our chief engine
fers to call it, will remove
appeared to be a rather
travel for westbound tra
19th st., in South Weehawke
Frank C. Ferguson, chair
the Port of New York Au
"Now, the outbound traffic
accom[illegible]dated on a three-la
speed roadway with a four
compensated grade. Tunn

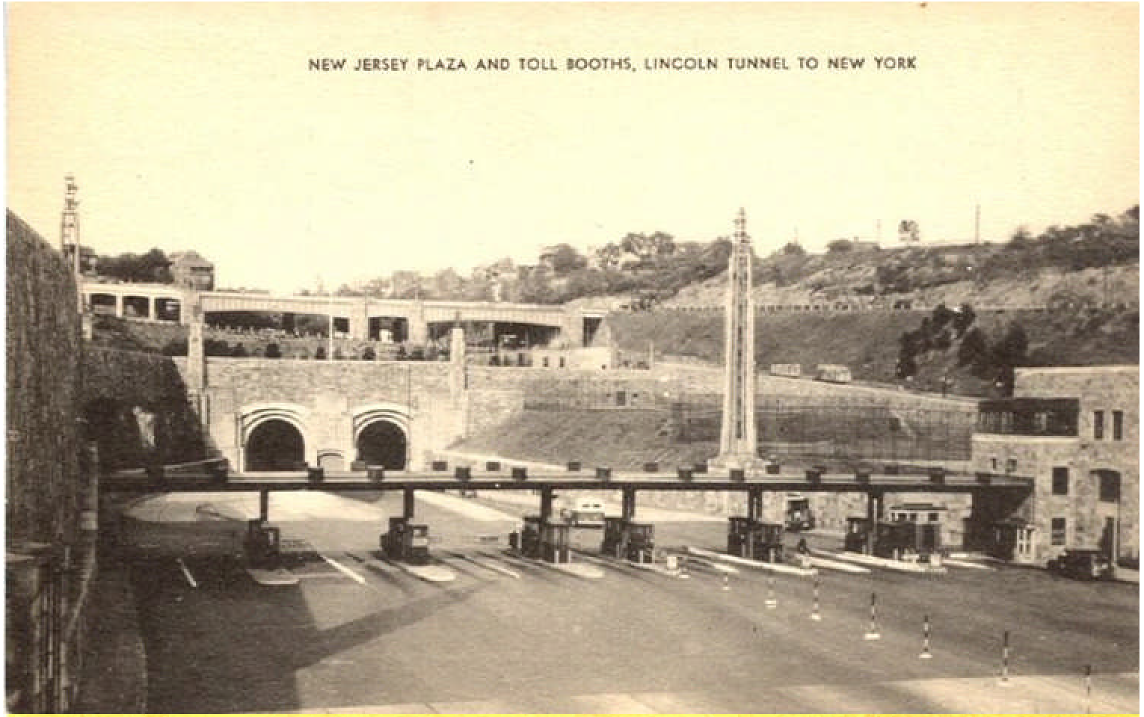
(Turn to Page 8, Column

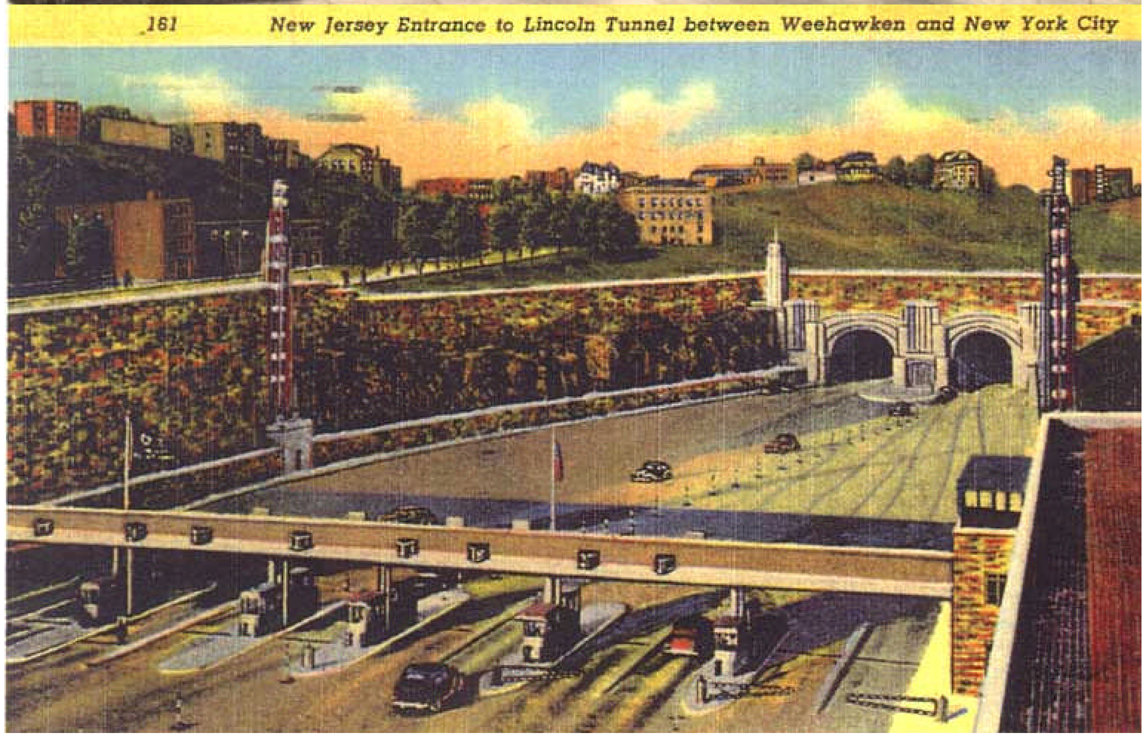
“Three years of digging, blasting, shoveling, sketching and leveling having ended the loop of the Lincoln Tunnel in Weehawken will open for traffic at noon today…gradually science performed one of its finest face-lifting jobs and today there stands in Weehawken one of the most praiseworthy masterpieces of architecture in the United States. Graceful roadways mounted on concrete pylons sweep in from Union City to curve over Boulevard East and then sweep down to the tunnel plaza. Starting at the southerly end of the plaza, the loop turns left as a viaduct over Boulevard East and runs along a rock hewn space in King’s woods. The road re-crosses Boulevard East to pass in the rear of the municipal building and out into Union City. However, there is a marginal highway on either side of the two main highways, one leading to Park av. in Weehawken and the other to Boulevard East…”

***Hudson Dispatch,* Saturday, October 15th 1938**

"…When the helix opened in 1938, a year after the opening of the Lincoln Tunnel, it was hailed as an engineering marvel. The Hudson Dis-patch called it 'one of the most praiseworthy master-pieces of architecture in the United States.' Drivers no longer had to join local traffic in down-town Weehawken on their way to and from the Lincoln Tun-nel. The massive helix pro-vided three traffic lanes in each direction, connecting to Weehawken's Pleasant Ave-nue. In 1939, a depressed express highway (now Route 495) opened, connecting the helix through Union City to Interstate Routes 1 and 3…"

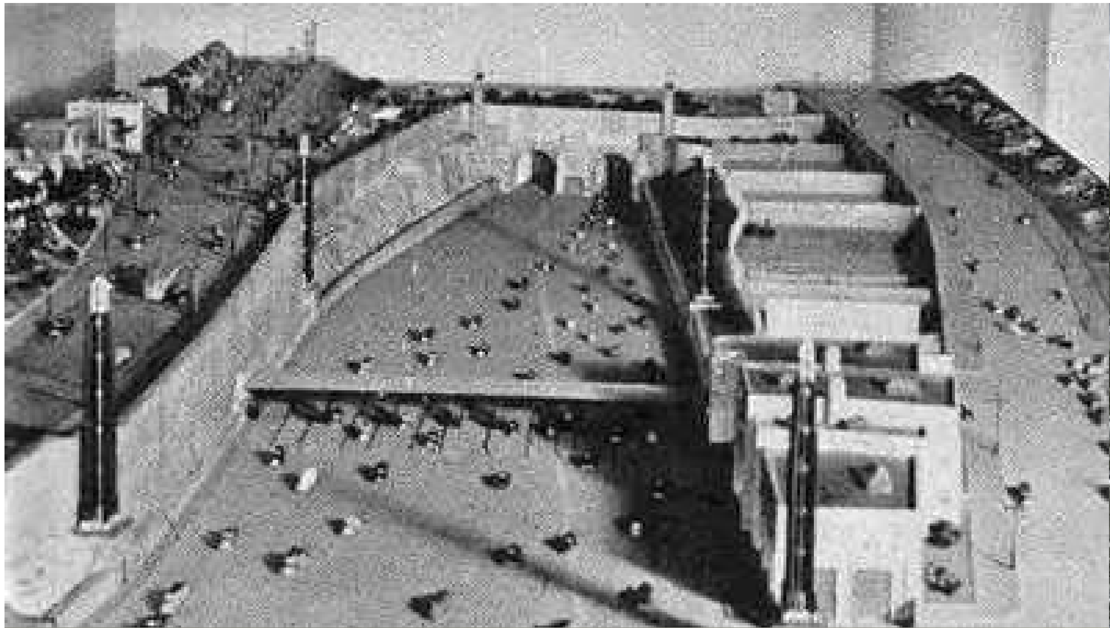
***Metrofocus,* July 2012**

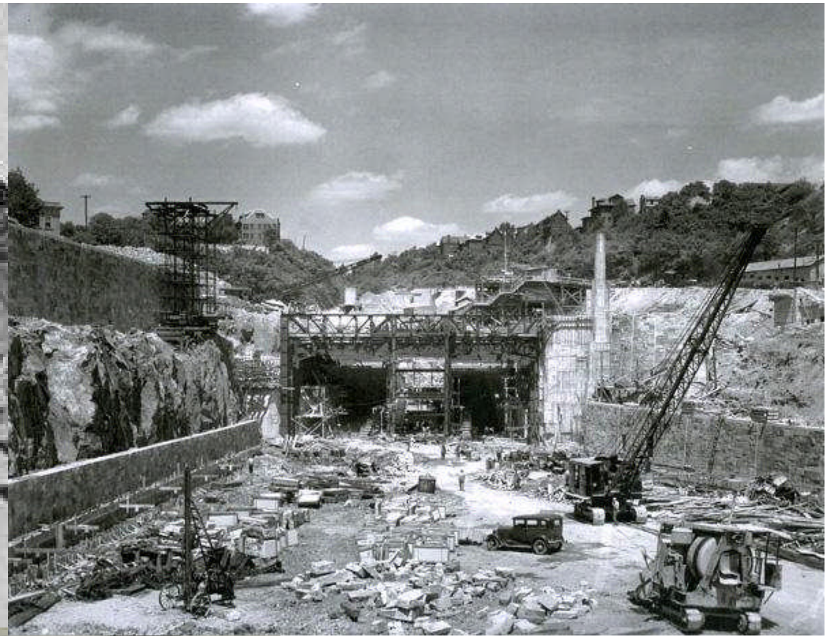


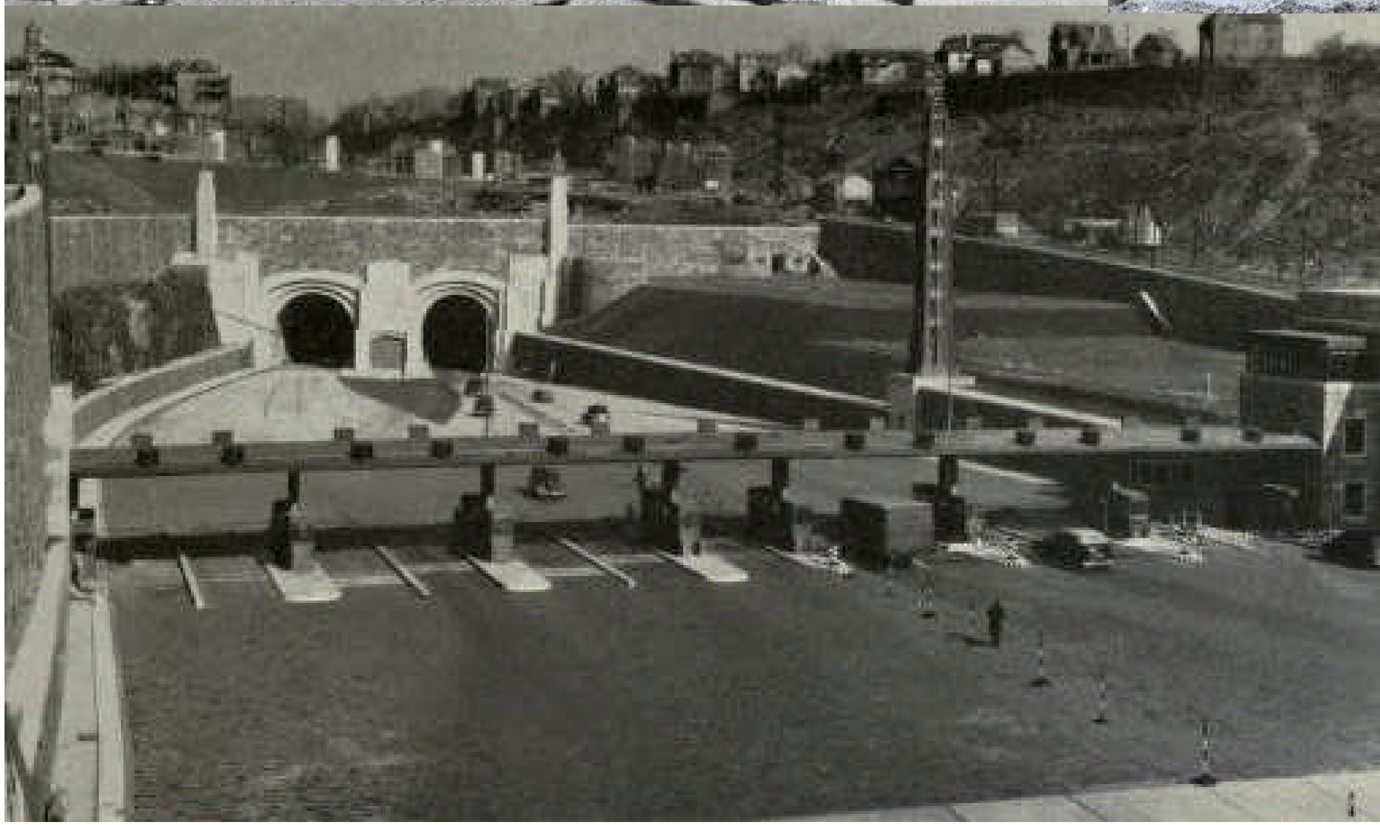


"…When the Port of New York Authority told the township of Weehawken that the loop would not be an eyesore to the community, such as was left in Jersey City in the form of the Holland Tunnel approaches, it meant just what it had promised. The Connecticut granite walls, blended in brown, red and gray, look like autumn foliage in color. The concrete work leaves nothing to be desired as there is not an unfinished piece in the entire construction. Unlike other concrete finishes, the loop presents a novel feature in that the supports of the girders look to be of white marble instead of concrete…"

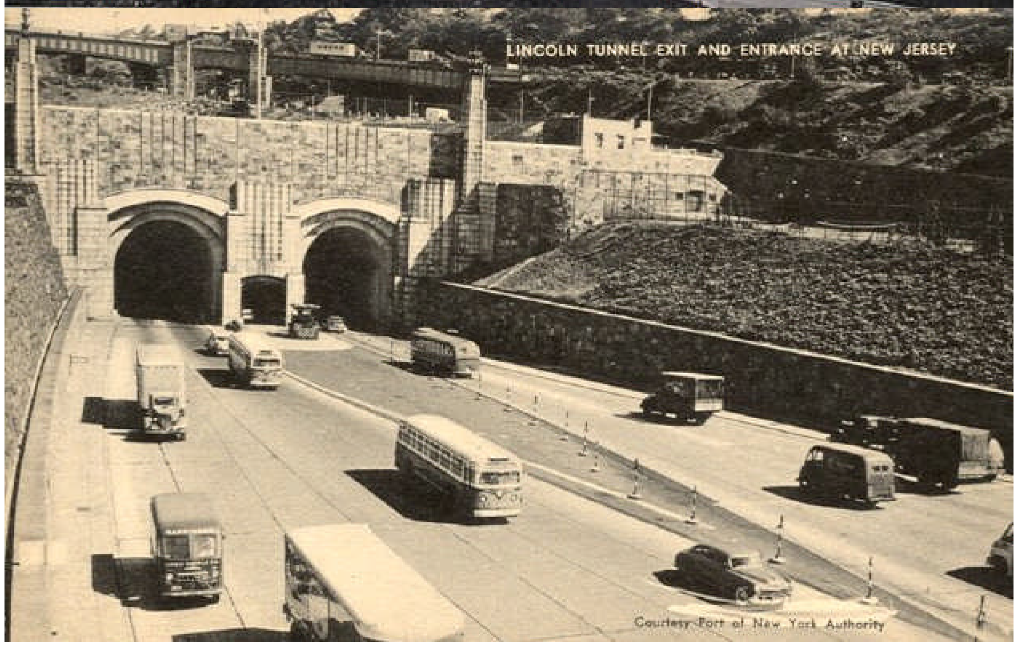
***Hudson Dispatch,* Saturday, October 15th 1938**







<u>Top Left</u>: caption: “Model of New Jersey Toll Plaza”
<u>Top Right</u>: caption: “New Jersey entr-ance of the Lincoln Tunnel 1937”
<u>Left</u>: caption: “New Jersey Toll Plaza”



"Every year, 40 million vehicles use the Lincoln Tunnel to travel between New Jersey and New York City, where the tunnel empties onto West 39th Street. To get into the city, the vast majority of drivers use a single entry point called the helix. This 4,000-ft, sloping roadway loop connects traffic from Route 495 to the tunnel entrance. When congestion clogs the city-bound lanes, one can at least enjoy an expansive view to the east of the Hudson River and Manhattan skyline…"

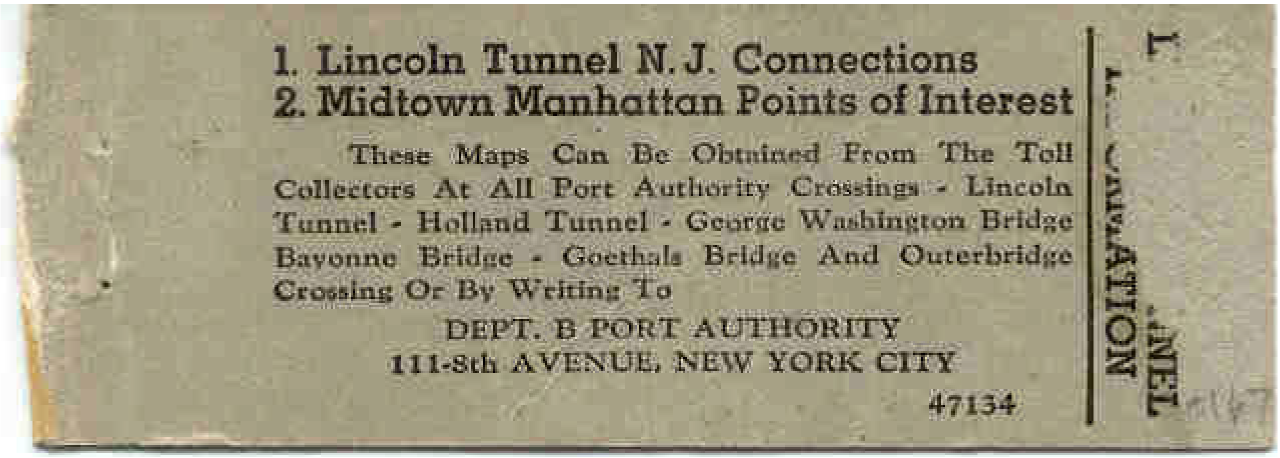
***Metrofocus,* July 2012**

"We used to bet a dime on whether we'd pass one, two or three vehicles while driving through the tunnel!"

Austin Tobin, **PNYA Executive Director**

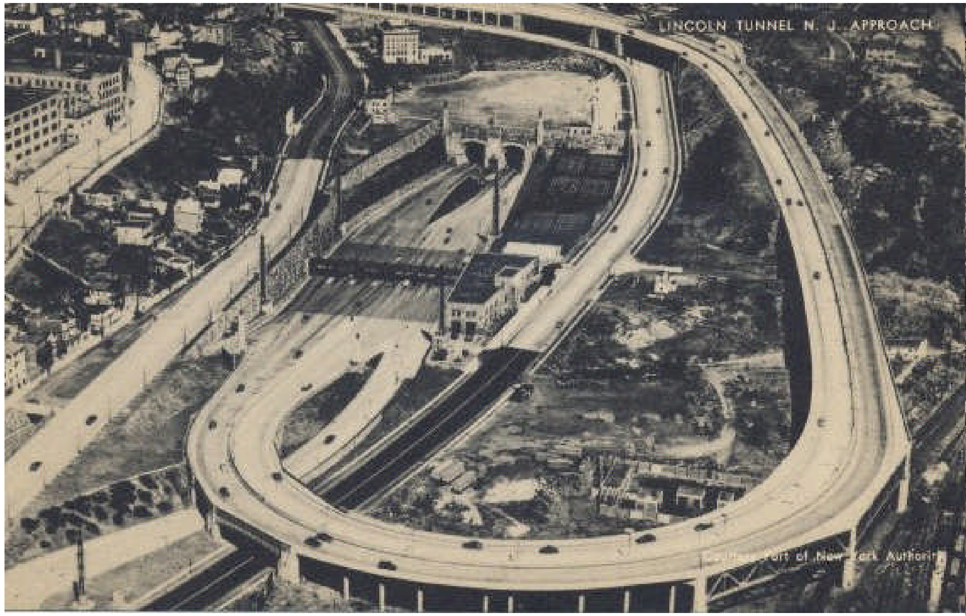
Left: matchbooks promoting use of the PNYA's *Lincoln Tunnel* to the public. The first tube (present-day center tube) of the Lincoln Tunnel was opened on December 22nd 1937. With only one lane of traffic in each direction in its first year of operation, a less-than-spectacular 1.8 million vehicles used the new tunnel. A second tube was opened north of the original tube in 1945, after years of WWII-related delays. This allowed for two lanes of eastbound and westbound traffic.


WHEN TIME IS SHORT
AND
TRAFFIC HEAVY
TRY THE
LINCOLN TUNNEL
34-42 STREETS, MANHATTAN. WEEHAWKEN, N.J.
SEE INSIDE COVER


1. Lincoln Tunnel N.J. Connections
2. Midtown Manhattan Points of Interest
These Maps Can Be Obtained From The Toll Collectors At All Port Authority Crossings - Lincoln Tunnel - Holland Tunnel - George Washington Bridge Bayonne Bridge - Goethals Bridge And Outerbridge Crossing Or By Writing To
DEPT. B PORT AUTHORITY
111-8th AVENUE, NEW YORK CITY
47134

<u>Top</u>: caption: “In this promotion for the 1939 World’s Fair in Queens, the helix can be seen as ‘under construction,’ leading out to present-day Route 495”

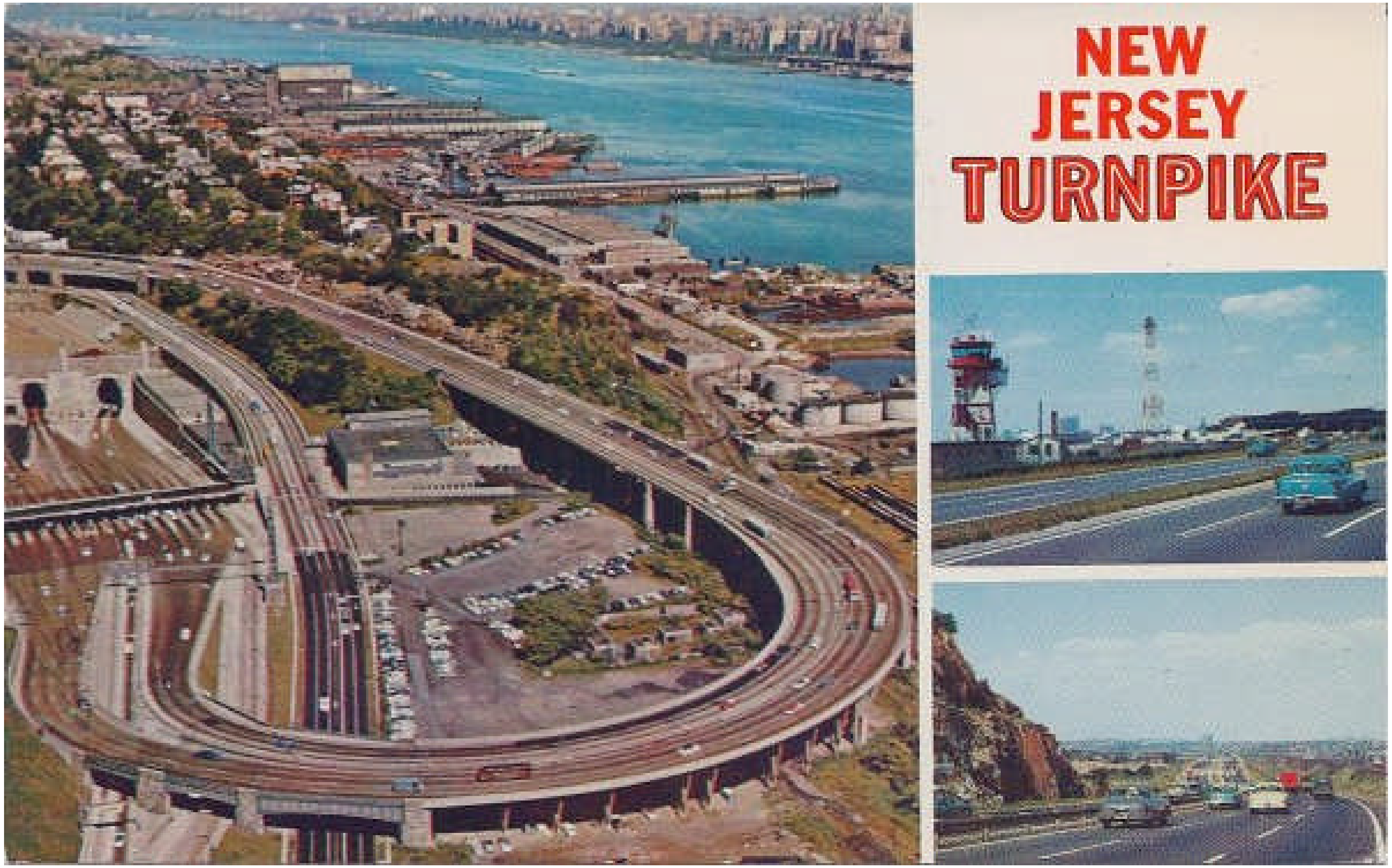
<u>Bottom</u>: caption: “Information Booths - Attendant helping men and woman at booth shaped like Perisphere outside of Lincoln Tunnel”



In 1952, the PA and the *New Jersey Turnpike Authority* (NJTA) extended the Lincoln Tunnel western approach for 0.9 mile west to *EXIT 16* of the recently opened *New Jersey Turnpike* in *Secaucus*. The extension provided for grade-separated interchanges for *US 1/9* and *NJ 3*, as well as for a toll plaza. The *Lincoln Tunnel Approach* became part of the Interstate highway system in 1956. In 1971, the *Mid-Manhattan Expressway* that was to connect the two *I-495* sections in *New Jersey* and *New York* (the Lincoln Tunnel Approach and the *Long Island Expressway*) was canceled. It was not until 1989 that the Lincoln Tunnel Approach was re-designated *NJ 495*.

<u>Left</u>: caption: “Helix in the 1940s”

<u>Right</u>: caption: “Helix in the 1960s”


NEW
JERSEY
TURNPIKE

<u>Top Left</u>: caption: "New Jersey Approach and Entrance to the Lincoln Tunnel looking North (October 1991)"
<u>Top Right</u>: caption: "Lincoln Tunnel Entrance showing Approaches from the South, view looking South (October 1991)"
<u>Left</u>: caption: "New Jersey Toll Plaza Entrance to the Lincoln Tunnel looking Northeast (Oct. 1991)"

New York

<u>Above</u>: caption: “Initial Arrangement of New York Approach. Plaza and approaches for the First Operating Unit of Lincoln Tunnel, as now completed. The new approach (named Dyer Avenue in memory of a former Chairman of the Port of New York Authority, Gen. George R. Dyer) extends from West 34th Street to West 42nd Street, midway between Ninth Avenue and Tenth Avenue. It has been constructed for use of tunnel exclusively.” (as of December 1937)

Above: caption: "Ultimate Arrangement of New York Approach. How the plazas and approaches for both tubes of Lincoln Tunnel, as well as plazas of the proposed Crosstown City Tunnel, will appear when completed. The new approaches (named Dyer Avenue and Galvin Avenue in memory of former Chairmen of the Port of New York Authority) extend from West 34th Street to West 42nd Street, midway between existing avenues. They are planned for use of tunnel traffic exclusively." (as of December 1937)

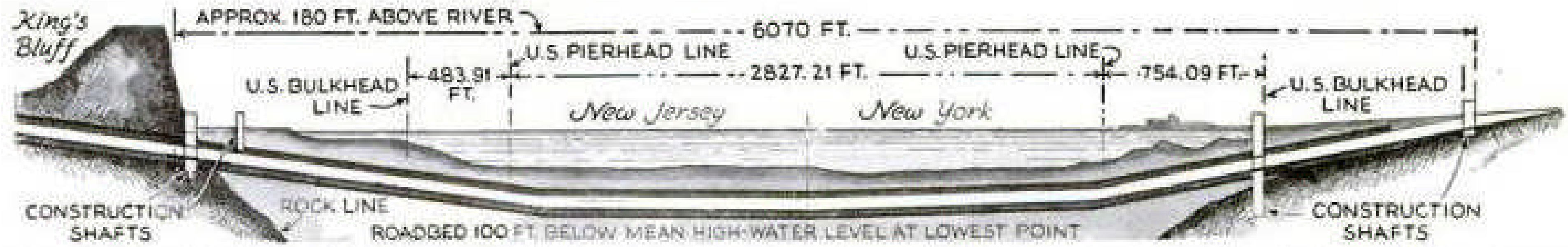
<u>Top</u>: caption: "Opening ceremonies Lincoln Tunnel, New York entrance, December 21, 1937"

<u>Bottom</u>: caption: "Photo shows the Art Deco-style Manhattan portal of the Lincoln Tunnel and the east ventilation tower"

Similar, But Different

"…The tunnel will closely resemble the Holland Tunnel, excepting for a slight increase in size, to correspond with trends in vehicle design. The roadway will be 21½ feet wide, or a foot and one half wider than that of the Holland Tunnel. Three ventilation buildings, designed so that they can be enlarged for the second tube if necessary, will be constructed. One will be on the New Jersey side at the foot of the Palisades and the two on the New York side will be at the corner of 39th Street and 11th Avenue and at the bulkhead line. The tunnel will be some 8,000 feet long, of which 4,600 feet will be under the river…"

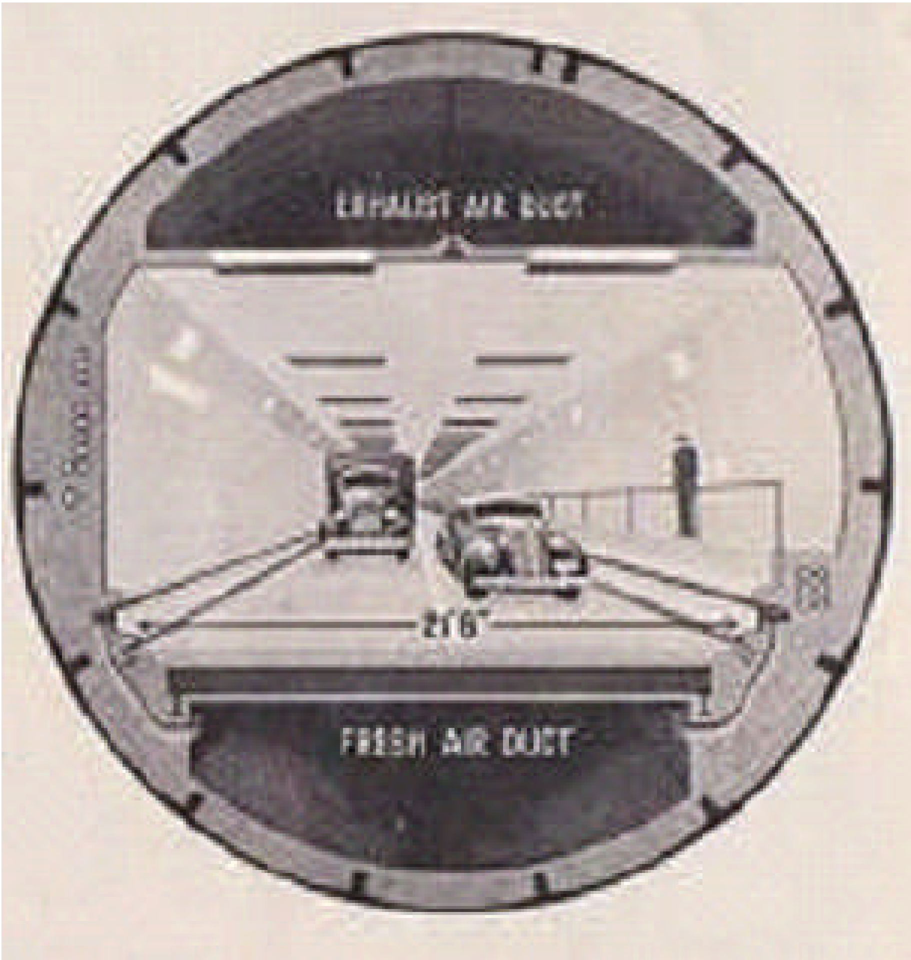
RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* ground breaking ceremony booklet (May 17th 1934)



"…Facts and figures revealed by Wharton Green, resident project engineer, show the magnitude of the undertaking. The new tunnel, passing from New York beneath the Hudson River and piercing the solid rock of the Palisades on the New Jersey shore, will measure about 8,000 feet between portals. Its thirty-one-foot diameter will permit a roadway a foot and a half wider than that of the Holland Tunnel. More than 170,000 cubic yards of rock, earth, and silt have been displaced, and 2,300 rings erected, to construct this huge shaft since ground was broken in May, 1934…"

***Popular Science,* March 1936**

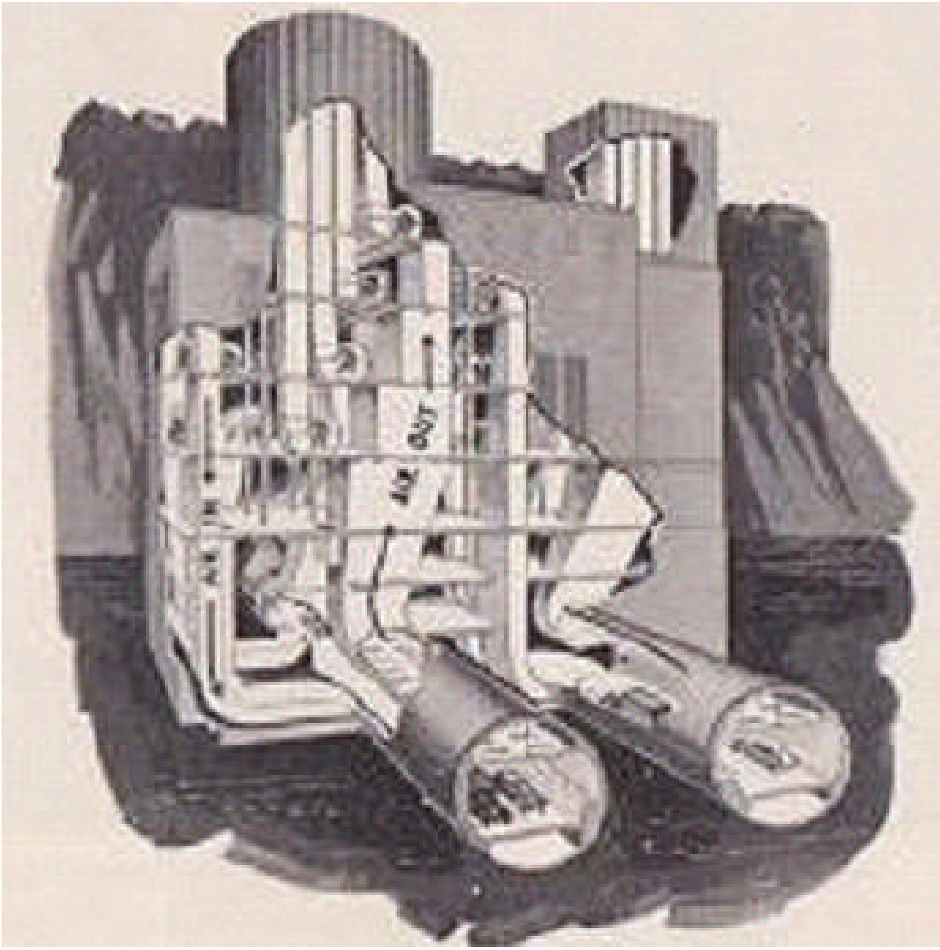
<u>Above</u>: caption: "Cut-away view of the bed of the Hudson River, with the new tunnel plunging under it to link the midtown section of New York City with New Jersey"



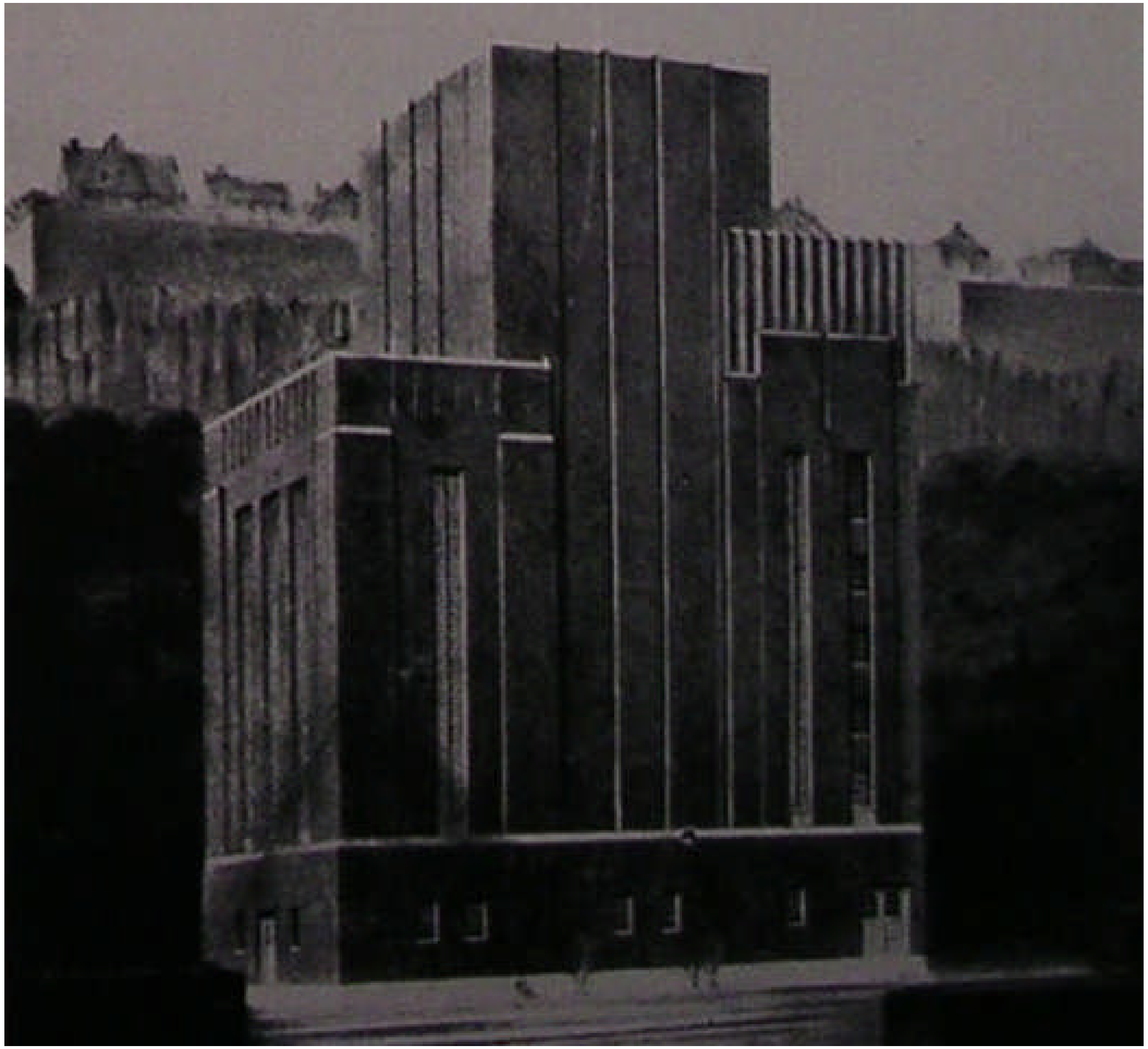
"…When both units of the Lincoln Tunnel shall be ready for use they will accommodate 13,000,000 motor vehicles, the estimated annual capacity. To insure an adequate fresh air supply, three ventilation buildings have been provided…"

Port of New York Authority

Left: caption: "Completed tube looks like this in cross section. Fresh air is pumped into duct at bottom, passes into tunnel through slits in curb. Vitiated air is drawn through ceiling and sucked out by top duct. Conduits on either side are for water, telephone, electricity. Trucks of over five tons and other vehicles unable to maintain a 20 m.p.h. speed are banned from the tunnel."



<u>Left</u>: caption: “Ventilation building provides the tunnel with complete protection from poisonous fumes which are continuously emitted by automobiles. Giant fans located on different floors blow fresh air into the tube continuously. Exhaust fans create a semi-vacuum to draw out bad air. Since harmful gases are lighter than air, they naturally rise in the tunnel and in the vertical shafts where they are blown out at the top of the building. Control room for power, lighting and traffic signals in on top floor.”



<u>Left</u>: in 1921, *Charles Watson Murdock*, who was then employed as an engineer by the *New York State Bridge and Tunnel Commission* and the *New Jersey Interstate Bridge and Tunnel Commission*, was assigned by *Clifford Holland* to work on the design and testing of the tunnel's ventilation system. Murdock conducted and supervised ventilation tests at the *University of Illinois* and at *Bruceton, PA*. and was later chosen to oversee the installation of the ventilation system on the *Lincoln Tunnel*. Fifty-six fans performed the air-handling duties and twenty men (in three shifts) monitored the carbon monoxide levels in the tunnel. In 1939, the year after the Lincoln Tunnel first opened, Murdock's presentation: "Ventilating the Lincoln Vehicular Tunnel" was made before the *American Society of Heating and Ventilating Engineers*, setting the standard for similar tunnels around the world.

<u>Top Left</u>: caption: "Excavation at Site of New Jersey Ventilation Shaft looking Northeast"

<u>Top Right</u>: caption: "Excavation for New York Land Ventilation Building, Looking East"

<u>Left</u>: caption: "Removing Temporary Segments and Grout to Permit Air Duct Construction at New Jersey Ventilation Shaft, Looking North-east"

<u>Left</u>: caption: "Forms and Reinforcing for Air Ducts and Ventilation Shaft, Weehawken, New Jersey"

Above: caption: “View of Manhattan Ventilation Building from New Jersey”

Left: caption: “Manhattan Ventilation Building: 11th Avenue – W. 39th Street (1937)”

ENGINEERING

O. H. AMMANN, Director of Engineering

J. C. EVANS, Chief Engineer

EDW. W. STEARNS, Assistant Chief Engineer

RALPH SMILLIE
Engineer of Design (Tunnel Crossings)

ALLSTON DANA
Engineer of Design (Bridge Crossings)

CHAS. E. OLEIM
Engineer of Construction

W. E. THOMPSON
Tunnel Engineer

GEORGE L. LUCAS
Engineer of Inspection

R. F. SCHAEFER
Assistant Engineer of Design

CHAS. W. MURDOCK
Mechanical Engineer

J. N. DODD
Electrical Engineer

CHARLES L. CRANDALL
Resident Engineer

THOMAS DARROW
Resident Engineer

A. B. LINCOLN
Resident Engineer

E. WARREN BOWDEN
Assistant to Chief Engineer

L. L. BERWIND
Assistant to Chief Engineer

CONSULTING ENGINEERS

JAMES FORGIE
Consulting Engineer

OLE SINGSTAD
Consulting Engineer on Tunnels

ROBERT RIDGWAY
Consulting Engineer

MORGAN F. LARSON
Advisory Engineer on Terminals and Highways

PROF. GEORGE H. BROWN
Ceramic Engineer

LEWIS B. STILLWELL
Consulting Electrical Engineer

ARCHITECT

AYMAR EMBURY II

CONSULTING GEOLOGIST

PROF. CHAS. P. BERKEY

A Major Advance

“‘Holed Through’ months ahead of schedule and seventy-five percent completed at this writing, the new Midtown Hudson Tunnel linking New York City and New Jersey reflects the striking progress that has been made in engineering methods in the last few years. Mechanical innovations employed to speed the construction of New York’s latest vehicular tube are declared to mark a major advance in the art of tunneling…”

***Popular Science*, March 1936**

"…A new invention, a mighty hydraulic wrench, helped sandhogs toiling far below the bed of the Hudson River to shatter long standing records in erecting the twenty-two-ton iron rings that form the backbone of the tunnel. Each of these rings is composed of fourteen curved segments, bolted together, and the assembled ring is bolted to the last preceding one as the tunnel progresses. Formerly, two husky workers strained at the end of a five-foot wrench to pull each of the nuts tight. The new hydraulic wrench eliminated the manual labor…"

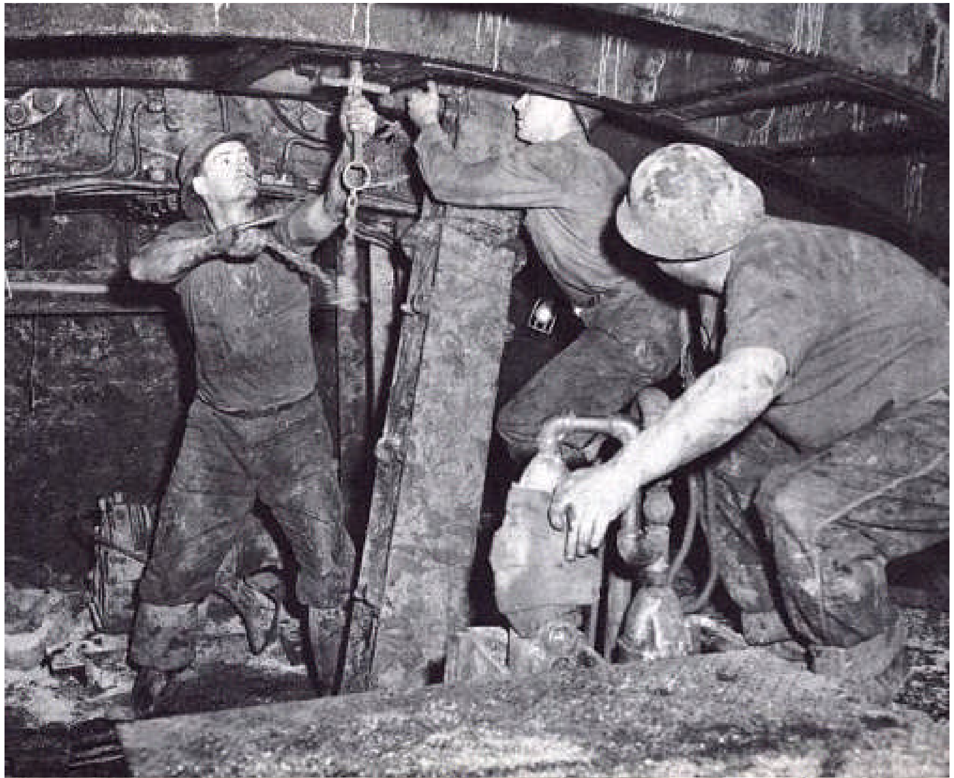
Popular Science, **March 1936**

"…Resembling the minute hand of a monster clock, it rode around a circular track within the tunnel, while its metal hand grasped each nut and speedily whirled it home to just the proper tension. With this potent aid, sandhogs were able to erect as much as forty-five feet of tunnel wall – eighteen rings – in a single day, as compared with a maximum of twenty-four feet when the work was done by hand…"

Popular Science, **March 1936**

Top: caption: "Hydraulically-operated bolt tightener in use"

Bottom: caption: "Sandhogs tighten a bolt in a tunnel-lining ring with ratchet wrench (Queens Midtown Tunnel)"



"…Thanks to this device and to a host of other, if less spectacular, refinements in mechanical technique – including an improved type of erector arm to lift the heavy segments into place, and high-speed muck conveyors that disposed of the river-bed ooze through which the tunnel was pushed – its construction is expected to set a speed record for undertakings of its type. Its scheduled opening date of January 1, 1938, may be materially advanced…"

***Popular Science,* March 1936**

<u>Top</u>: caption: "Sandhogs place locking ring segment in place to complete a ring prior to making another push of the shield. Note the erector arm in the center of the photo."

<u>Bottom</u>: caption: "Removing muck from tunnel with shovel operated by compressed-air"

Glass Ceiling

"…Motorists will then have a first-hand opportunity to inspect a real novelty in tunnel design – a roof of glass. Eight thousand panes of cream-colored glass will line the top of the tube and form the largest glass ceiling in the world. The novel lining is expected to save large sums that otherwise would have to be expended periodically for cleaning and repainting a bare concrete ceiling, like that of the Holland Tunnel which connects the two states a little farther down the river…"

Popular Science, **March 1936**

"…Although the walls of this earlier tunnel were tiled, its ceiling was merely of painted concrete, since it was feared that the constant jarring of traffic would shake tiles loose and cause them to fall out. The problem has now been solved by the invention of ingenious metal grippers, that hold a tile or a pane of glass with equal facility, securing it firmly to the concrete base. In the Midtown tube, these frames will hold glass panes because these have been found cheaper than ceramic tile. The glass will have a stippled surface, designed to minimize glare and to improve the efficiency of the tunnel lighting system…"

***Popular Science,* March 1936**

<u>Left</u>: caption: "The Lincoln Midtown Tunnel as it neared completion"

<u>Right</u>: caption: "This is the interior of the new Lincoln Tunnel which will be opened to traffic December 21 connections New Jersey and Manhattan. This picture was taken as one of the first cars to test the runway passed through."


DON'T
SOUND
HORN

Dedication

"…Even as these ceremonies of dedication are taking place, the companion north tube is burrowing its way through the bed of the river, and drilling rigs and steam shovels are cutting a highway approach across the Palisades. Excellent progress is being made so that the entire New Jersey approach may be completed and opened to traffic by the summer of 1939. The north tube with its New York approach will complete the project and is expected to be opened in 1940…"

RE: excerpt from the Port of New York Authority's *Midtown Hudson Tunnel* dedication ceremony booklet (December 21st 1937)

PRINCIPAL DATA

Length of first (south) tube, portal to portal	8215 feet
Length of second (north) tube, portal to portal	7400 feet
Length of each tube under river,	about 4600 feet
External diameter of cast iron and cast steel shell	31 feet
Maximum depth, surface of river to top of tunnel	75 feet
Maximum depth of roadway below surface of river	97 feet
Minimum covering of mud and silt above tops of tubes	20 feet
Distance between tubes under river, center to center	75 feet
Width of roadway	21½ feet
Cast iron and cast steel in shell, both tubes	101,000 tons
Concrete in tunnel between portals, both tubes	114,000 cu. yds.
Glass ceiling tile, both tubes	1,390,000 tile
Glazed wall tile, both tubes	2,590,000 tile
Ventilation buildings	3
Fresh air fans for both tubes	26
Exhaust fans for both tubes	30
Maximum amount of fresh air to be supplied to both tubes,	3,460,000 cu. ft. per minute

THE PORT OF NEW YORK AUTHORITY

DEDICATION OF LINCOLN TUNNEL

Tuesday, December 21, 1937

Admit One

Not Transferable

NEW YORK PLAZA	NEW JERSEY PLAZA	LUNCHEON
11:00 A. M.	12:00 NOON	1:00 P. M.
ENTRANCE	ENTRANCE	HOTEL ASTOR
40TH STREET, BETWEEN NINTH AND TENTH AVENUES	HUDSON COUNTY BOULEVARD EAST WEEHAWKEN, N. J.	BROADWAY AT 44TH STREET MANHATTAN

NO AUTOMOBILES ALLOWED THROUGH TUNNEL. PORT AUTHORITY TRANSPORTATION PROVIDED BETWEEN NEW YORK AND NEW JERSEY CEREMONIES AND TO THE LUNCHEON.

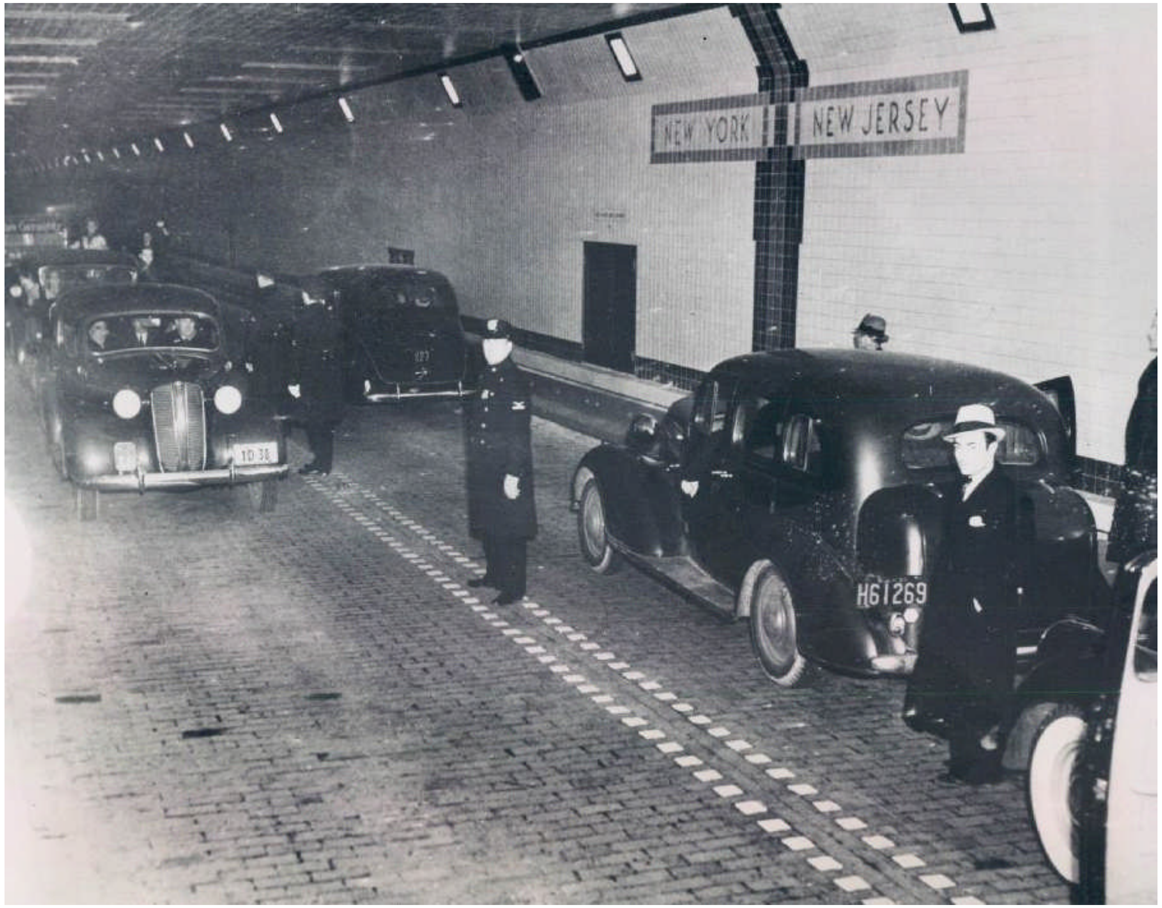
Lincoln Tunnel Dedication Medal

PRESENT THIS PORTION OF THE TICKET AT LUNCHEON TO RECEIVE THE DEDICATION MEDAL.

<u>Above</u>: caption: "Gold colored medal with a profile of Abraham Lincoln and the wording 'For a further unification of the people' on the front side. The reverse shows the entrance to the original two tubes of the tunnel and has the wording 'Lincoln Tunnel Dedicated 1937. Built and owned by the Port of New York Authority.'"

Above: caption: "Former President Herbert Hoover, Mayor F.H. LaGuardia, representatives of the states of New York and New Jersey, officials of the Port of New York Authority and other dignitaries take part in ceremonies on the brick paved south tube that was opened to traffic December 22, 1937"

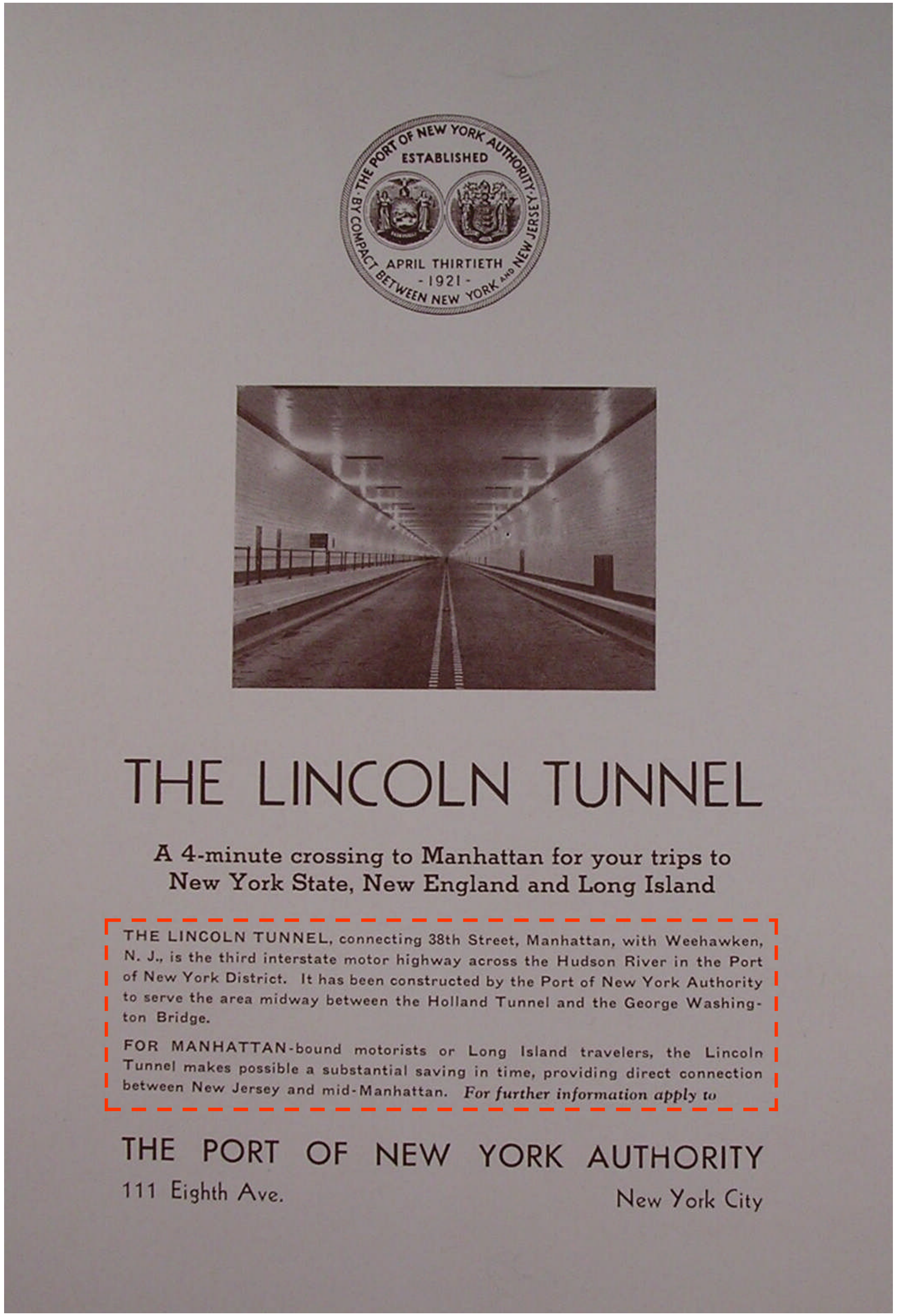
Left: commemoratives of the dedication of the *Lincoln Tunnel*


NEW YORK
NEW JERSEY
H61269

<u>Top</u>: caption: "Gigantic Tunnel is Opened, New York City - Manhattan Island is lined again with the mainland, this time by the magnificent $85,000,000 Lincoln Tunnel crossing under the Hudson to Jersey from mid-town New York. Brilliant ceremonies mark the opening of one tube of the tremendous project."

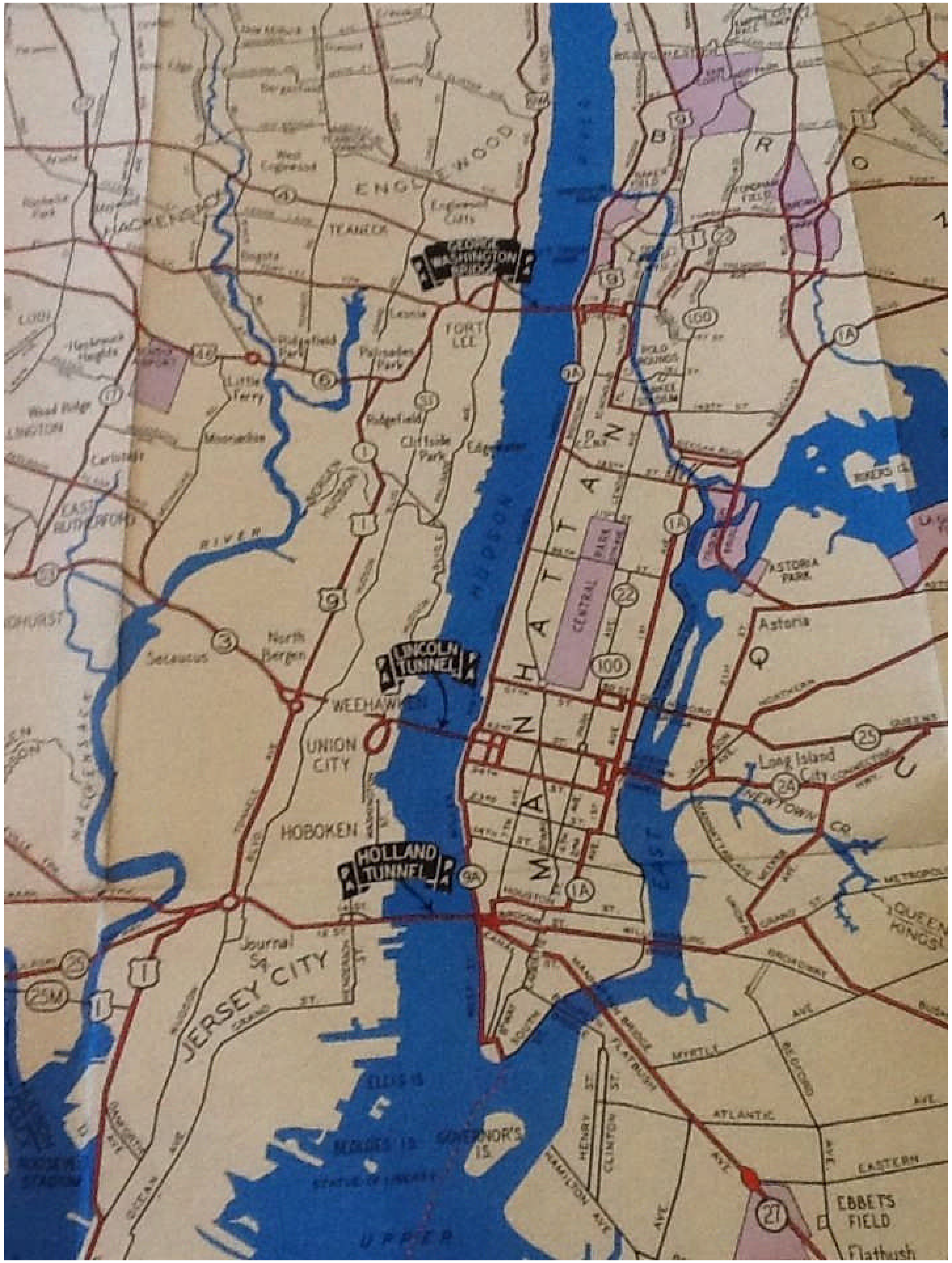
<u>Bottom</u>: caption: "Weehawken Mayor Meister and NYC Mayor LaGuardia meet in the Lincoln Tunnel on opening day"

A Dream Come True



"With the completion of the Lincoln Tunnel and its wonderful system of approaches to and from the main arteries of travel in New Jersey, the latest extraordinary engineering achievement of the Port of New York Authority became a reality…"
Port of New York Authority

Left: caption: "The Lincoln Tunnel, connecting 38th Street, Manhattan, with Weehawken, N.J., is the third interstate motor highway across the Hudson River in the Port of New York District. It has been constructed by the Port of New York Authority to serve the area midway between the Holland Tunnel and the George Washington Bridge. For Manhattan-bound motorists or Long Island travelers, the Lincoln Tunnel makes possible a substantial saving in time, providing direct connection between New Jersey and mid-Manhattan."



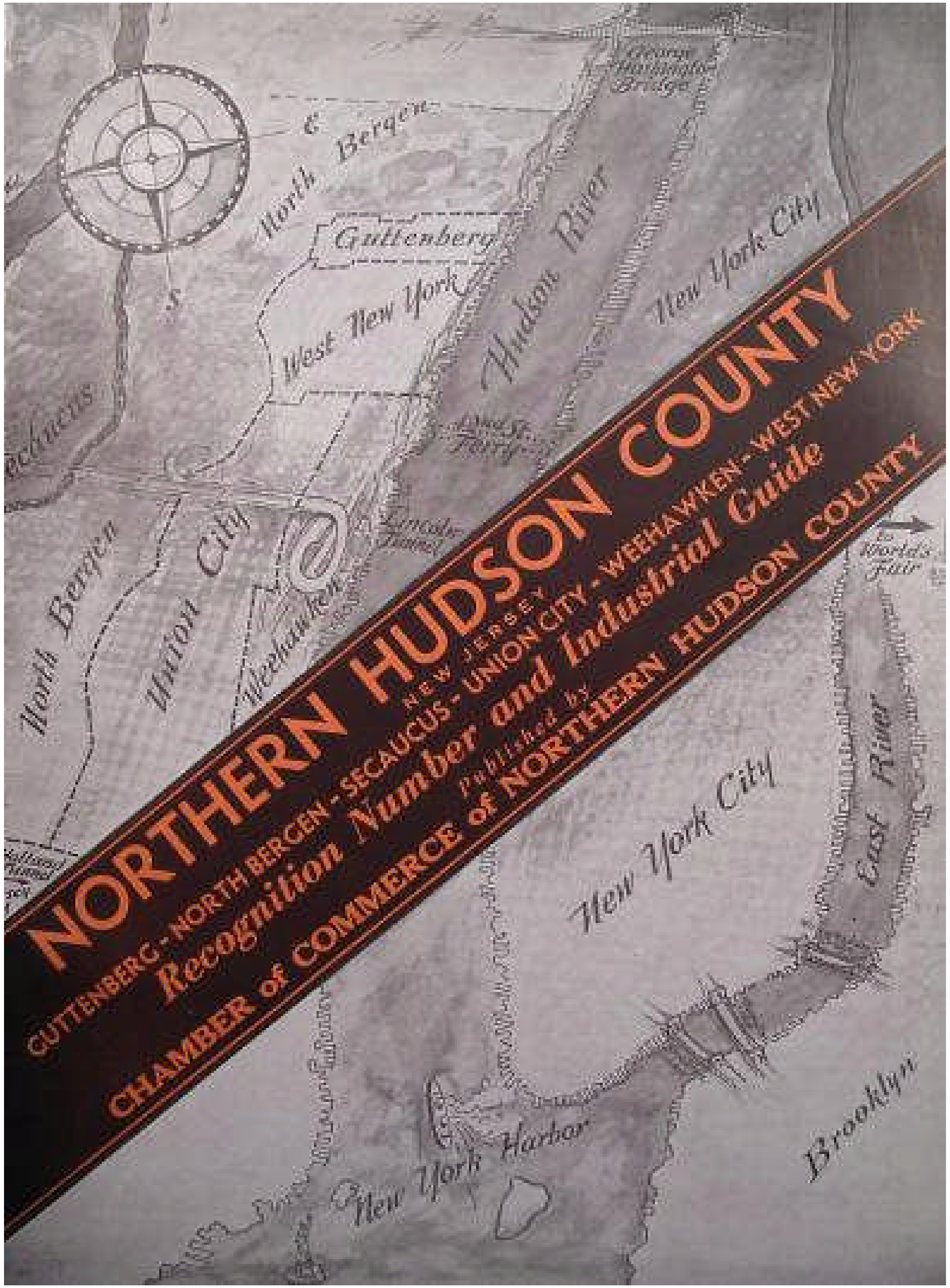
"…Within the span of a single generation means have been provided for shorter and more convenient travel between New Jersey and New York. What had been merely a thought, a vision, in the minds of even our earliest settlers over two hundred years ago, is now a completed masterpiece of engineering skill – not building, but built! – conceived, constructed and in actual use. All accomplished within the span of a single generation!..."

Port of New York Authority

<u>Left</u>: caption: "1949 PNYA map showing Hudson River crossings"

"…And so, a $100,000,000 project intended to solve an interstate rapid transit problem of the most vital importance to Northern Hudson County – so important that it has been in the minds of men for over two hundred years – is now in operation without a cent of cost to any taxpayer; for it is a self-liquidating undertaking, the cost of which is defrayed out of toll payments by the users, to whom again it means a saving in time and expense…For splendid team-work and unselfish cooperation between officials of the Port of New York Authority and the Chamber of Commerce of Northern Hudson County, without which a project of such magnitude could not have been put through successfully, this splendid engineering achievement will stand as a permanent monument…"

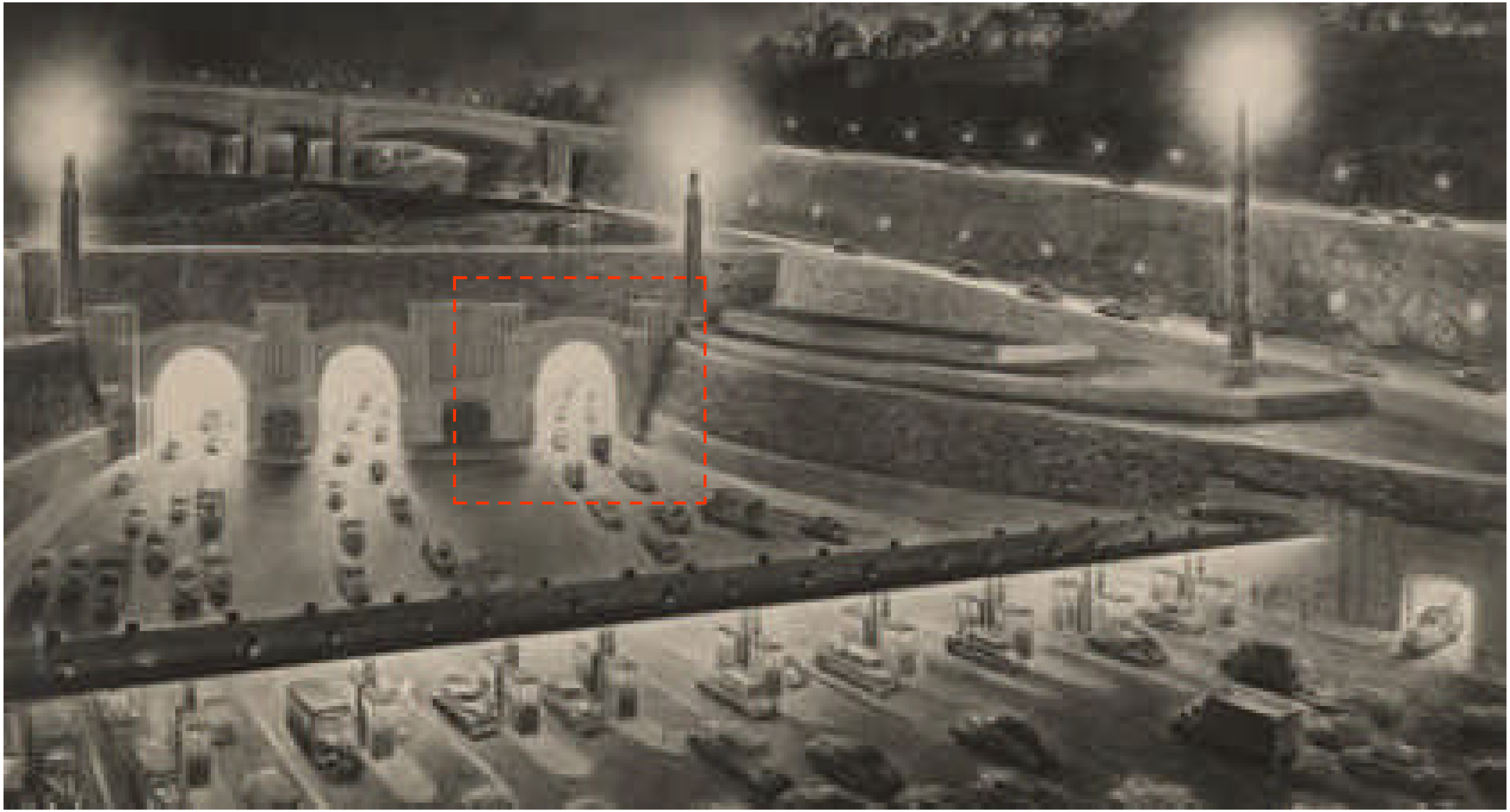
Port of New York Authority



"…It is not generally understood that other interests affecting the welfare of the Port of New York are the direct concern of the Port of New York Authority also and they are of almost equal importance. For instance, it is not widely known that the Port of New York Authority is in a certain sense, a sort of 'watch dog' safeguarding the interests of the Port of New York as against rival seaports, striving to obtain some of its legitimate commerce through subversive methods. It has consistently fought for the basic principle on which the Port of New York Authority is founded, namely, that all sections of the Port of New York must be considered as a unit. Northern Hudson County is one of these sections. Our local shippers are well aware of the tremendous advantage to them of adherence to this principle…"

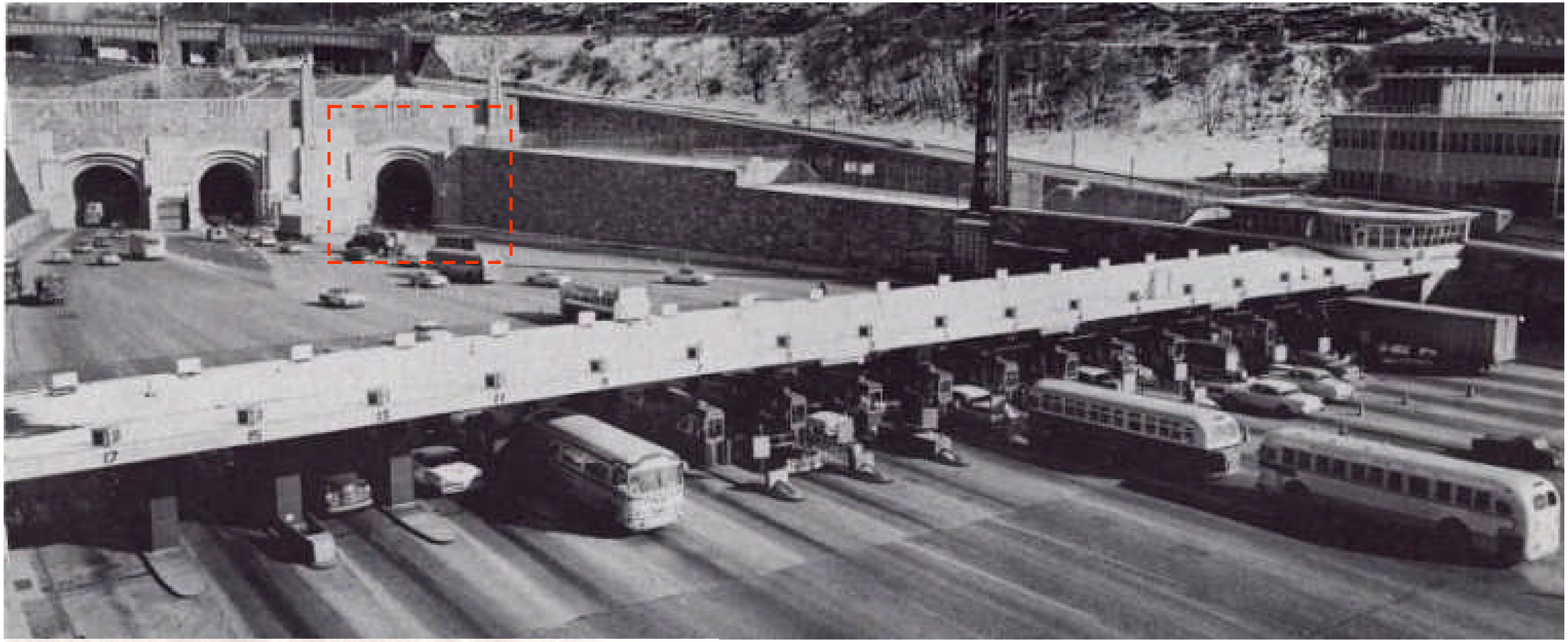
Port of New York Authority

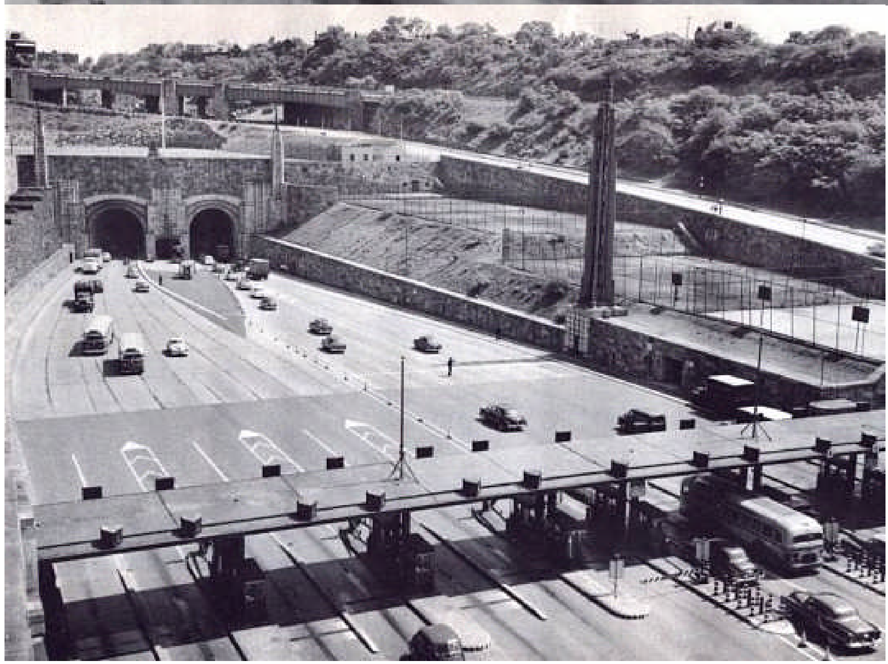
Third Tube



Trans-Hudson traffic continued to accelerate after WWII, prompting consideration of a new twin-tube tunnel between *14th Street* in *Manhattan* and *Hoboken, New Jersey*. Instead, the PNYA decided (in 1951) to construct a third tube for the *Lincoln Tunnel*. This project, which included the approach roads in Manhattan and Weehawken, and the "peripheral parking area" outlined in the *Joint Study of Arterial Facilities* (1955), was completed in 1957 at a cost of $85 million.

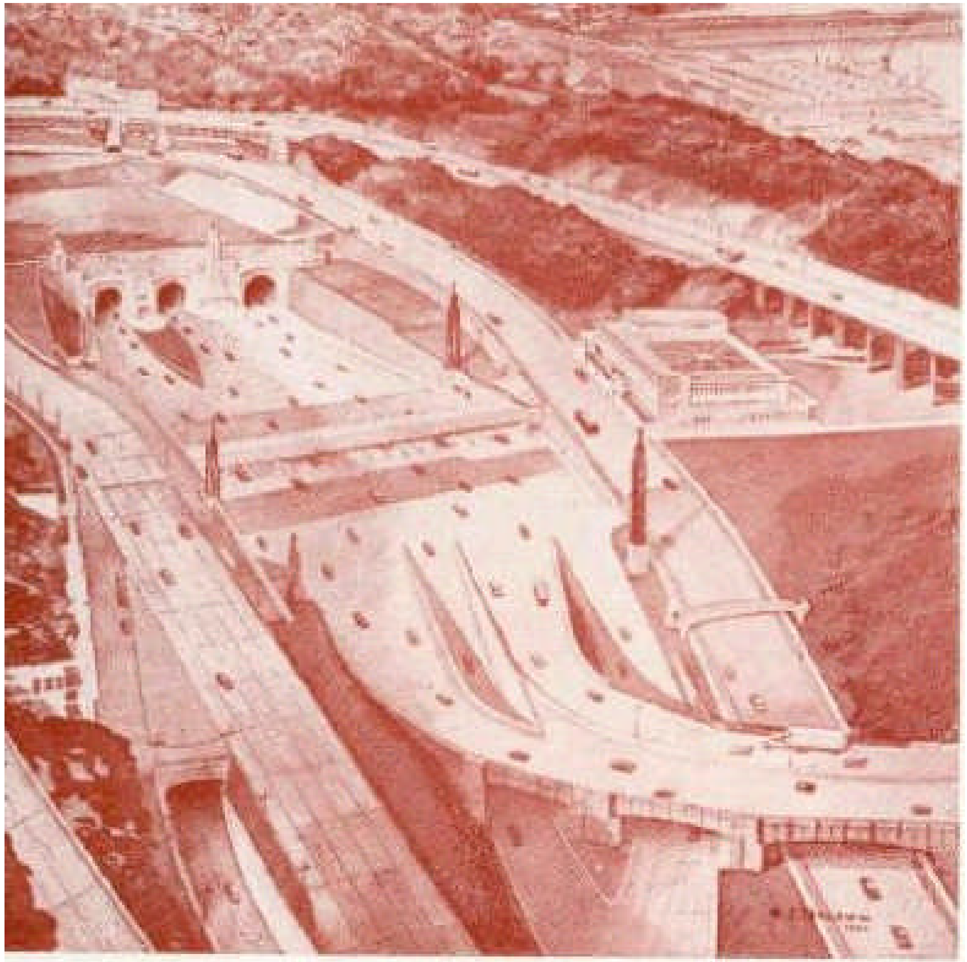
<u>Above</u>: rendering of reconfigured *Weehawken* toll plaza with addition of a third tube

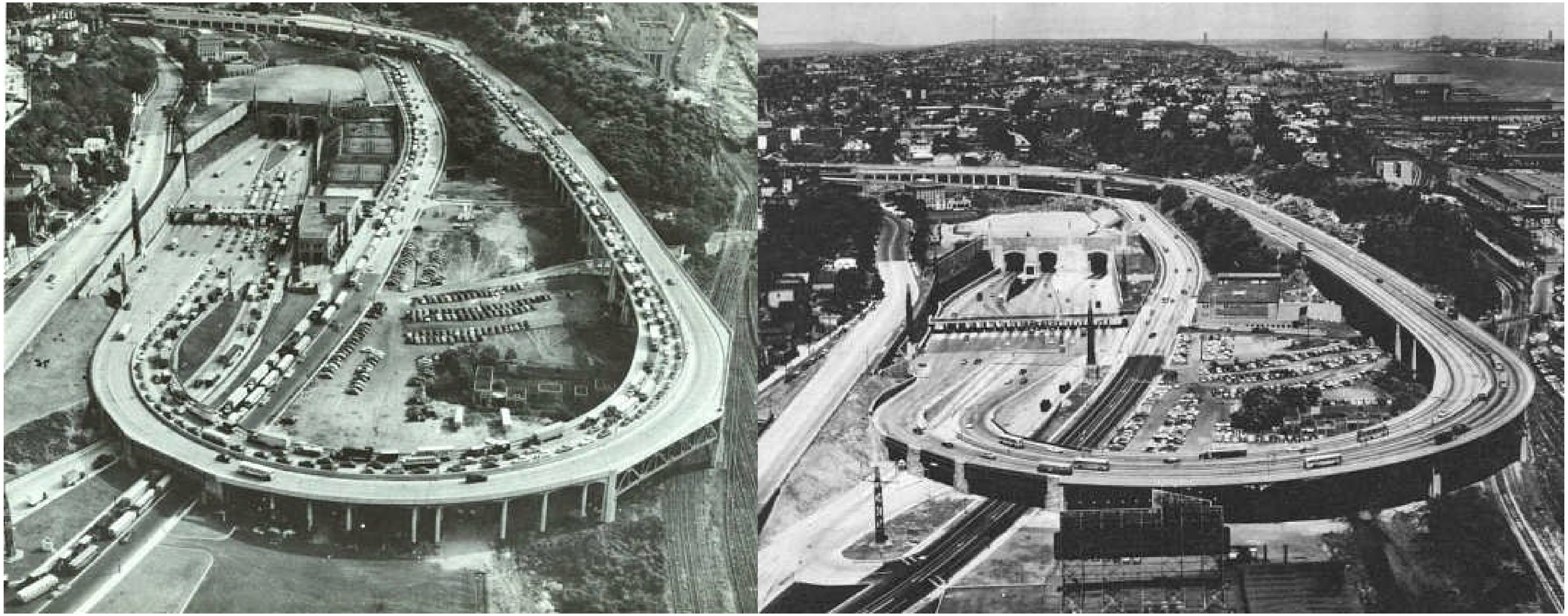




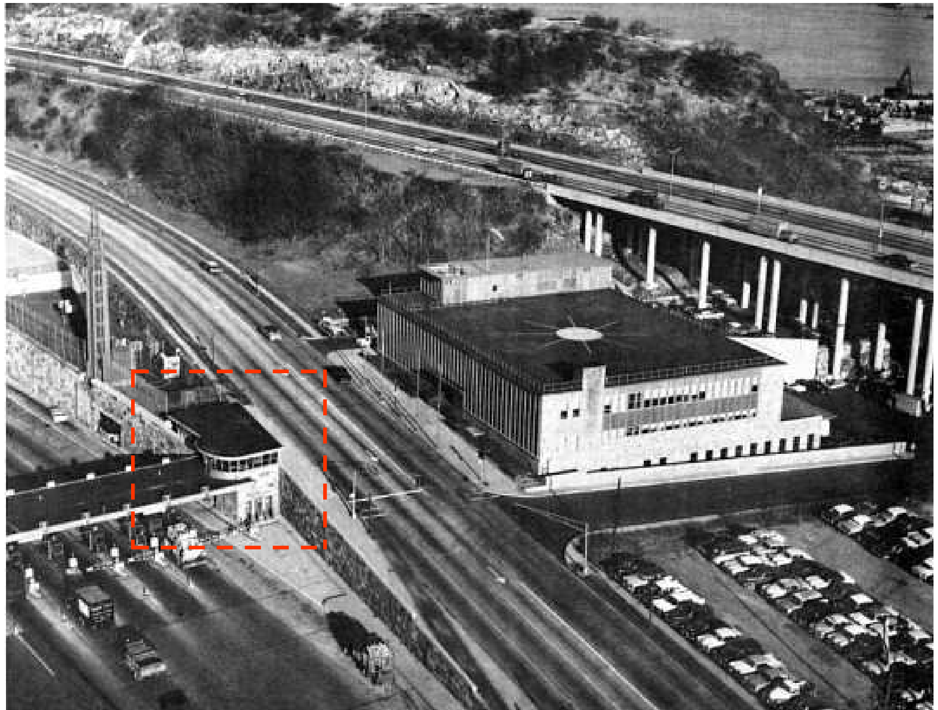
<u>Left</u>: caption: "Toll booths and New Jersey Plaza prior to the start of construction of the Third Tube Project"

<u>Above</u>: caption: "Toll booths and New Jersey Plaza after completion of the Third Tube Project"





Left: caption: “New Jersey Plaza and Helix prior to start of construction of the Third Tube Project”
Right: caption: “New Jersey Plaza and Helix after completion of the Third Tube Project. Note third portal, new administration building, widened tolls area, new center ramp, widened westbound helix.”

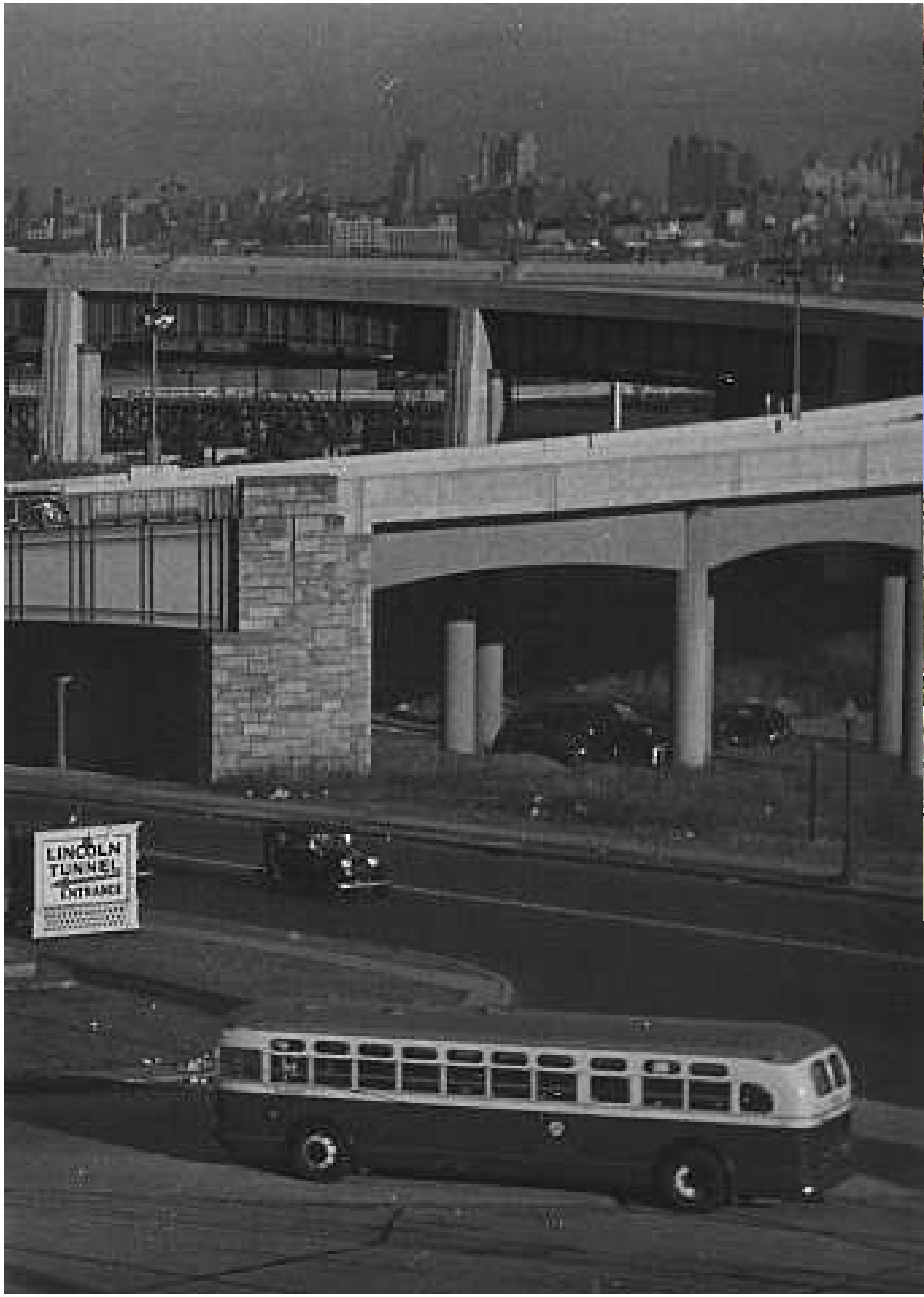


<u>Top</u>: caption: "Administration Building at corner of Hudson County Boulevard East and Baldwin Avenue in Weehawken"

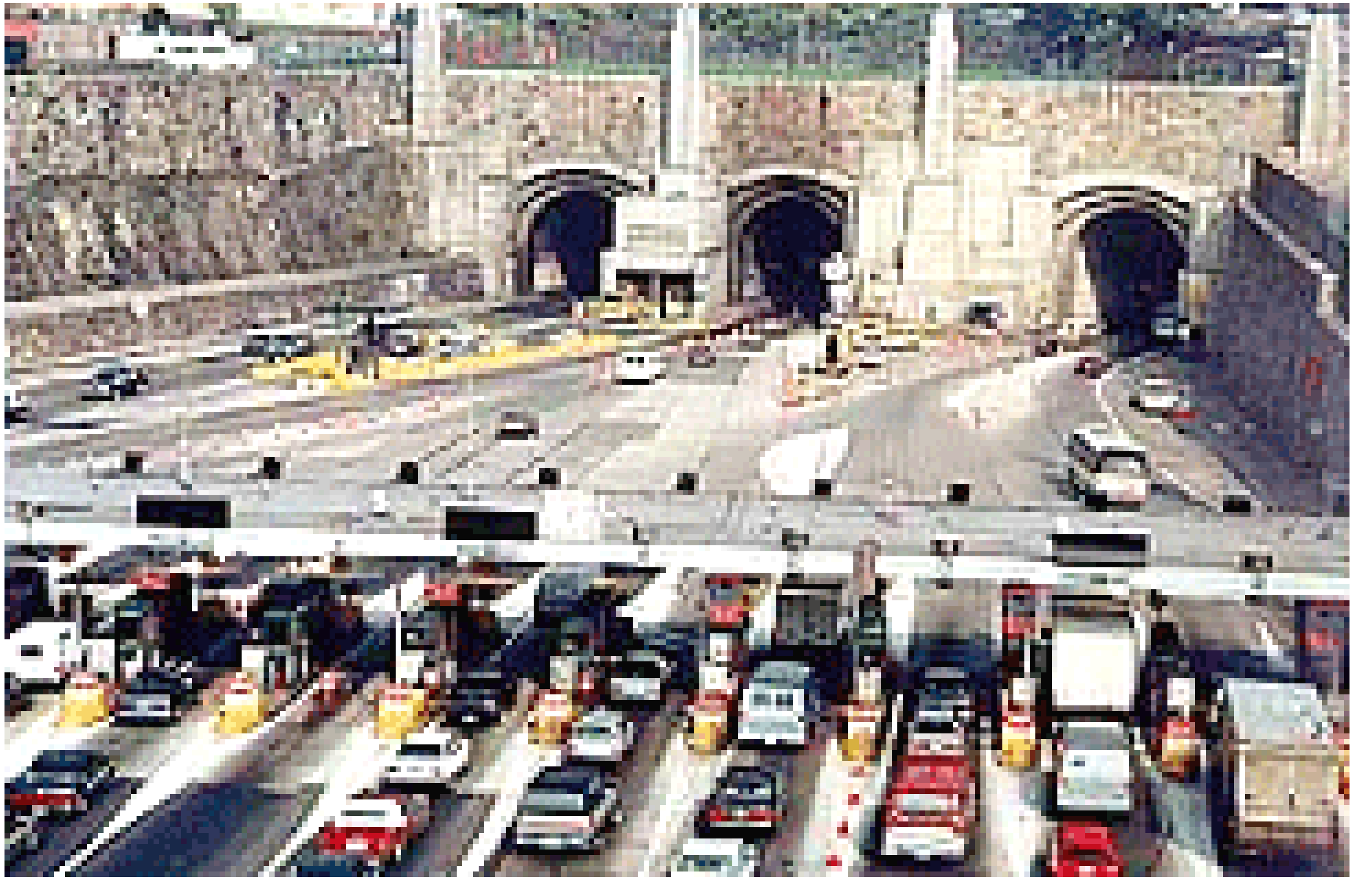
<u>Bottom</u>: caption: "Traffic Control Building on New Jersey Plaza" (highlighted in top photograph)

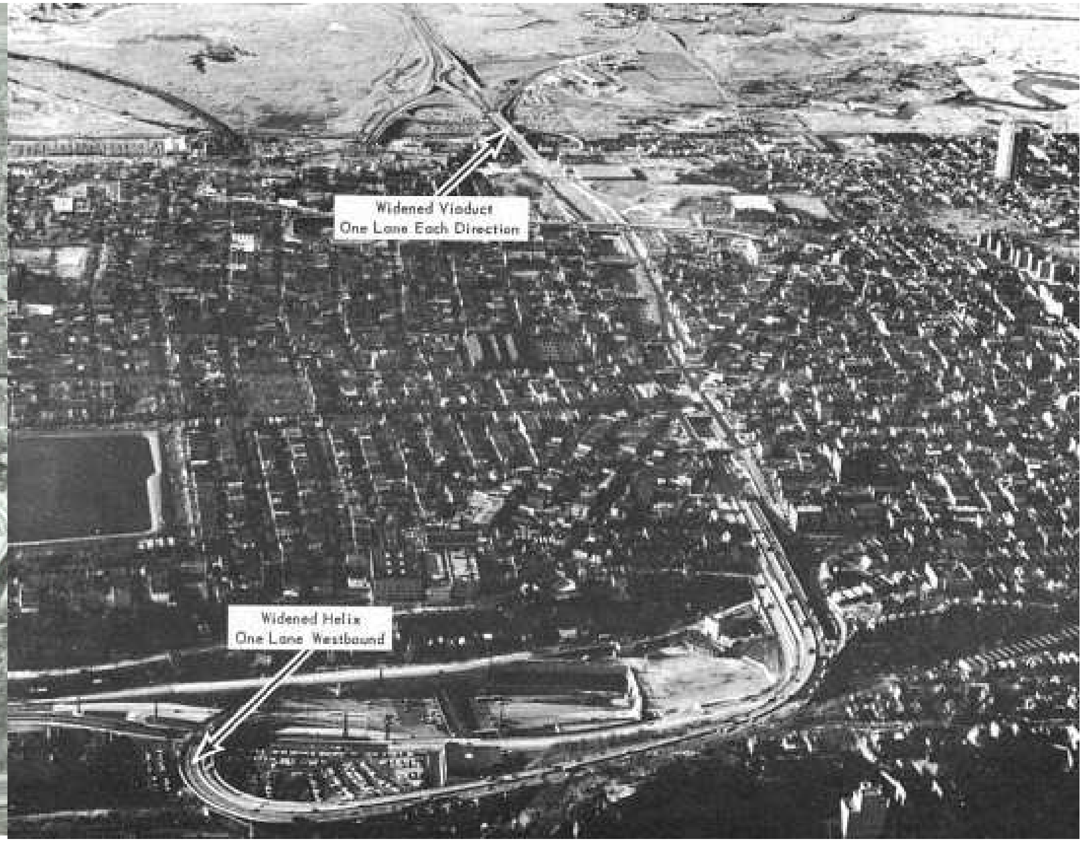
<u>Above</u>: caption: “That great curving ramp, called a helix by the engineers who built it, leads down into three of the world’s most expensive holes in the ground: The triple-tube Lincoln Tunnel from New Jersey to New York City. Eighteen traffic lanes pass under the toll booths on the plaza at lower left, and they merge into six as they enter the tunnel. Beyond the Hudson River, the lights of the metropolis glamorize the night. The tallest building (upper left) is the Empire State. Each day, nearly 40,000 automobiles go underground here at Weehawken, N.J. and emerge after a five minute trip on the west side of Manhattan between 38th and 39th Streets. And an equal number escape the jammed streets of the crowded island and sweep back up the helix. The impatient drivers take little note of the design which their headlights emphasize, but they are part of an accidental pattern of beauty. And even these weary travelers must find subconscious satisfaction in traversing this mighty spiral, upward and outward from deep beneath the river.”

***Saturday Evening Post*, September 1958**

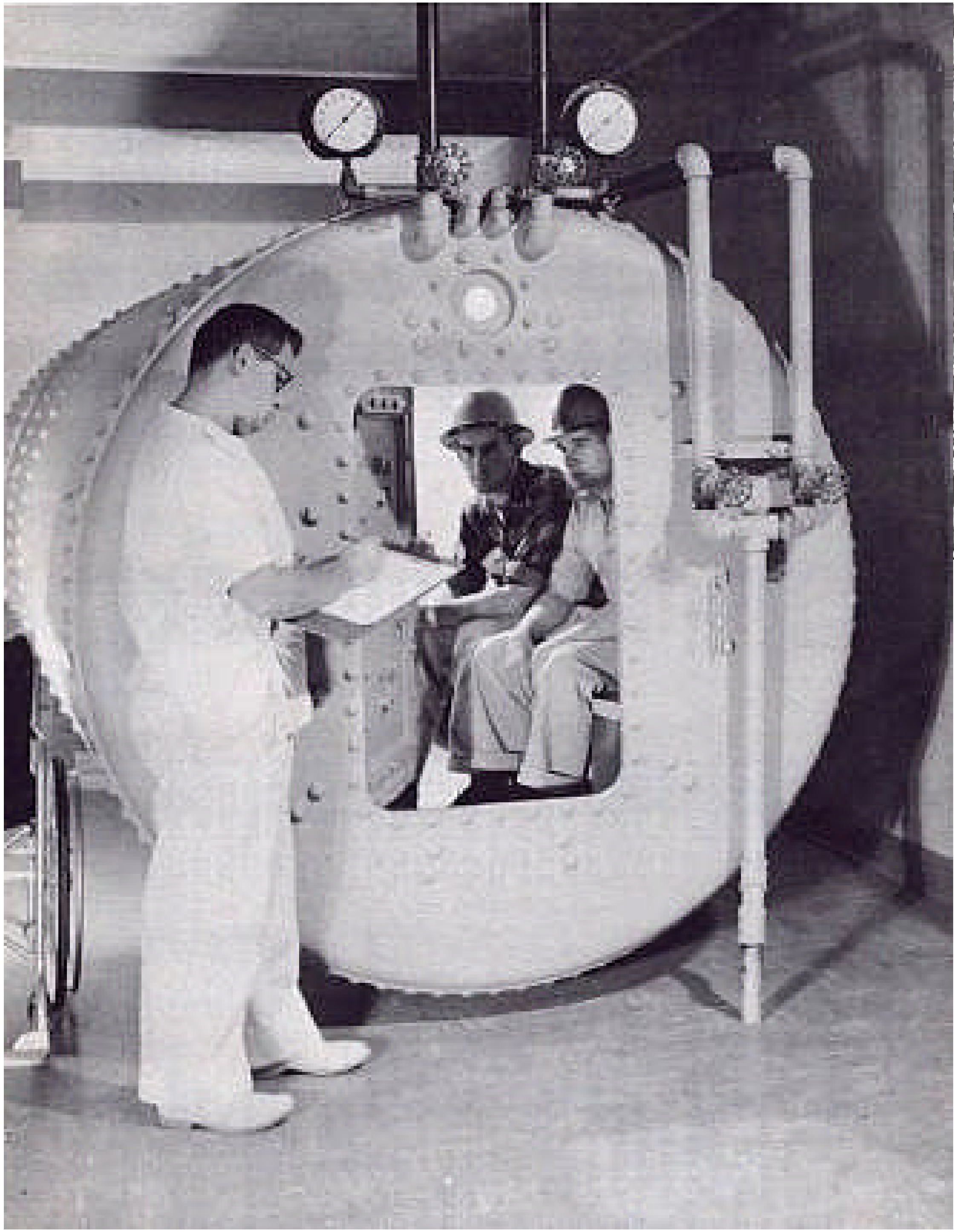


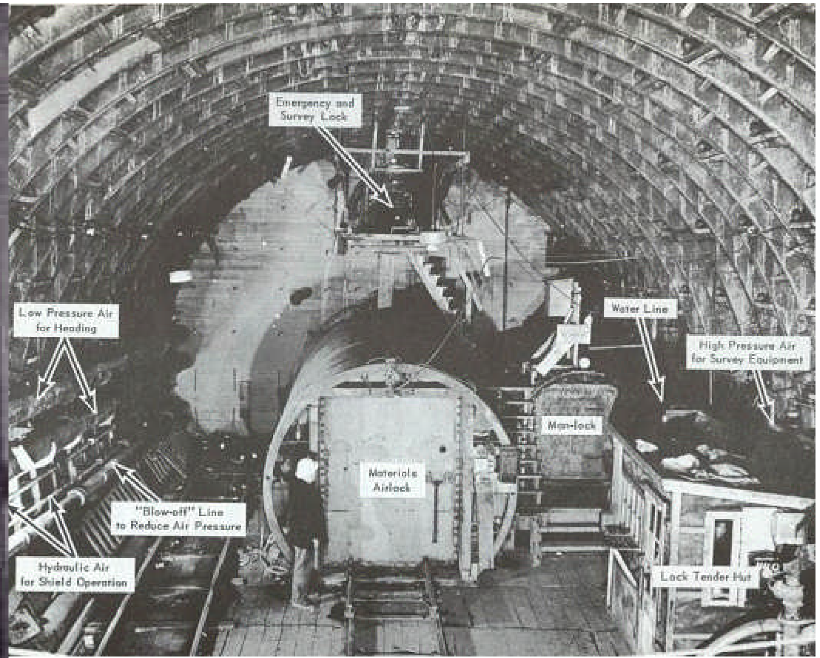
<u>Above T&B</u>: caption: “Three-portal Weehawken entrance of the Lincoln Tunnel and the toll plaza”
<u>Left</u>: caption: “Bus on its way from Weehawken to New York City”





<u>Left</u>: caption: "New Jersey Approaches prior to start of construction of the Third Tube Project"
<u>Right</u>: caption: "New Jersey Approaches after completion of the Third Tube Project"





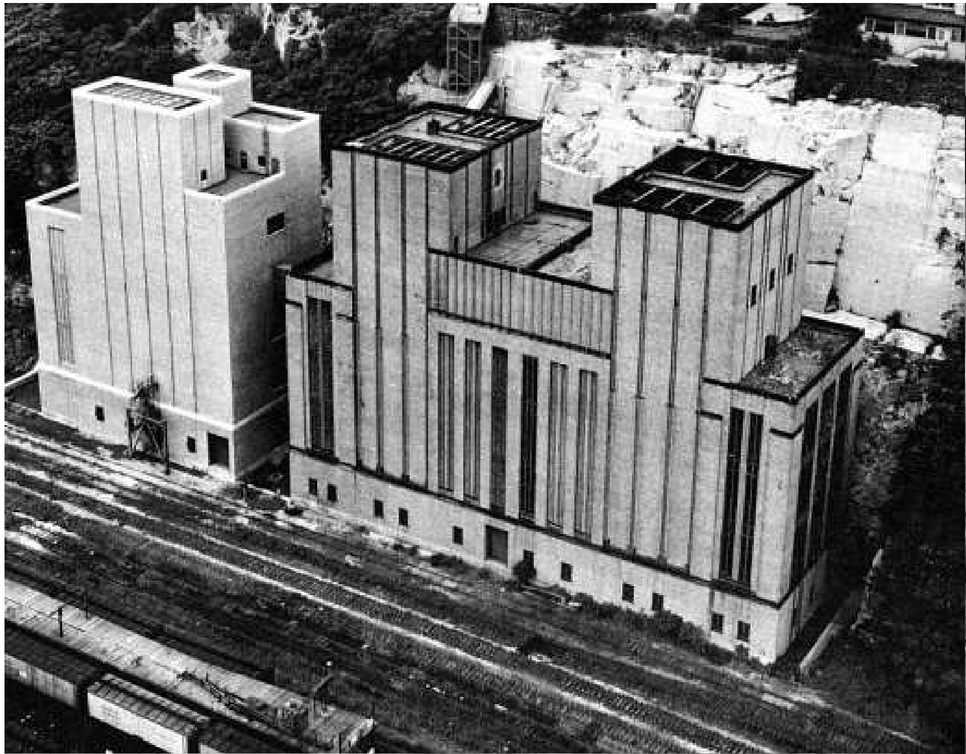
<u>Above</u>: caption: "Air locks and equipment on free air side of concrete bulkhead where men are working driving the tunnel"

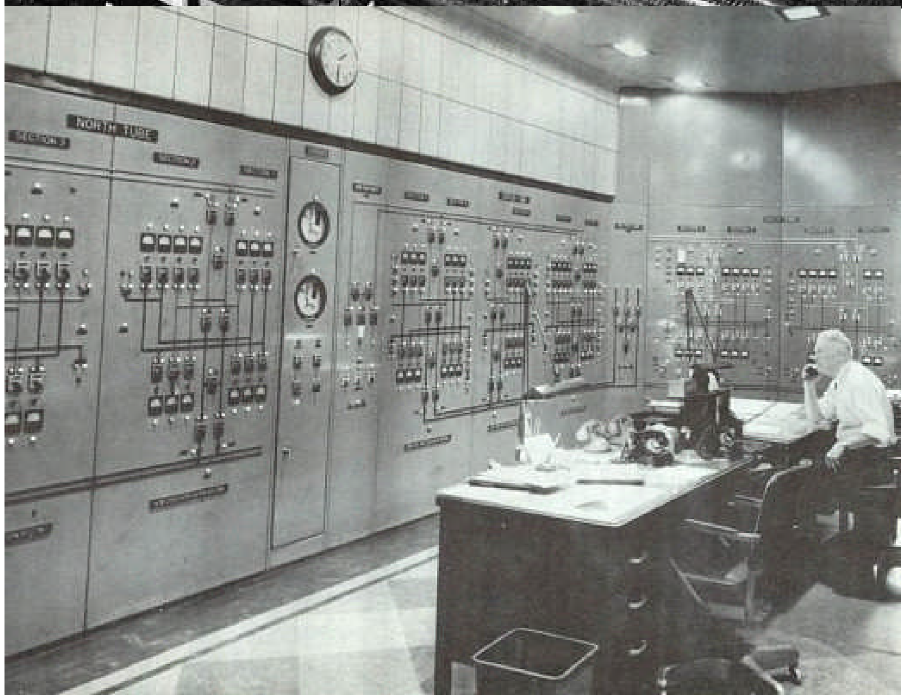
<u>Left</u>: caption: "Decompression Chamber in New Jersey Medical Clinic"

<u>Left</u>: caption: “Third tube of the Lincoln Tunnel under construction”

<u>Above</u>: caption: “Last Bolt Ceremony. Left to right are Port Authority Chief Engineer Kyle, Governor Meyner of New Jersey, Mayor Krause of Weehawken, Port Authority Chairman Lowe, Governor Averell Harriman of New York. The governors are tightening the last bolt.”

Above: caption: "Lincoln Tunnel Third Tube Dedication Ceremony on New Jersey Plaza, June 1958"





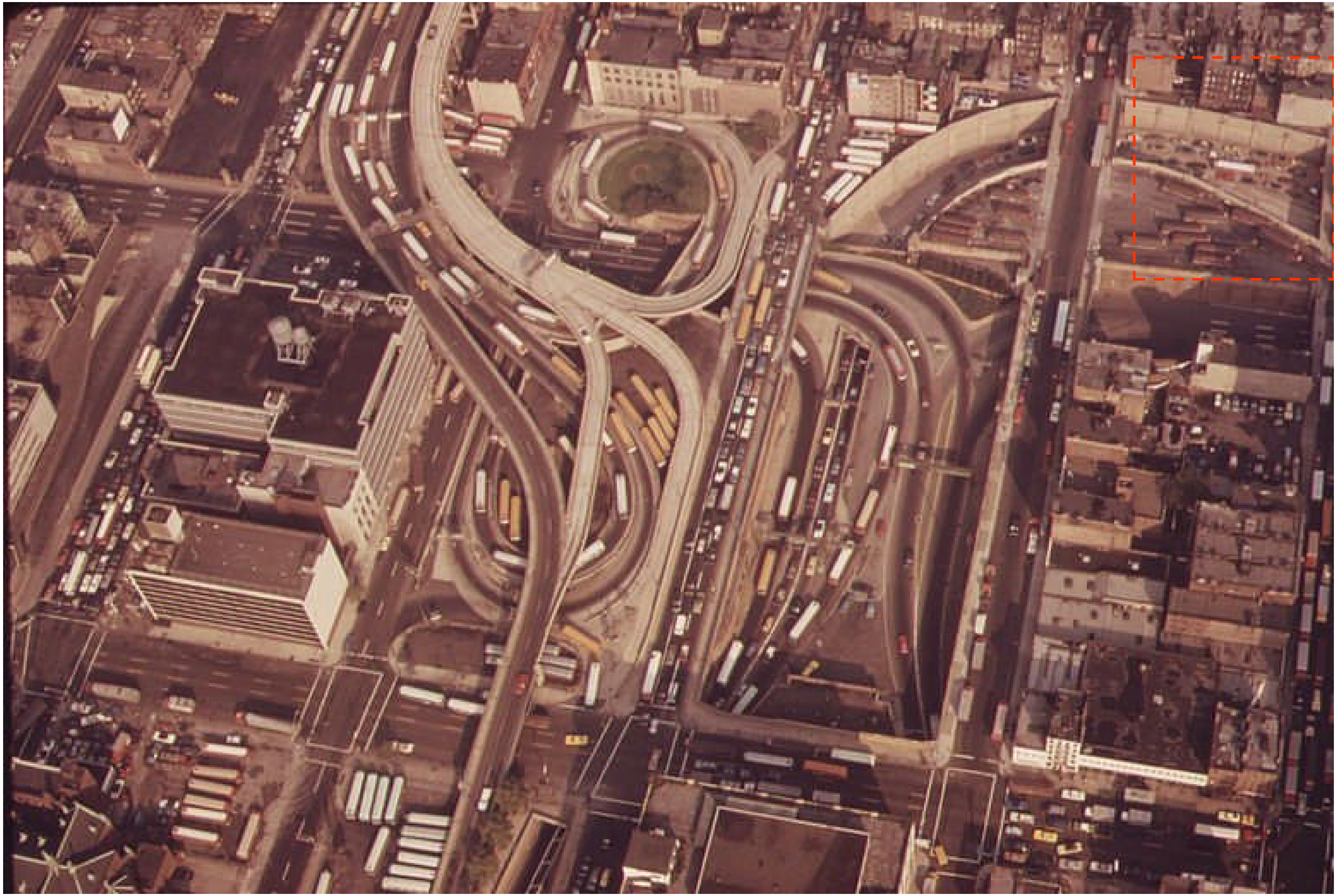
<u>Top Left</u>: caption: "New Jersey Ventilation Buildings with new Third Tube building on the left"

<u>Top Right</u>: caption: "Four-speed motor installed for Third Tube ventilation"

<u>Left</u>: caption: "Supervisory Control Room in New Jersey Ventilation Building upon completion of Third Tube construction"

The Lincoln Tunnel Expressway

At about the time the third tube of the *Lincoln Tunnel* was completed, the four-lane, $10 million *Lincoln Tunnel Expressway* was completed. The expressway (which runs north-south between the *Manhattan* plaza of the tunnel and *West 30th Street*) connects with all three tubes of the tunnel. In constructing the approach highway, PNYA engineers had to build a bridge under an existing bridge, provide two twin tunnels and five viaducts, depress and elevate part of the roadbed as necessary and develop an intricate network of entrance and exit ramps at intermediate points. Also, as part of the expressway's design, ramps were constructed to the *Port Authority Bus Terminal*. The Lincoln Tunnel Expressway was to be integrated into the *Mid-Manhattan Expressway*, a crosstown route leading to the *Queens-Midtown Tunnel*.



<u>Above</u>: caption: "Manhattan entrance to the Lincoln Tunnel"

<u>Above</u>: caption: "New York Emergency Garage with Third Tube Portal on left and Center Tube Portal on right"

<u>Left</u>: caption: "Emergency Jeep and Emergency Tractor"

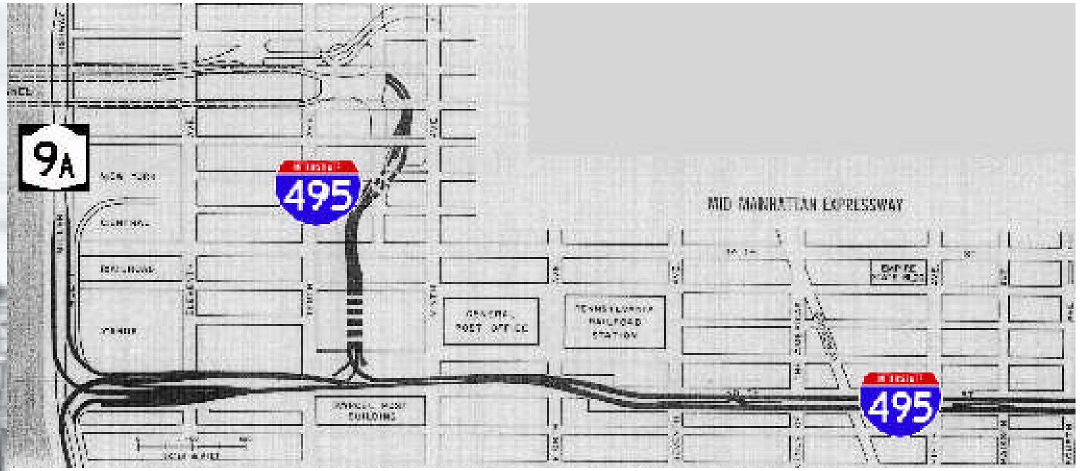
Mid-Manhattan Expressway

"Mid-Manhattan Crosstown Highway: This is a proposed express connection between the Queens-Midtown and Lincoln tunnels to serve crosstown traffic from the tunnels, through traffic between Long Island and New Jersey, and local crosstown Manhattan traffic. The Commission agrees in principle to the desirability of exits and entrances in the center of the island in a Manhattan crosstown express route. This is an essential part of the highway pattern that has not been built because of the difficulties of financing the project. However, it would appear that the travel time savings that it would afford to very large volumes of traffic, would warrant an expenditure of the amount required for its construction. Consideration should be given to the financing of this improvement as a toll facility. Engineers for the Borough President of Manhattan have estimated that its cost as a tunnel would be approximately $40,000,000."

RE: excerpt from NYC's Master Plan, 1941. First proposed in 1926 by the *Regional Plan Association* (RPA), the *Mid-Manhattan Expressway* was adopted as part of the RPA's 1929 master arterial plan entitled: "Plan of New York and Its Environs." NYC construction coordinator *Robert Moses* envisioned the Mid-Manhattan Expressway to be an elevated, limited-access link between the *Queens-Midtown* and *Lincoln Tunnel/s*. After receiving the I-495 designation in October 1958, this crosstown artery was to have connected the I-495 segment in *New Jersey* with the *Long Island Expressway* in *Queens*.

“An elevated expressway, from its connection with the West Side Highway, would start as a depressed highway in the center of a widened 30th Street to 10th Avenue. At this point, it would swing to the north side of 30th Street to make connections between 10th and 9th Avenues with the Lincoln Tunnel Third Tube approaches now under construction. After underpassing 9th Avenue, the six-lane expressway would rise to over-pass 8th Avenue and continue across Manhattan as an elevated structure. Between 8th and 7th Avenues the roadway would recross 30th Street and occupy a one-hundred-foot right-of-way immediately south of 30th Street. After overpassing 2nd Avenue, the expressway would swing north to follow the 30th Street alignment as a four-lane elevated expressway to connections with the East River (FDR) Drive. At 1st and 2nd Avenues, ramps would be constructed to provide access to and from the Queens-Midtown Tunnel via 1st and 2nd Avenues and the existing tunnel approach roadways. Access to the expressway would be provided in each direction in the section between 5th and 7th Avenues. If the expressway were constructed, it is estimated that it would be used to its estimated capacity of 24,000,000 vehicles a year. It is estimated that the cost of the elevated expressway alone would be $77,000,000, of which $33,500,000 represents real estate.”

RE: excerpt from the *Joint Study of Arterial Facilities*, published by the *Triborough Bridge and Tunnel Authority* and the PNYA in 1955



"Can you imagine an elevated expressway at 30th Street just so Long Island guys could get to New Jersey?"

***Robert A.M. Stern,* Architect**

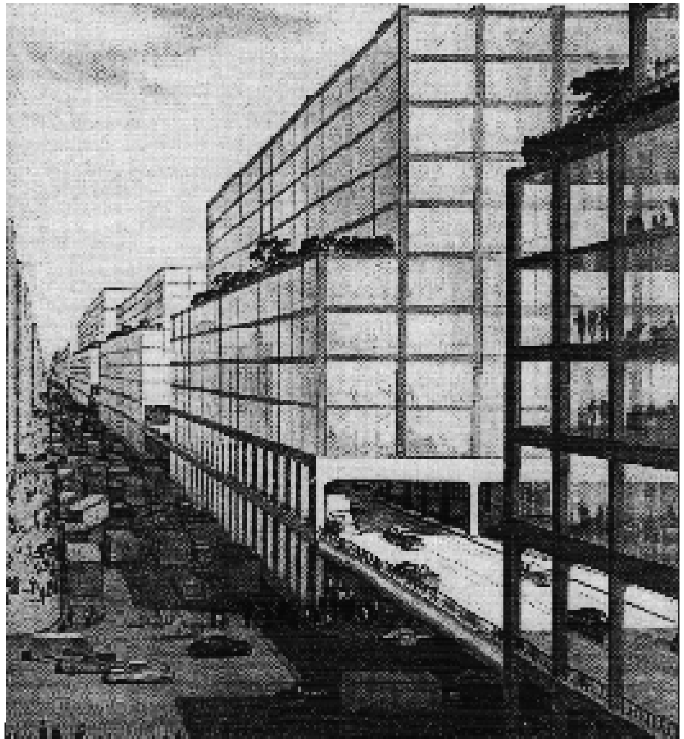
<u>Above</u>: caption: "This 1963 map from Future Arterial Program for New York City shows the proposed Mid-Manhattan Expressway, with connect-ions to the Lincoln Tunnel and the West Side Highway (NY 9A) to the west."

<u>Left</u>: caption: "Mid-Manhattan Express-way (proposed), looking east, ca. 1959"

According to the Joint Study, the chief argument against the *Mid-Manhattan Expressway Tunnel* was its cost. This would have ranged from $119 million for a no-exit, express link between the *Lincoln Tunnel* and *Queens-Midtown Tunnel*, to $145 million for a tunnel link that would have provided entrances and exits at *Fifth Avenue.* To accommodate future traffic along the Mid-Manhattan corridor, Moses proposed construction of a $120 million third tube to the Queens-Midtown Tunnel. The third tube, which would allow four lanes of traffic in one direction during rush-hour periods, was to be constructed in conjunction with the expressway. Through a succession of NYC mayors (starting with *Fiorello LaGuardia*), Moses found support for his Mid-Manhattan Expressway. He also received the support of most of the NYC press (especially *The New York Times*) and the *Bureau of Public Roads.*

“As a newspaper we have previously endorsed those cross-town expressways (the Mid-Manhattan and Lower Manhattan), and we stand by that earlier endorsement. But we must admit to a growing disenchantment with great urban highway and expressway schemes.”

RE: excerpt from a *New York Times* editorial. By the early 1960s, public sentiment had begun to shift in favor of mass transit and against Robert Moses’ various transportation infrastructure schemes for NYC and its environs. In large part, this was due to the construction of the infamous *Cross-Bronx Expressway* which decimated many vital, thriving *Bronx* neighborhoods.



A novel feature of the *Mid-Manhattan Expressway* was the allowance for development both above and below the expressway. The two, three-lane roadways (ten stories above street level) would be separated by a median in which elevators (serving the development above the expressway) would be located. Below the expressway, space for commercial development and parking were to be provided. According to the Joint Study, the proposed development would have added $14 million to the cost of the expressway.

Left T&B: caption: "Artist's conceptions of the elevated Mid-Manhattan Expressway. The top conception shows the expressway tunneling under skyscrapers that would have been constructed through the sale of air rights.

Mid-Manhattan Tunnel (?)

"It would be necessary to build two separate tubes under adjacent crosstown streets. A two-lane eastbound tube could pass under 29th Street; a two-lane tube westbound under 30th Street. Ventilation buildings would be located in the block between 29th and 30th Streets fronting on the west side of 8th Avenue and the east side of Lexington Avenue. The least costly type of construction for such a tunnel would be the steel-bent and concrete subway-type, installed by cut-and-cover method. The tunnel providing only two lanes in each direction would, of course, have only two-thirds the capacity of a six-lane expressway. Provision of more than two lanes in each tube is not feasible due to limitations imposed by building foundations on either side of 29th and 30th Streets and extremely high costs. Limited street access in Midtown could be provided in the vicinity of 5th Avenue at a cost that would depend on the degree to which the interchange was developed."

RE: excerpt from the *Joint Study of Arterial Facilities* (1955). As early as 1937, the RPA advocated construction of a four-lane, twin-tube tunnel under *36th Street* and *37th Street/s*.

“A route crossing midtown Manhattan, connecting the East River (FDR) Drive and the West Side Highway, as well and the Lincoln and Queens-Midtown tunnels, has long been proposed. It is intended to remove from city streets traffic that wishes to cross from one side of the island to the other. This facility, currently a segment of the Federal Interstate highway system, would penetrate the area of highest-cost real estate and greatest commercial density in the nation. Clearly, this should receive the most intensive study and design evaluations to assess whether such a road-way can be satisfactorily adapted to the very dense and complicated environment. Also, the potential effect on the delicate transit balance in the midtown area must be carefully weighed, particularly in view of the proposed East River subway tunnel. In such an evaluation, radical departures from the present design concept should be examined.”

RE: excerpt from *Transportation 1985: A Regional Plan* (1966 report of the *Tri-State Transportation Commission*). In August 1969, the *NYC Planning Commission* recommended against building the *Mid-Manhattan* and *Lower Manhattan Expressway/s* and on March 24th 1971, NYS Governor *Nelson Rockefeller* terminated plans for the Mid-Manhattan Expressway.

Left: caption: "Model of the proposed Mid-Manhattan Expressway along 30th Street. The model, which was built in 1966, shows the Empire State Building on the right and the proposed Madison Square Garden (which opened in 1968) on the left."

<u>Above</u>: In 1958, the *I-495* designation was given to the proposed *Mid-Manhattan Expressway*. The expressway was removed from official plans in 1971, but remnants of Robert Moses' grand plan (in the form of I-495 signs) survived long after in *Manhattan*. These two I-495 signs were located on *East 34th Street* (ca. 1998).

“If (and it is a very remote ‘if’) the Mid-Manhattan Expressway (I-495) were ever constructed, it would be connected to deficient river crossings with vertical and horizontal roadway clearance problems for interstate trucking. Also, these river crossings currently carry traffic loads above their original design capacity, and therefore could not carry additional traffic. The Queens-Midtown and Lincoln Tunnels, which are maintained by MTA Bridges and Tunnels and by the Port Authority of New York and New Jersey respectively, would need to be upgraded and expanded. Add to this the cost of tunneling expressways through some of the most expensive real estate in the nation, blasting through solid bedrock while not disturbing building foundations, subway and utility lines, and you have a project that would make the Boston Central Artery project appear simple and cheap by comparison.”

Ralph Herman

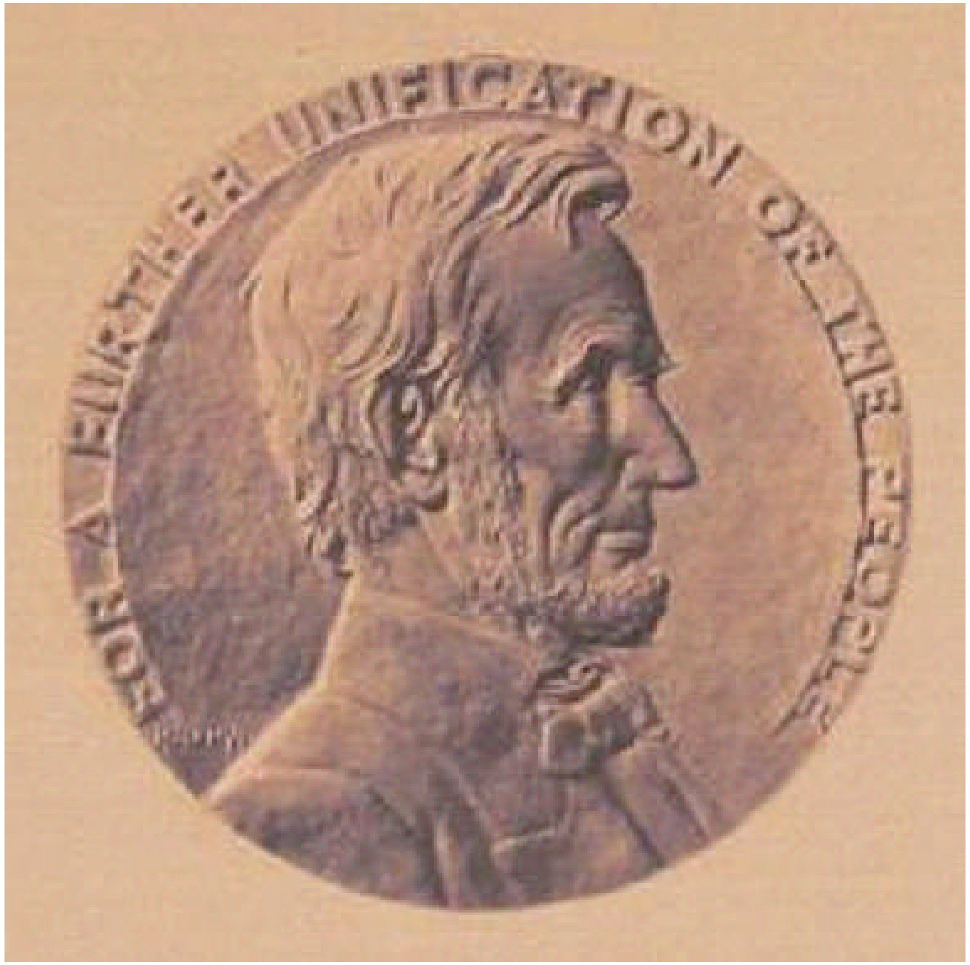
RE: discussions begun in 1998 on reviving plans for I-495 across midtown *Manhattan*

“Certainly, the added cost of tunneled roads is still going to be sufficiently significant to preclude their widespread use. However, for road links that would handle and serve large amounts of traffic, they can be justified. Such an underground tunnel would certainly be justified for the Mid-Manhattan Expressway between the Lincoln and Queens-Midtown underwater tunnels. To supplement the Mid-Manhattan Expressway, new tubes will certainly have to be constructed across the Hudson and East rivers. With regard to these potential projects, bored tunneling was cited at an April 1997 Regional Planning Association panel as providing the advantage of far less surface disruption than cut-and-cover tunnels, thus having the advantage of being far more politically feasible. Moreover, bored tunneling would offer more latitude in determining a road link’s exact alignment, providing greater flexibility in avoiding building foundations, subways and utility lines. An express tunnel directly connecting New Jersey with Queens without access to Manhattan would be a logical thing, even if in conjunction with a more local crosstown Manhattan tunnel with exits serving the East Side and the West Side. However, because of the construction and maintenance expenses involved, it would have to be built as a toll facility.”

Douglas A. Willinger

RE: in 1999, Willinger (of the *Takoma Park Highway Design Studio*) made the case for a *Mid-Manhattan Expressway Tunnel*. Also in 1999, a research paper entitled: “How To Build Our Way Out of Congestion” (published by the *Reason Public Policy Institute*) advocated a proposed Mid-Manhattan Expressway Tunnel. The proposed tunnel (based on Paris’ “Metroroutes”) would allow buses and most fire equipment access, but not heavy trucks or long-distance coaches. Nevertheless, smaller vehicles constituting +90% of rush-hour traffic flows would be permitted.

For A Further Unification of the People


FOR A FURTHER UNIFICATION OF THE PEOPLE