PDHonline Course C555 (8 PDH)

Brooklyn Bridge: Epic of the Age

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2020

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BROOKLYN BRIDGE

Epic of the Age

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Part 1

Praiseworthy

"Lo, Soul, seest thou not God's purpose from the first?...the earth be spann'd, connected by network...the lands welded together...the shapes arise"

Walt Whitman

“All that the age had just cause for pride in – its advances in science, its skill in handling iron, its personal heroism in the face of dangerous industrial processes, its willingness to attempt the untried and the impossible – came to a head in Brooklyn Bridge.”

Lewis Mumford, 1924

"It so happens that the work which is likely to be our most durable monument, and to convey some knowledge of us to the most remote posterity, is a work of bare utility, not a shrine, not a fortress, not a palace, but a bridge."

***Harpers Weekly*, 1883**

"When the perfected East River bridge shall permanently and uninterruptedly connect the two cities, the daily thousands who cross it will consider it a sort of natural and inevitable phenomenon, such as the rising and setting of the sun, and they will unconsciously overlook the preliminary difficulties surmounted before the structure spanned the stream, and will perhaps undervalue the indomitable courage, the absolute faith, the consummate genius which assured the engineers triumph."

The Brooklyn Eagle

"The stone plays against the steel; the heavy granite in compression, the spidery steel in tension. In this structure, the architecture of the past, massive and protective, meets the architecture of the future, light, aerial, open to sunlight, an architecture of voids rather than solids."

Lewis Mumford

"The bridge is likely to outlast all the traditions of the men who built it. But one of the most enduring of these traditions is likely to be the touching story of the successive masters of the work, the Roeblings, father and son."

***Harper's* Weekly, 1883**

"This bridge is to be built, appealing as it does to our pride, our gratitude and prosperity. When complete, let it illustrate the grandeur of our age; let it be the Mecca to which foreign peoples shall come. Let Brooklyn now take up the pen of progress. Babylon had her hanging gardens, Nineveh her towers, and Rome her Coliseum; let us have this great monument to progress."

John Roebling, 1869

"…He is the thinker who acts. He contributes to his country's sum of achievements as much as and less expensively than the soldier. His ends, in the elevation of the race and in increasing the aggregate of its capacity and performance, are kindred to the statesman's. And if there be those who think that the worth of the Engineer is only hard and material, that there is no charm of art in its processes, let them read the story of the building of the Bridge."

***The Brooklyn Eagle*, 1872**

RE: The profession of Engineering

"...the bridge is a marvel of beauty viewed from the level of the river. In looking at its vast stretch, not only over the river between the towers, but over the inhabited, busy city shore, it appears to have a character of its own far above the drudgeries and exactions of the lower business levels."

***Scientific American*, 1883**

"this alluring roadway, resting on towers which rise like those of ancient cathedrals: this lacework of threads interweaving their separate delicate strengths into the complex solidity of the whole."

Rev. Richard Storrs, May 24, 1883

"The beautiful and stately structure fulfills the fondest hope…The impression upon the visitor is one of astonishment that grows with every visit. No one shall see it and not feel prouder to be a man."

Mayor Seth Low of Brooklyn, May 24, 1883

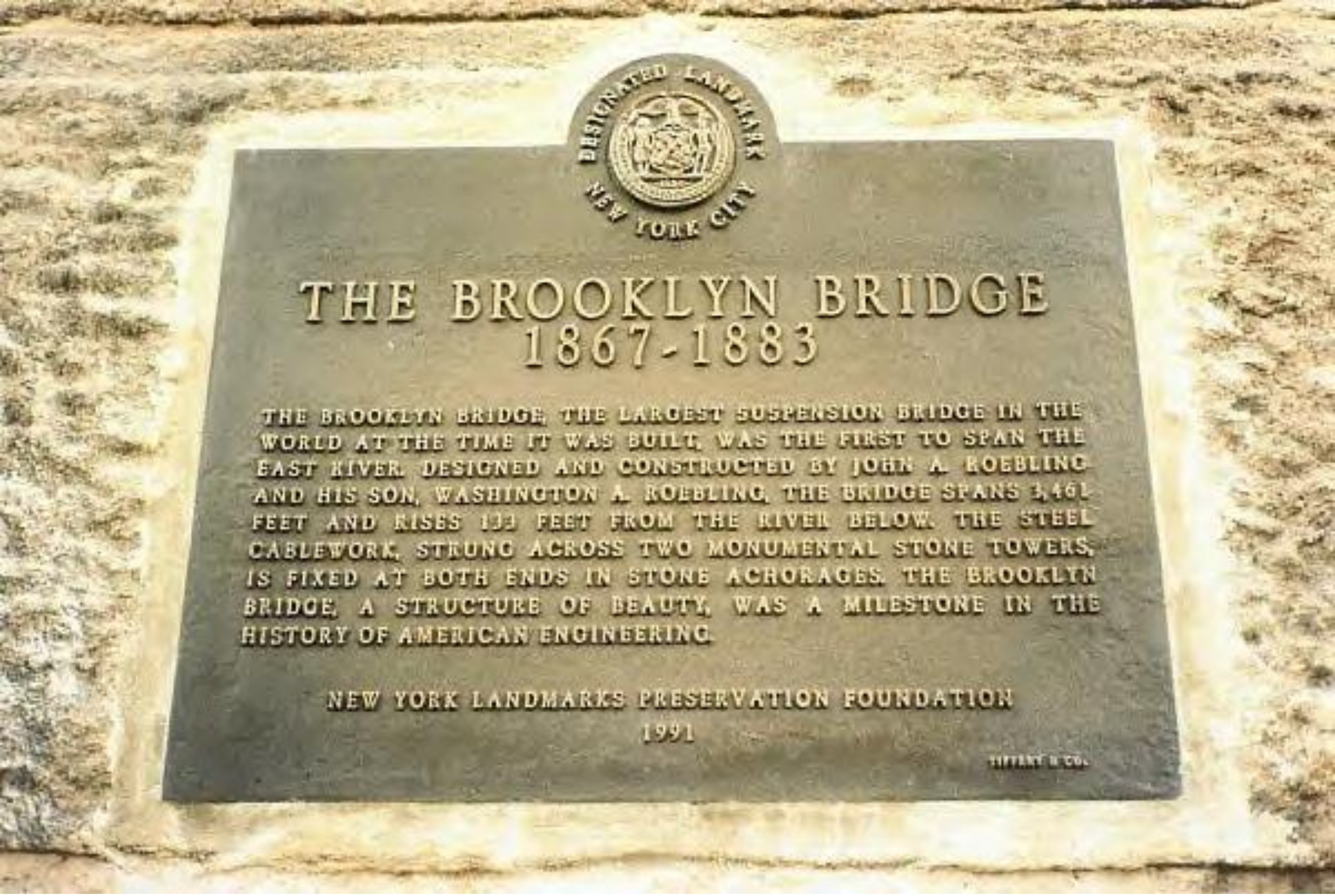
“The thing about the Brooklyn Bridge, in the end, is that it is just so beautiful”

Paul Goldberger – Architectural Critic

"As far as we are concerned, it will last forever"
NYC Dept. of Public Works

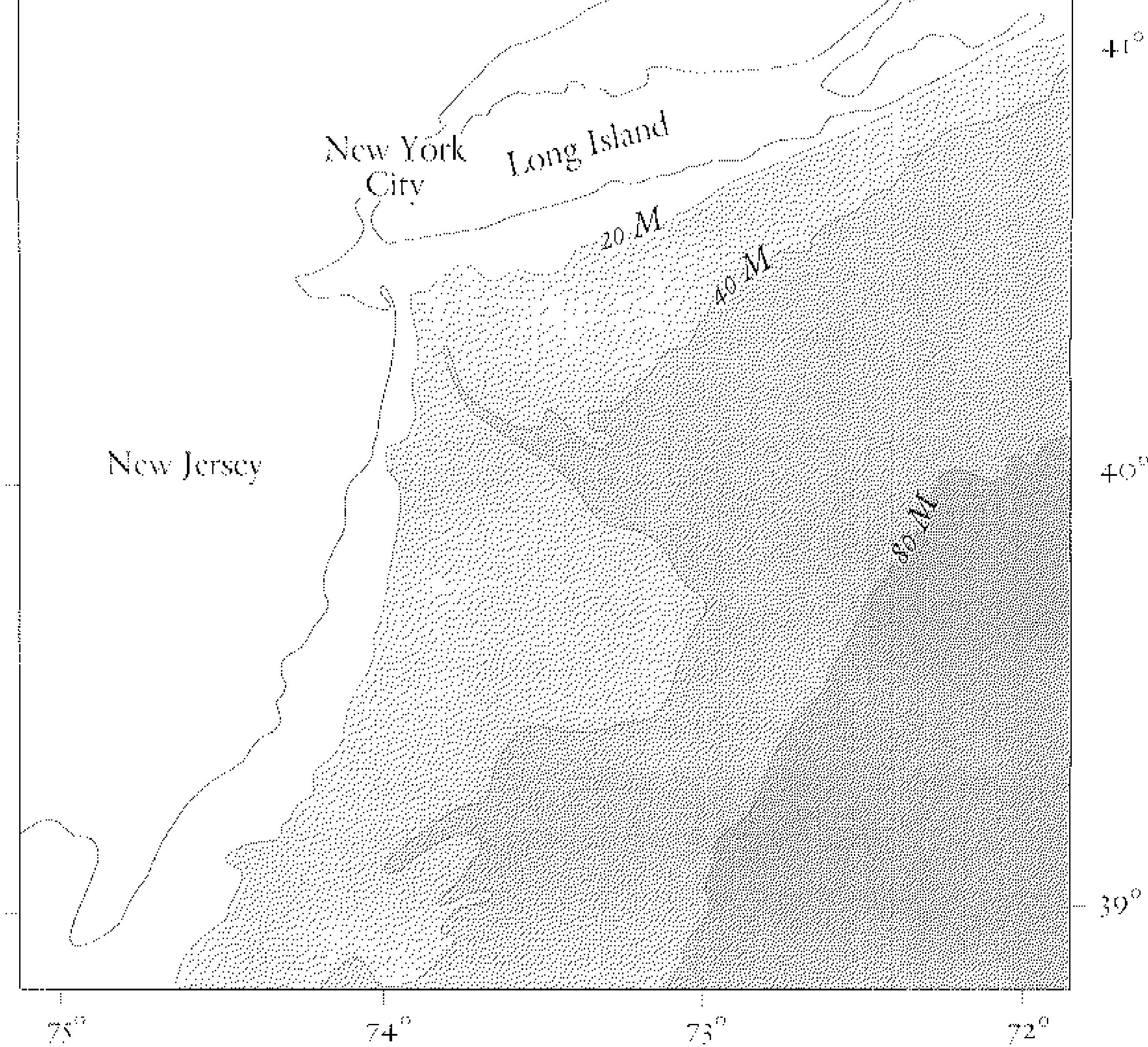
"All that trouble just to get to Brooklyn"

Vaudeville comedian


DESIGNATED LANDMARK
NEW YORK CITY
THE BROOKLYN BRIDGE
1867-1883
THE BROOKLYN BRIDGE, THE LARGEST SUSPENSION BRIDGE IN THE WORLD AT THE TIME IT WAS BUILT, WAS THE FIRST TO SPAN THE EAST RIVER. DESIGNED AND CONSTRUCTED BY JOHN A. ROEBLING AND HIS SON, WASHINGTON A. ROEBLING, THE BRIDGE SPANS 1,461 FEET AND RISES 133 FEET FROM THE RIVER BELOW. THE STEEL CABLEWORK, STRUNG ACROSS TWO MONUMENTAL STONE TOWERS, IS FIXED AT BOTH ENDS IN STONE ACHORAGES. THE BROOKLYN BRIDGE, A STRUCTURE OF BEAUTY, WAS A MILESTONE IN THE HISTORY OF AMERICAN ENGINEERING.
NEW YORK LANDMARKS PRESERVATION FOUNDATION
1991

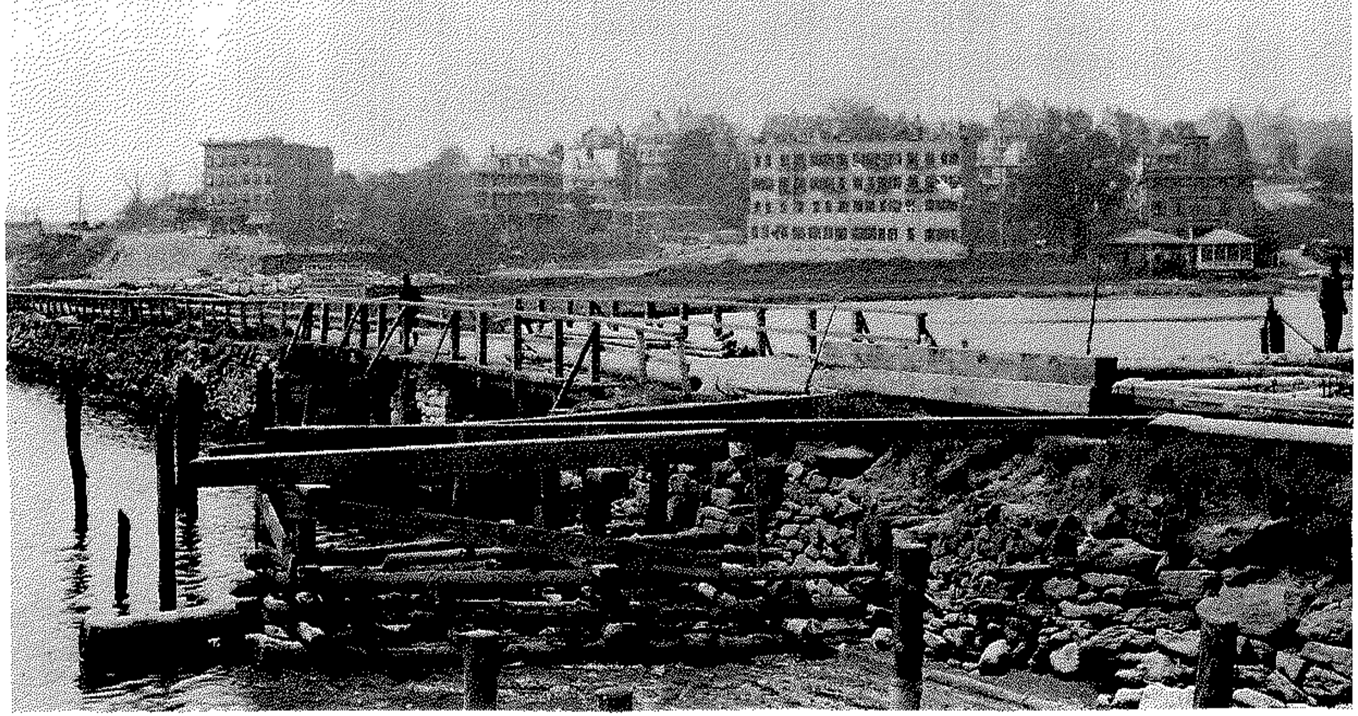
Part 2

Predecessors

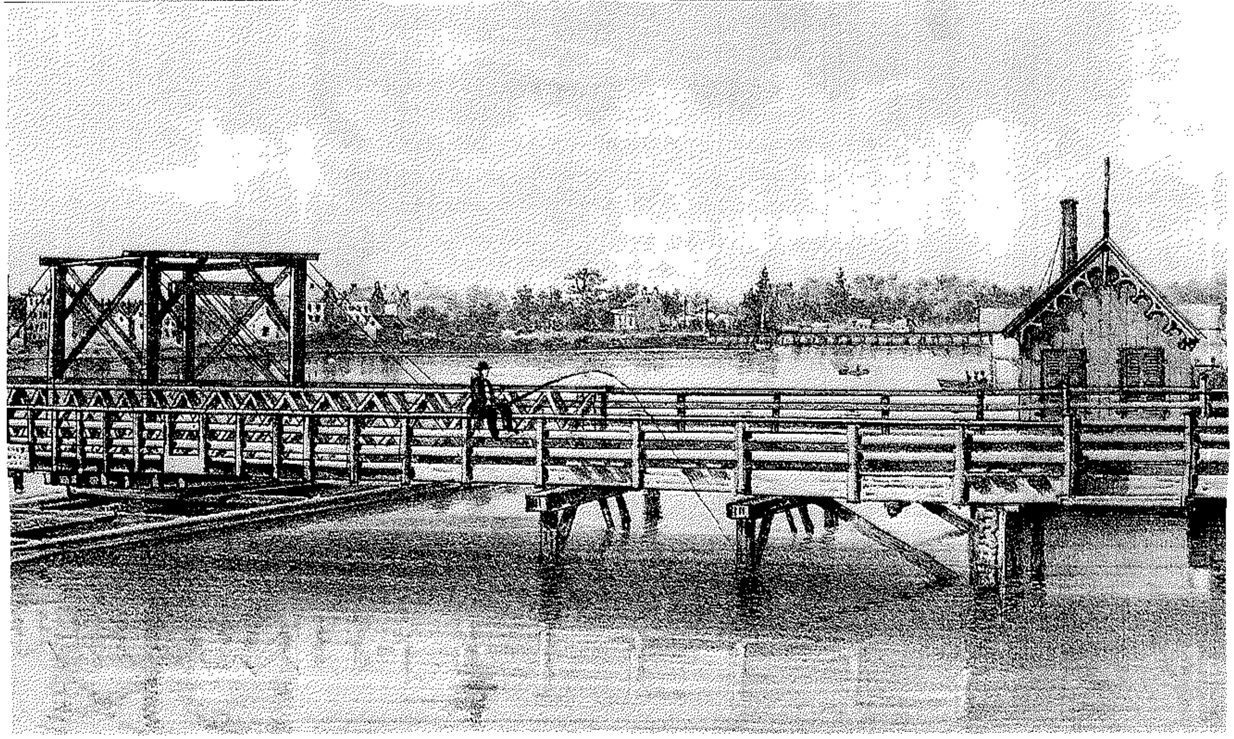


The NJ/LI shoreline (left to right);
Present Day / 6K / 8K / 10K years ago

This photograph of NYC's first bridge - over the *Spuyten Duyvil* (*In Spite of the Devil,* in Dutch) creek, was taken in 1917 before it was demolished and the creek land-filled. It was a private toll bridge owned by the Philipse family, opened for use in 1693. A heavy toll was charged to cross save for those in service to the King of England, thus it was named *Kingsbridge*.

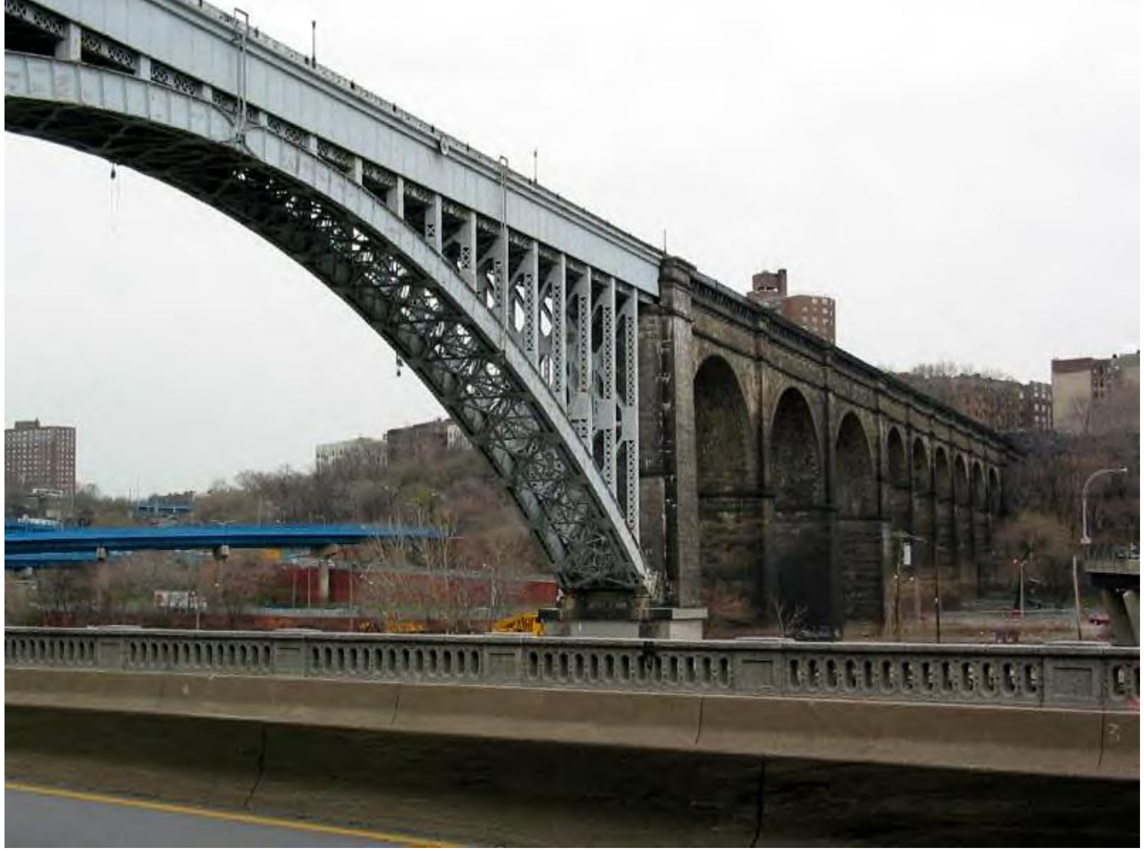


Then and now, New Yorkers don't suffer in silence, so it was inevitable that a wider, free bridge whereby farmers north of the city could bring their produce to market without going broke would one day be built. So it was that in 1758, at what is now W. 225th Street and Broadway in the Bronx, the *Farmer's Free Bridge* opened and tolls on *Kingsbridge* came to an end. In 1776, the original stone and timber drawbridge was destroyed by the British, but it was rebuilt after the Revolutionary War and served until 1911, when this photograph was taken (before its demolition).

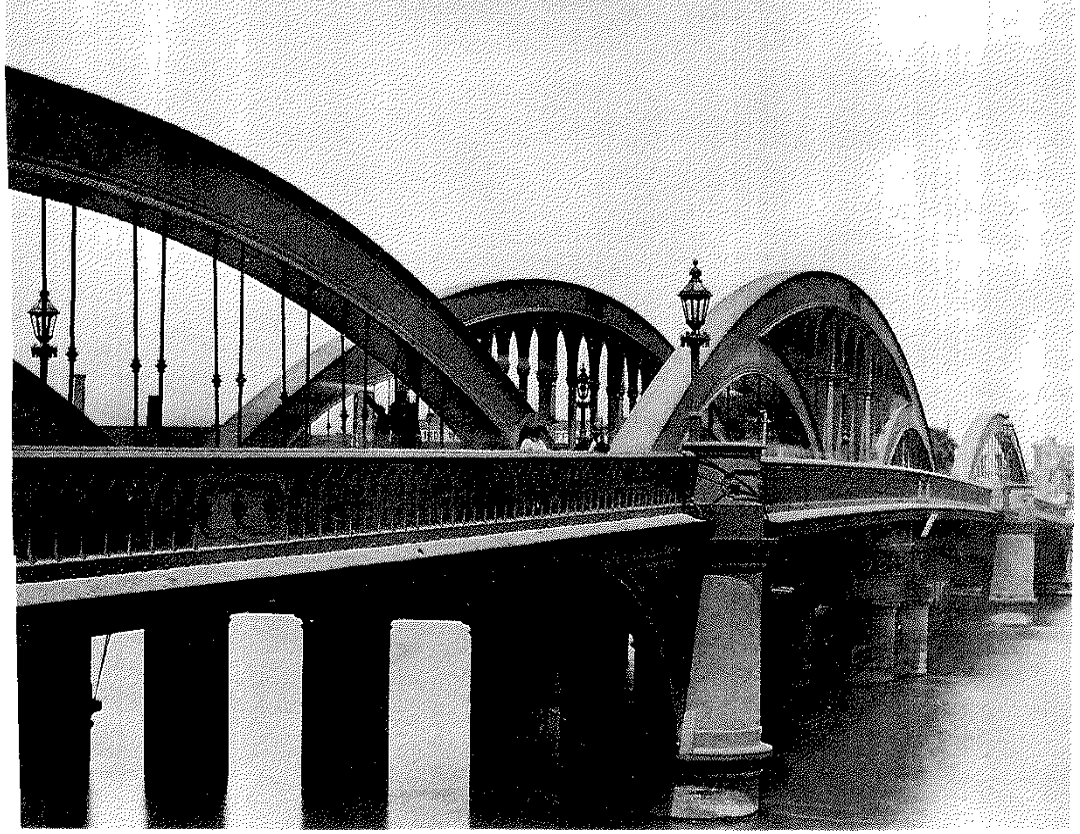


First promoted by Colonel Lewis Morris to connect Manhattan with the new Boston Post Road, he lost interest after losing his bid to make a part of the Bronx he owned the nation's capital. John B. Coles was then assigned the rights to construct a dam (serving also as foundation for the bridge and providing power to nearby watermills on the Harlem River), a lock and bridge. *Cole's Bridge*, as it was known, opened in 1797 and was a highly successful venture. It would be the first of four bridges subsequently named; *Third Avenue Bridge.*

The first truly grand bridge in NYC was built as part of the *Croton Aqueduct Project* to bring water into the growing city. Thus, its narrow roadway atop the water pipes below was a secondary function. More economical structures could have been built to carry the water across the Harlem River, but the NYC fathers wanted to make a bold statement to the world that NYC was fast becoming one of the great cities of the world by the mid-19th century. Opened in 1848 and designed by John B. Jervis, the design was influenced by Roman aqueduct designs.



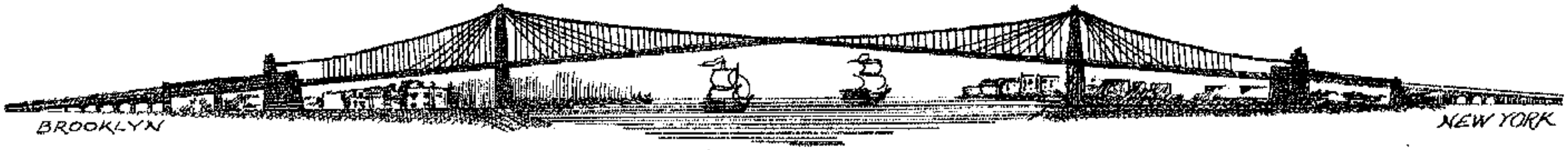
***High Bridge Aqueduct* today. With 80’-wide arches deemed too narrow by the Army Corps of Engineers and a new requirement of a minimum of one hundred feet of clearance for ships, the masonry arches over the river were demolished and replaced by a steel arch in the early 1920s. On the eve of America’s entry into WWI, the aqueduct was closed for fear of sabotage. Even today, High Bridge could supply NYC with water in an emergency.**

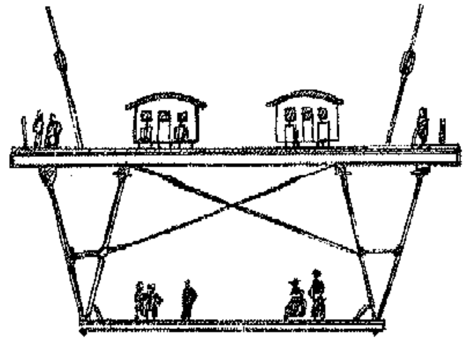


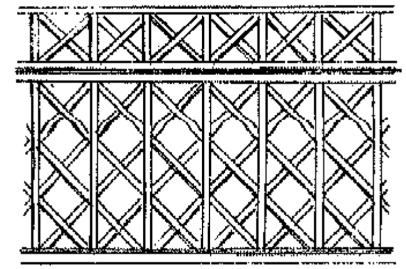
NYC's first iron bridge was a replacement for the earlier *Cole's Bridge* and NYC's first "swing bridge" over the Harlem River. Opened in 1868, the cast and wrought iron structure was plagued by cracking to its cast iron pier cylinders (and turntable wheels) and was buckling under its own dead weight (the ornamental iron alone weighed 100-tons). It would be replaced in 1898 by a larger swing bridge also known as the *Third Avenue Bridge*.

One Grand Flying Leap

That's how shipwright, carpenter, landscape gardener and visionary *Thomas Pope* described his *Flying Pendant Lever Bridge* that *"like a rainbow rising on the shore,"* could span either the East and/or Hudson Rivers (the latter in the rendering above). Though it was impractical and, of course, never realized, Pope is given credit for being the first person bold enough to suggest the spanning of the East/Hudson River/s with a bridge. In his 1811 treatise, he named his concept *Rainbow Bridge.*







Brooklyn contractor *William C. Kingsley* was a self-made man, socially and politically well connected and he was one of the driving forces behind the effort to span the East River with a bridge (he was not averse to turning a profit doing so). In this 1865 proposal for a suspension bridge over the East River (drawn by a consulting engineer Kingsley hired to gain publicity by publishing it in local newspapers), a very similar elevation (showing radiating cable stays), transverse cross-section (showing a double-deck roadway) and elevation (of the stiffening truss) to what John A. Roebling (JAR) would actually design a few years later (save for the double-deck roadway) is clearly evident.

William C. Kingsley

The first Brooklyn Bridge: *Breuklen Bridge* (Holland)

Part 3

Brooklyn

“The most magestic views of land and ocean, with panoramic changes more varied than any to be found within the boundaries of any city on this continent”

RE: Brooklyn’s varied topography. The word “Brooklyn” (*Brook-lyn*) is derived from the Dutch word for “broken land.”

Period painting showing the *Fulton Ferry* (foreground), the East River (busiest waterway in the world at the time), and the independent City of Brooklyn in the distance beyond (with its many church steeples). Brooklyn was considered the “moral capital of America” and it was a leader in the pre-Civil War abolishionist movement in the north.

***The Low-Lying Shore*. Village-like character of Brooklyn, captured in this artist's early 19th century painting.**

"Our institutions live in him, our thoughts as a nation breathe in him, our muscular Christianity finds in him the most vigorous champion. He is the Hercules of American Protestantism…"

The Brooklyn Eagle – RE: Henry Ward Beecher

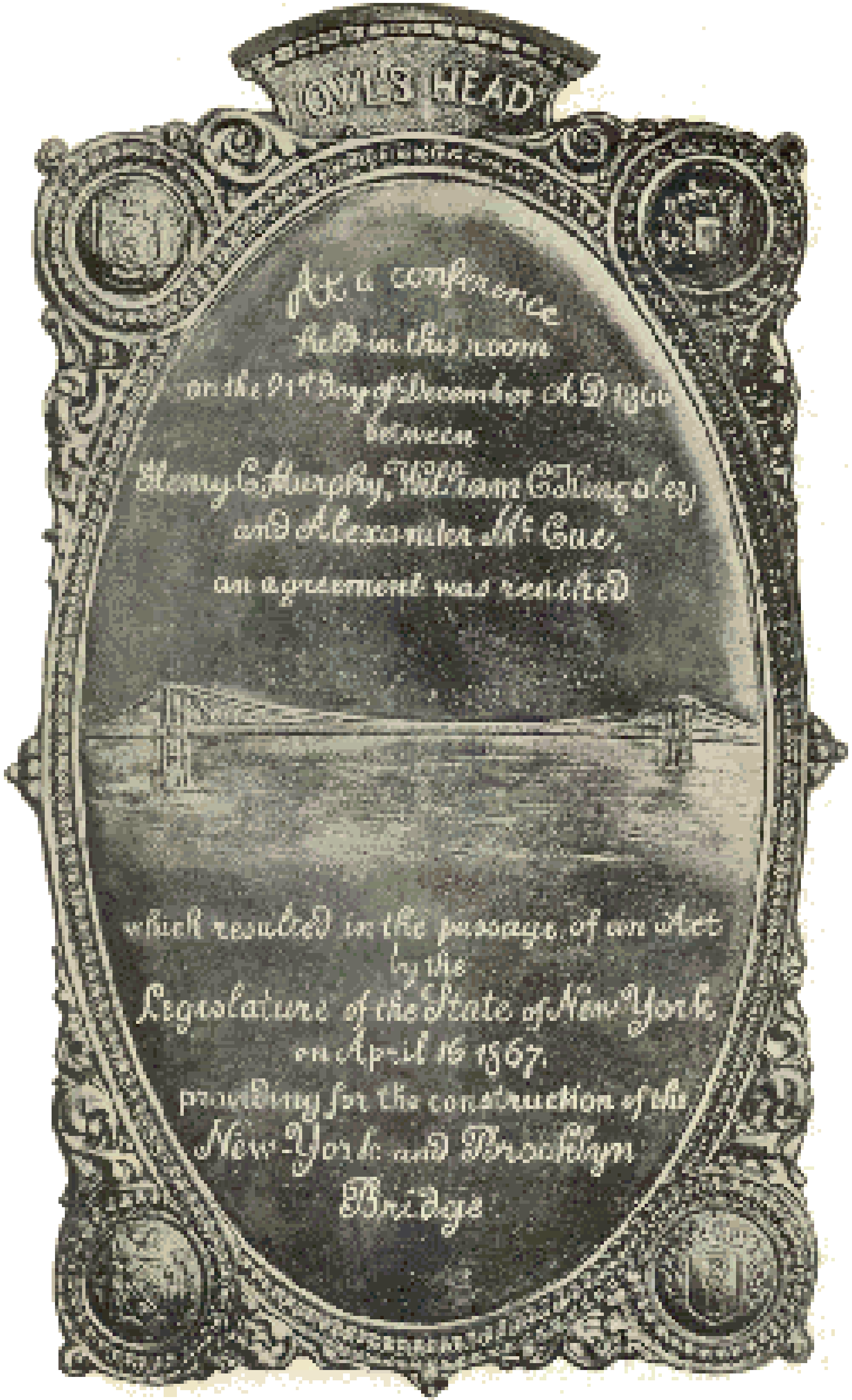
Henry Ward Beecher

"He went marching up and down the stage, sawing his arms in the air, hurling sarcasm's this way and that, discharging rockets of poetry, and exploding mines of eloquence, halting now and then to stamp his feet three times in succession to emphasize a point."

Mark Twain – RE: Henry Ward Beecher, Plymouth Church - Brooklyn

The Beecher Family
(Harriett Beecher Stowe at left)

As former Brooklyn Mayor, U.S. Congressman, founder of *The Brooklyn Eagle*, abolishonist and 3x NY State Senator for Brooklyn, *Henry Cruse Murphy* was Brooklyn's most prominent citizen. He would submit the bill to the NY State Senate which was passed on April 16, 1867 that formed *The New York Bridge Company* – a private corporation. Murphy would be acting president of the company until his death. His leadership was pivotal to the bridge's creation and, ultimately, its completion in 1883.



Plaque in *Owls Head Park* Commemorating the meeting held in Henry Cruse Murphy's house on the stormy night of December 21, 1866. William C. Kingsley and Judge Alexander McCue – a good friend of Murphy, went to seek Murphy's help in the NY State Assembly. As a long-time (Bay Ridge) Brooklyn resident, he was ambivalent about the need for a bridge but, critically, Kingsley and McCue convinced him to propose the bill that would form *The New York Bridge Company* in April of 1867.

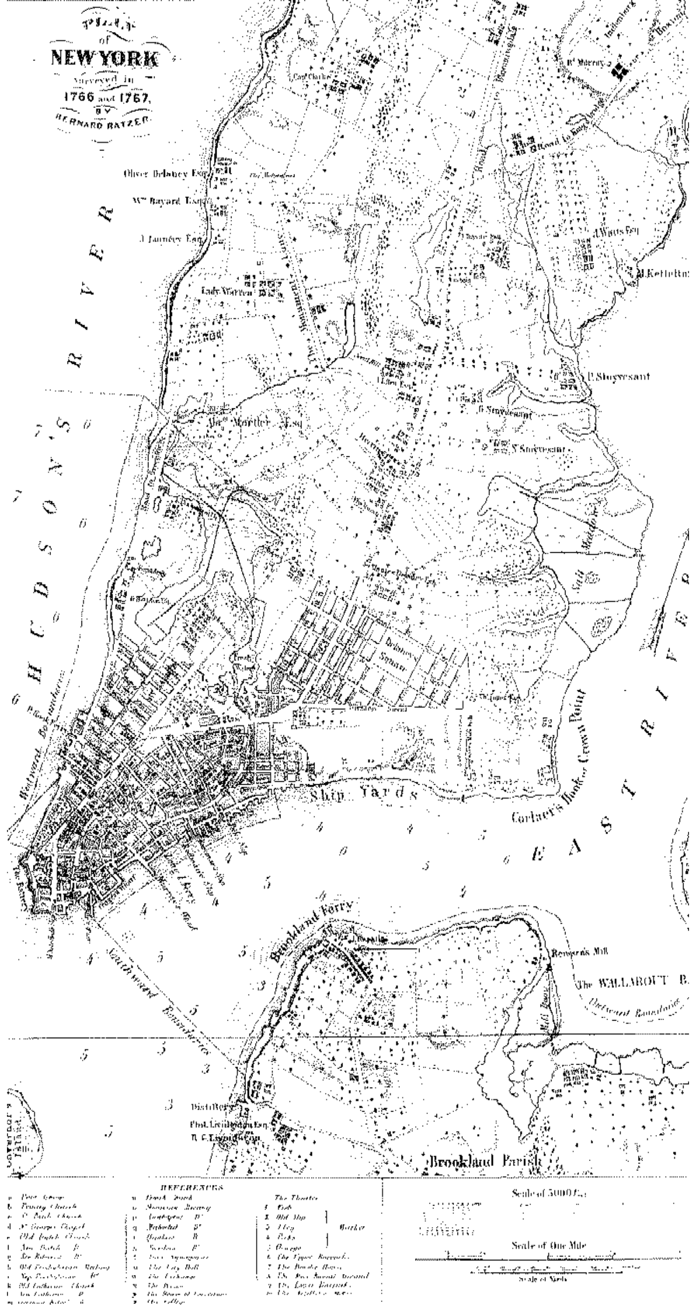
Part 4

New York

"Every man seems to feel he has got the duties of two lifetimes to accomplish in one, and so rushes, rushes, and never has time to be companionable – never has time at his disposal to fool away on matters which do not involve dollars and duty and business."

Mark Twain – observation upon his arrival in New York from California

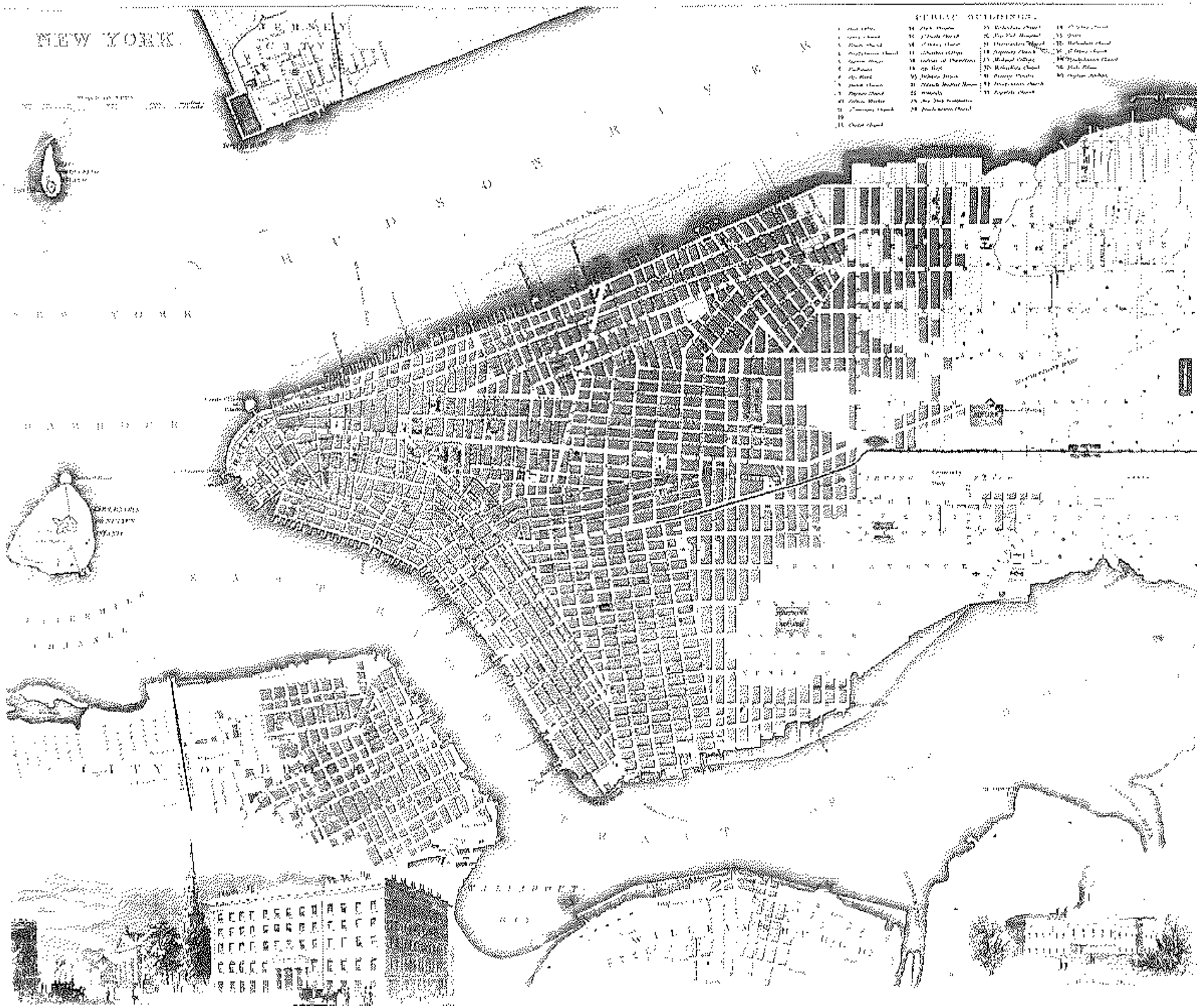
The Five Points - NYC



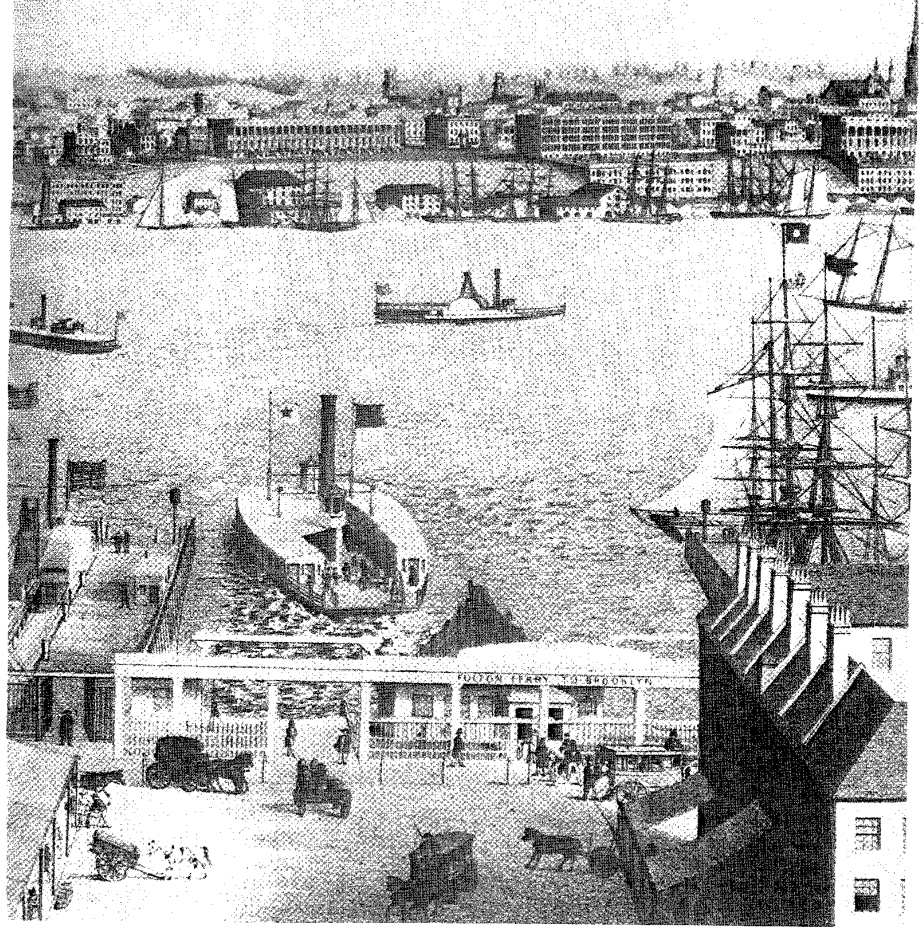
Map of NYC ca. 1767

"Nothing could be more depressingly miserable than these wooden hovels, these long muddy streets, and this impoverished population…one of the worst lighted, worst paved, worst kept cities in the world…the East's large cities offer a rich field for clever money lovers"

New York City in the late 1860's



NYC & Brooklyn ca. 1848



Fulton Ferry Landing **New York (foreground),** ***Fulton Ferry Landing*** **Brooklyn (opposite). The bridge would be located adjoining these two ferry landings since it made sense to do so. Most bridges, even today, are located where ferryboats once operated since it is usually the shortest distance across and existing infrastructure such as roads, trolley/rail lines etc. feed into them.**

Part 5

The Debate

"What are these huge castles running madly across the East River? Let us cross in the Montauk from Fulton Ferry and survey the freight. There are fourteen carriages, and the passengers are countless – at least 600. Onward she darts at headlong speed, until, apparently in perilous proximity to her wharf, a frightful collision appears inevitable. The impatient yankees press – each to be the first to jump ashore. The loud "twong" of a bell is suddenly heard; the powerful engine is quickly reversed, and the way of the vessel is so instantaneously stopped that the dense mass of passengers leans forward from the sudden check."

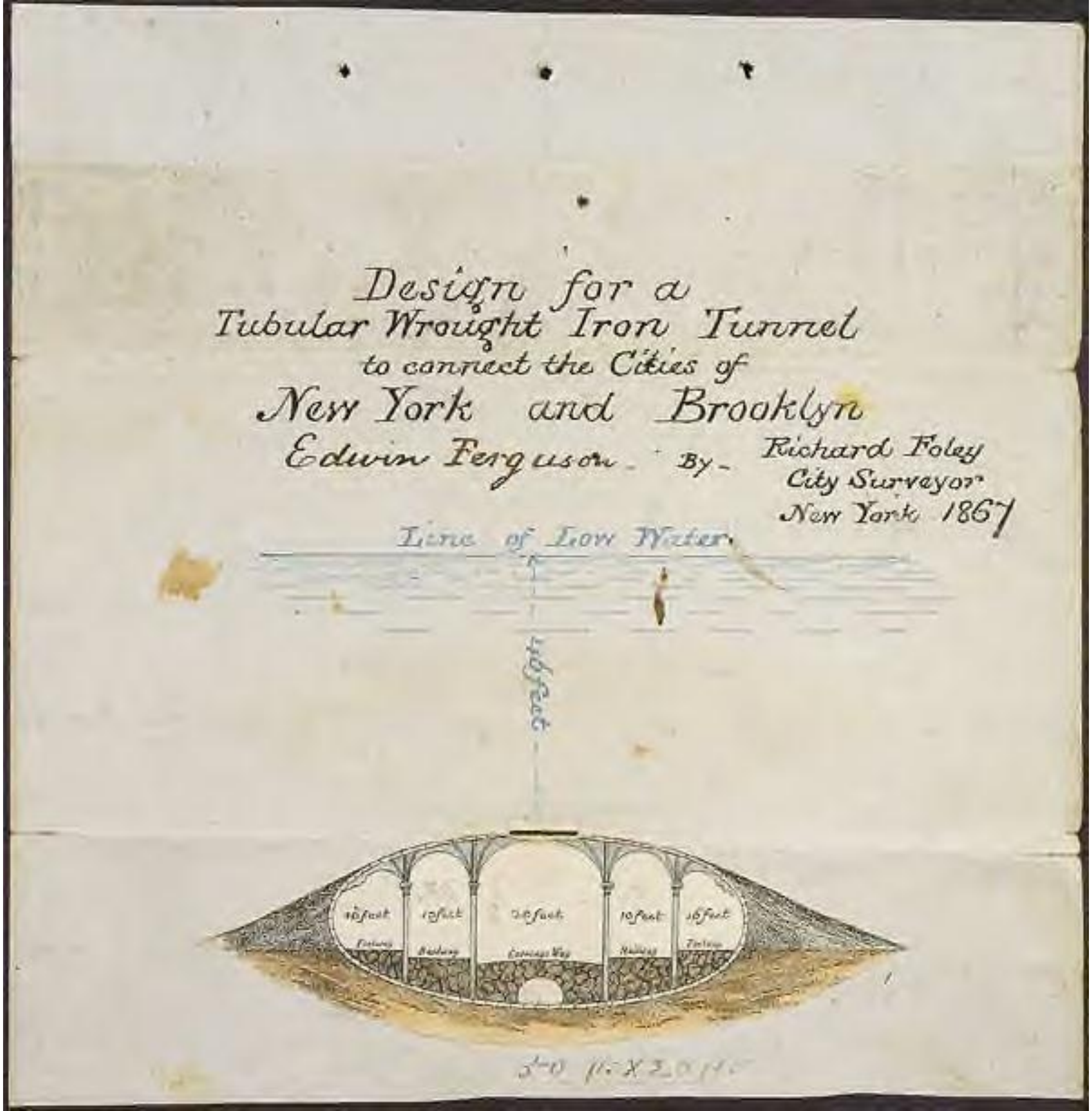
Visiting Englishman's comments on crossing to Brooklyn by ferry

"Ferries are rapidly becoming unequal to the immense and swiftly increasing intercourse between counting house and home so to many thousands of our citizens. The only thing to be thought of is a bridge…affording passage to a steady stream of vehicles and pedestrians."

New York Tribune

"The East River Bridge project has resolved itself into an impractical tunnel scheme, and for some time to come it's likely that the East River will be spanned only by bridges of ice"

Harper's Weekly*, 1867 – commenting on the poor progress of the East River Bridge in an article praising the completion of JAR's *Cincinnati-Covington Bridge


Design for a
Tubular Wrought Iron Tunnel
to connect the Cities of
New York and Brooklyn
Edwin Ferguson By - Richard Foley
City Surveyor
New York 1867
Line of Low Water
40 feet
10 feet
10 feet
Railway
Carriage Way
Railway

The Winter of 1867

Memorable for being one of the coldest in NYC/Brooklyn history. In the scene above, commuters who normally required a ferry to get across the river could walk across on a solid sheet of ice. All river commerce came to a stop.

In the 19th century, the East River rather than the Hudson was the main port-of-call and focus of ship-building & repair. From Buttermilk Channel to Greenpoint on the Brooklyn side, warehouses lined the shore. Goods arriving by ship were transported across Manhattan Island then by barge to NJ where the railheads were located. The East River was preferred as a port since it is not a river at all but, rather, a tidal strait thus it is comprised wholly of salt water. On the other hand, the Hudson River is a true river and consists of brackish water – part fresh, part salt water in the vicinity of Manhattan Island so it is/was more prone to freezing than the East River. Most commerce – and ferryboat service, came to a halt when the East River froze that winter and it dramatized the need for a bridge. To rub it in, John A. Roebling's *Cincinnati-Covington* suspension bridge opened in 1867. If Cincinnati could have a Roebling bridge across the Ohio River, certainly NY could have an even greater Roebling bridge across the East River.

Part 6

A Lesser Leonardo

"No Man was ever great by imitation"

John Augustus Roebling's favorite quote

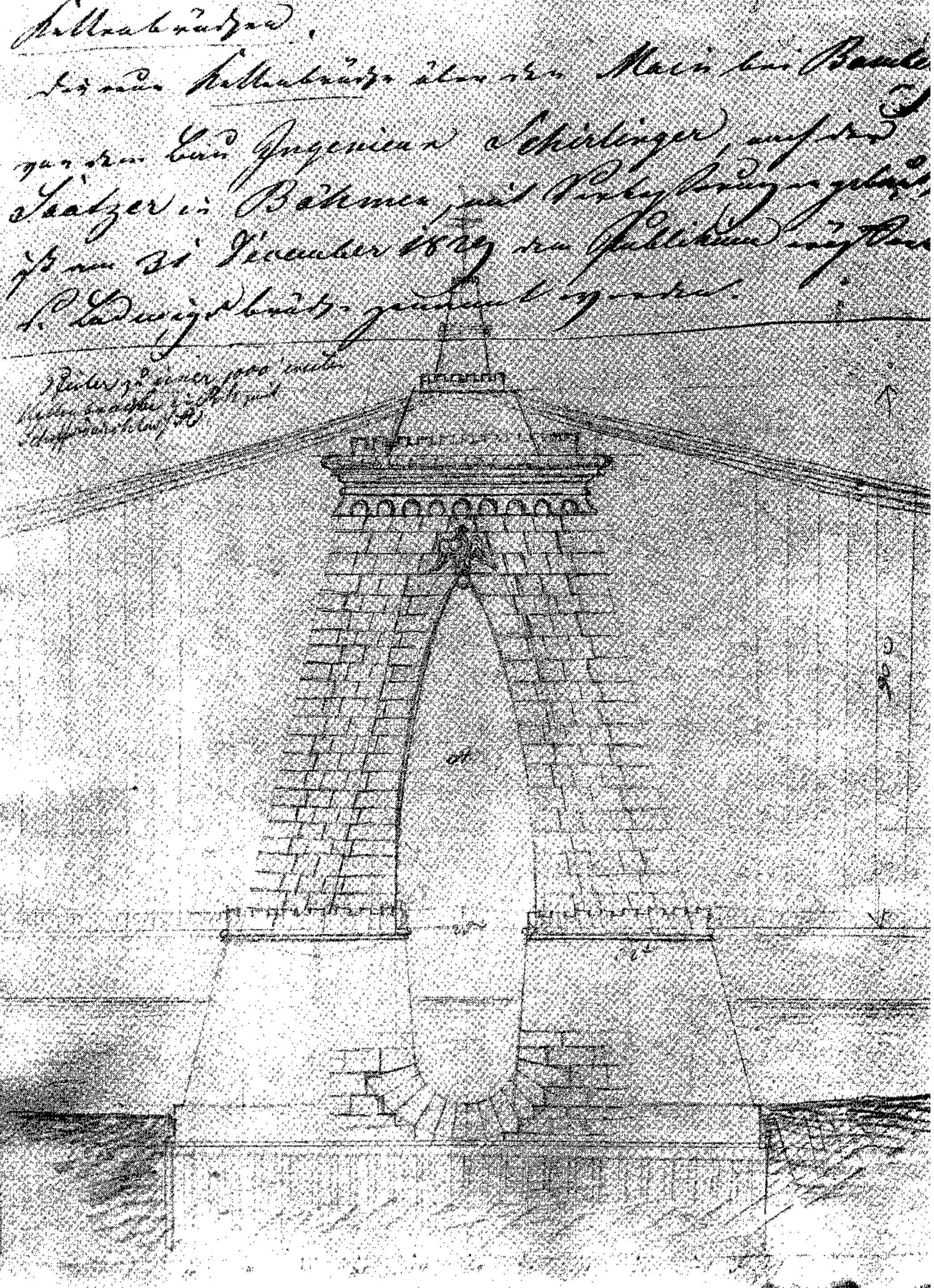
"One of his strongest moral traits was his power of will, not a will that was stubborn, but a certain spirit, tenacity of purpose, and confident reliance upon self…an instinctive faith in the resources of his art that no force of circumstance could divert him from carrying into effect a project once matured in his mind."

C.B. Stuart, Engineer

John Augustus Roebling

"Before entering upon any important work, he always demonstrated to the most minute detail its practicability...and when his own judgment was assured, no opposition, sarcasm, or pretended experience could divert him from consummating his designs, and in his own way."

RE: John Augustus Roebling



Early suspension bridge design by JAR

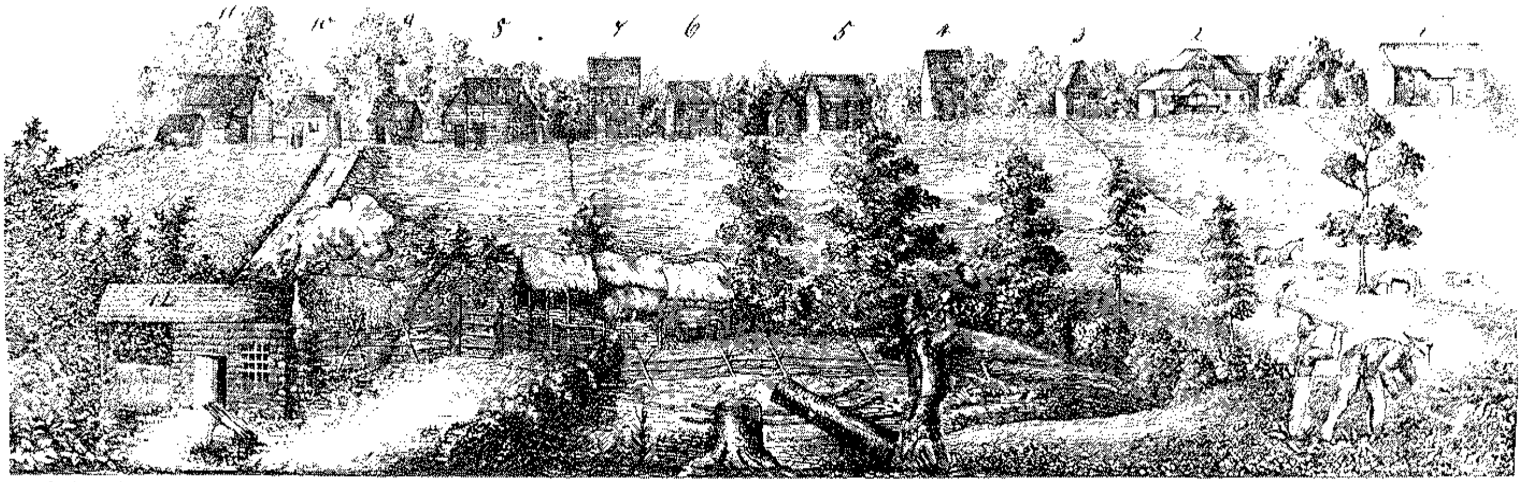
John Augustus Roebling was born on June 12, 1806 in the town of Muhlhausen in the German state of Saxony to a middle-class family. His grandmother recognized his genius and saved enough money to allow him to attend the prestigious *Berlin Polytechnic Institute*. He studied architecture, bridge construction, hydraulics, linguistics and philosophy under Thomas Hegel who remembered him as his favorite student. While working for the Prussian government building roads, he saw a suspension bridge in Bavaria and decided then and there he would be a bridge builder.

"...was the land of desire for all those who are weary of the historical lumber room of old Europe"

Hegel – JAR's philosophy professor - on emigrating to America

"It is not contempt for our Fatherland that causes us to leave it…it was an inclination and an ardent desire that our circumstances be bettered"

J.A. Roebling



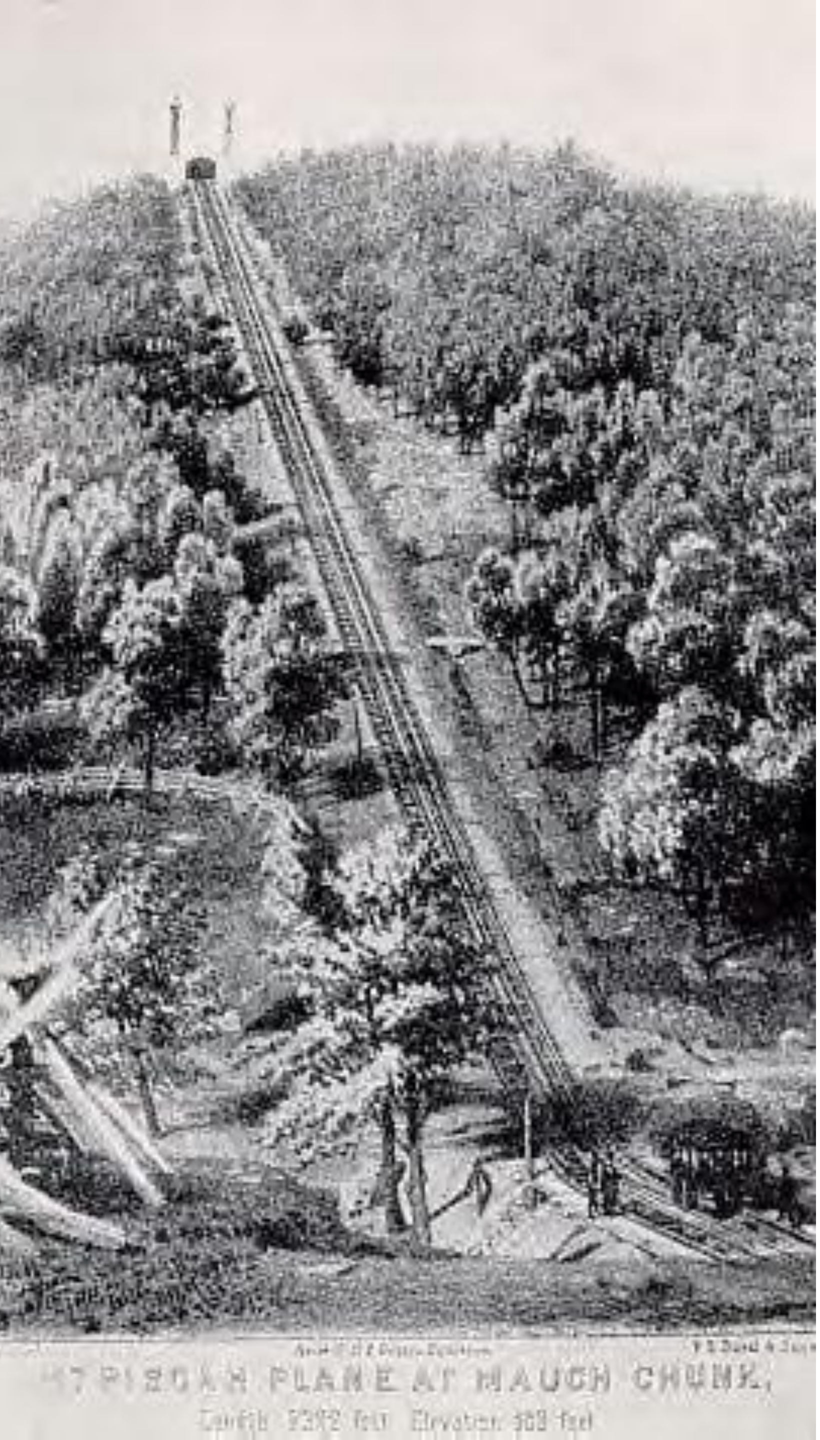
Nach der Natur gezeichnet von T. Oeswrisch im Juli 1835. Steindruck von F. W. Beblung in Mühlhausen

Sachsenburg,
Colonie von Thüringern und Sachsen bei Pittsburg.
(Von der Südseite.)

Upon Hegel's advice JAR, his brother and a small group left Germany for America intending to establish a utopian community on 7K acres in Butler County, Western Pennsylvania. They named it *Saxonburg*. JAR was not cut-out to be a farmer and began working for the State of Pennsylvania as a surveyor. In 1836, he married Johanna Herting – a fellow immigrant, and they began to raise a large family. He named his first-born son *Washington*, in honor of his friend *Washington* Dell – a fellow surveyor, not George *Washington*, as is commonly believed.

"I have found all that I sought: a free, reasonable, Democratic government and reasonable, natural relationships of the people toward each other; freedom and equality; a peaceful, generous, beautiful country the blessings of which are not forcefully and deceitfully taken away from the land toiler by tyrants"

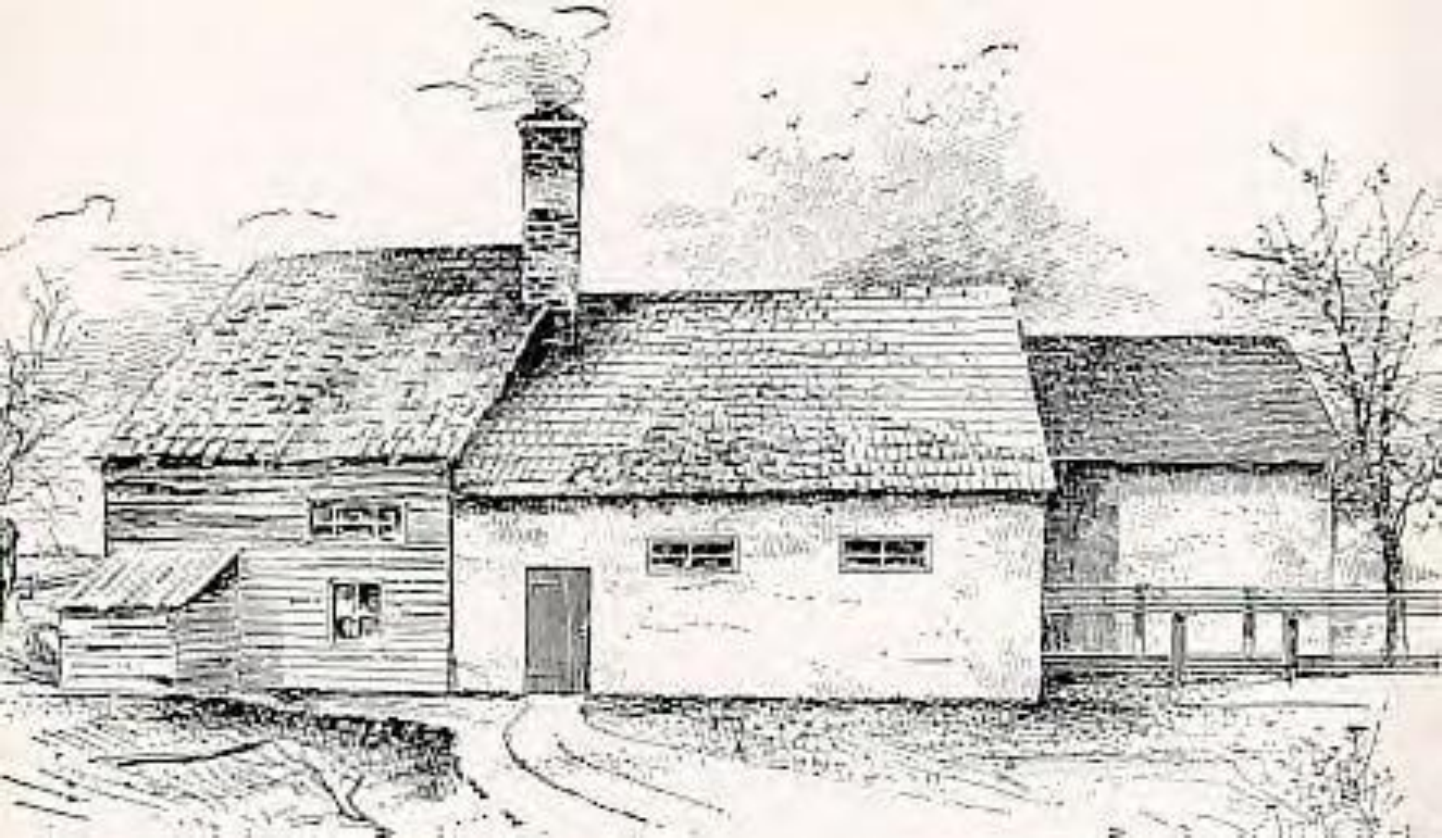
John Roebling, 1831



Portage Rail Road
(over the *Allegheny Mountains*)

A nine-inch diameter hemp rope was used to pull canal boats up the inclined plane, but there were many failures of the rope. In Germany, JAR had read about *wire rope* (just one-inch thick), being as strong or stronger than much larger diameter ropes. In 1841, working from his home in Saxonburg, he fashioned a 600-foot long by one-inch thick wire rope to be compared in strength with nine-inch hemp rope. After tampering by the hemp rope interests was discovered, JAR's wire rope passed the strength test and orders started to flood in. Wire rope made JAR a very wealthy man.

JAR's first make-shift wire-rope factory
Saxonburg, PA



JAR’s first wire-rope factory
Trenton, NJ


ROEBLING'S
WIRE ROPE
For Best
IRON or STEEL WIRE HOISTING, RUNNING or STANDING ROPES, or BEST GALVANIZED CHARCOAL WIRE ROPES FOR SHIP'S RIGGING,
Address, JNO. A. ROEBLING'S SONS, Manufacturers,
Trenton, N. J. or 117 Liberty St., N. Y.
Wheels and Rope for transmitting power long distances. Send for Circular and Pamphlet.

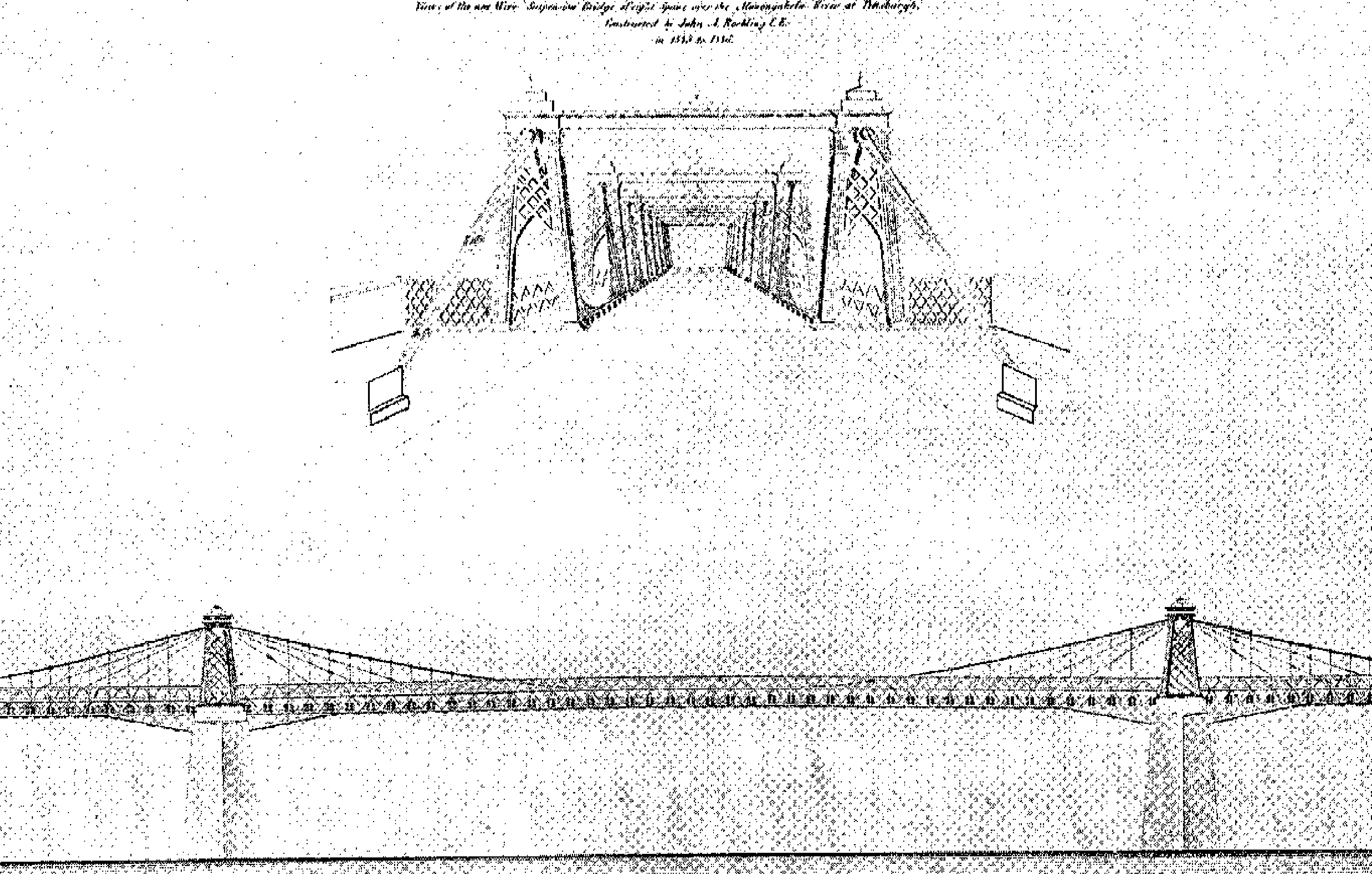
"Their grounds cover 14 acres, and within the walls are five rolling mills, and all the buildings needed for their 350 workmen and office purposes…Their products amount to three-quarters of all the wire rope made in this country. It was a rare sight to watch these busy workmen taking blocks of red-hot steel in their tongs from white-heat furnaces, passing them through rolling mills which stretched them until they lay upon the iron floor like interlacing snakes in bizarre shapes, ready to be carried by other hands to annealing furnaces, and thence through other draw plates until the wire was prepared to bind together either the delicate handiwork of the jeweler or the two cities of New York and Brooklyn with their millions of inhabitants."

Brooklyn reporter's account of touring John A. Roebling & Sons, Trenton, NJ, 1876

Upper Works of John A. Roebling & Sons Co. (JAR&S)
Trenton, N.J.
(one of three *Roebling Works*)

"...there are no safer bridges than those on the suspension principle, if built understandingly, and none more dangerous if constructed with an imperfect knowledge of the principles of equilibrium."

John Roebling, 1854 – excerpt from letter to railroad officials concerning the *Niagara* bridge after the collapse of the *Wheeling* bridge in 1854



Early JAR Suspension Bridge

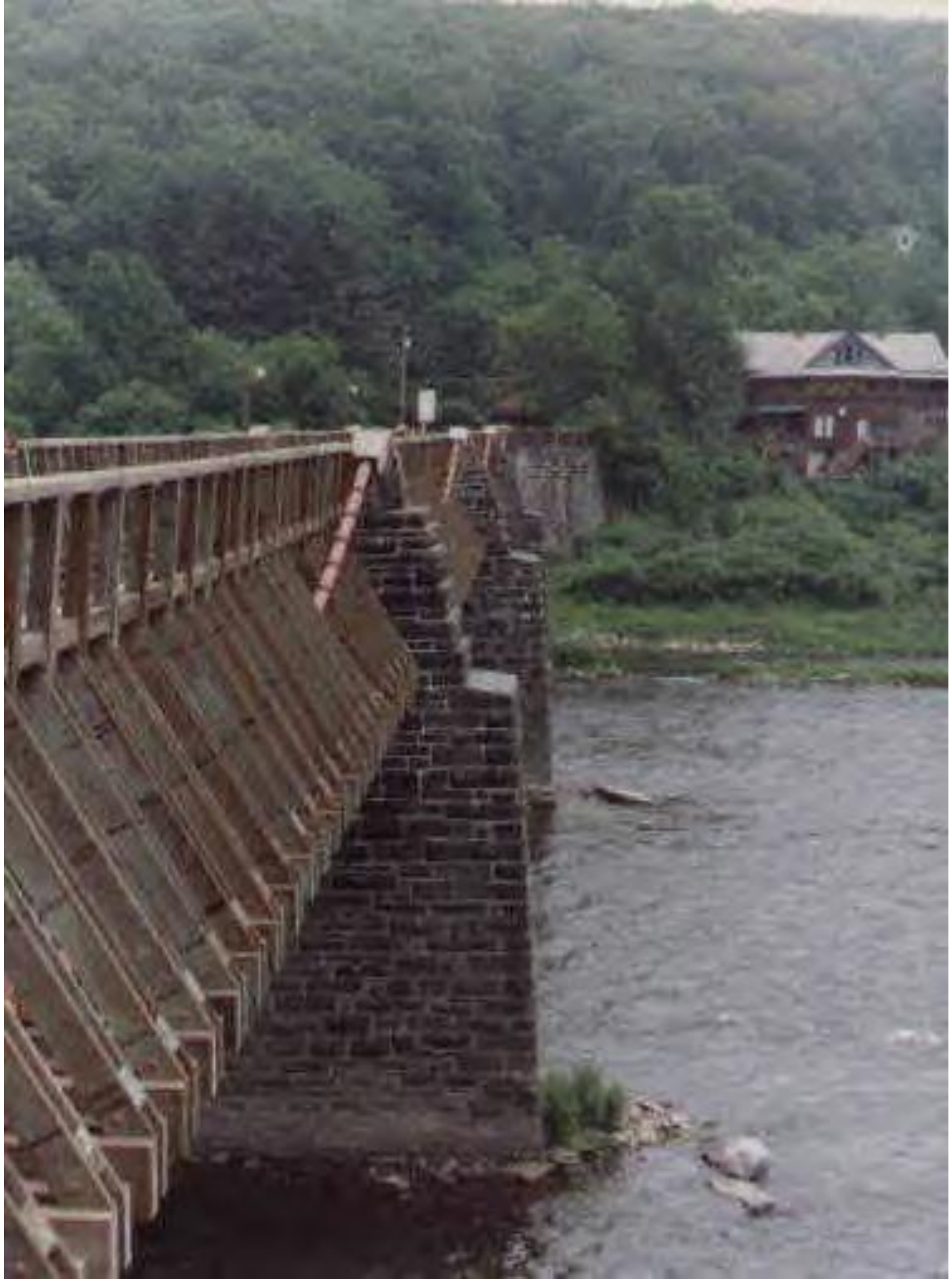
Pittsburgh, PA

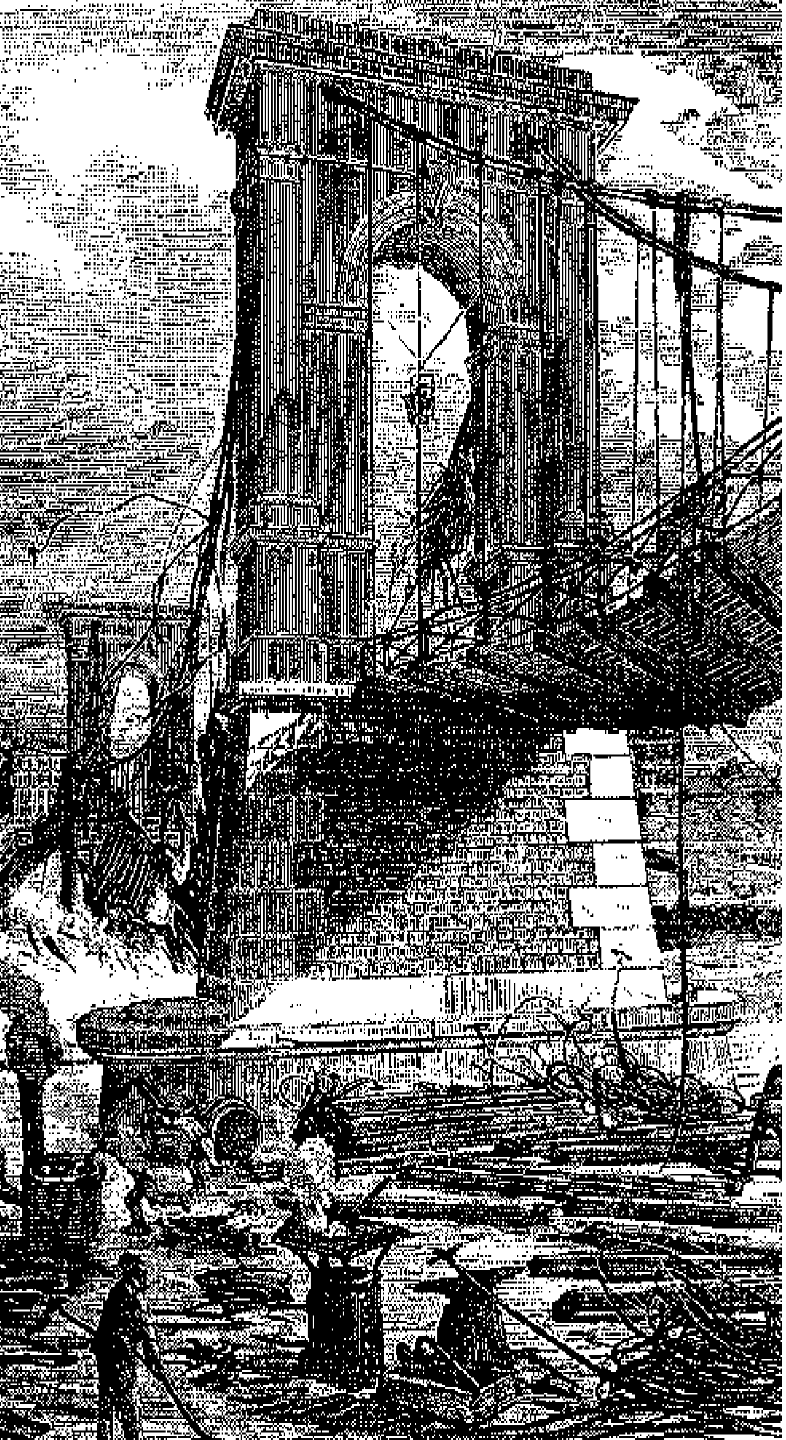
"A force at rest is at rest because it is balanced by some other force or by its own reaction"

J.A. Roebling, quote from *Scientific American* article

Suspension Aqueduct over the Delaware River by JAR

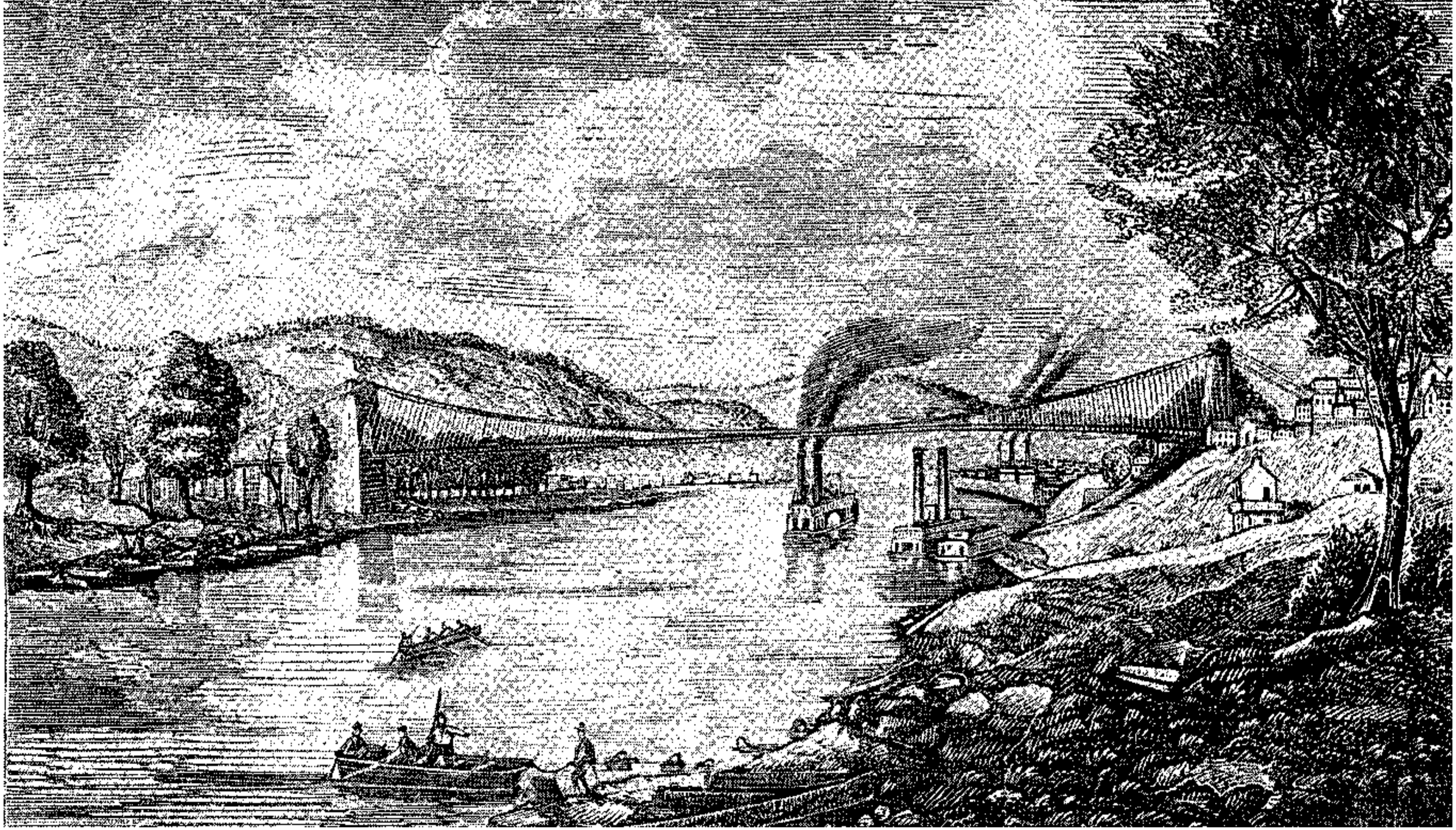
In 1844, JAR won a contest to build a suspension aqueduct over the Allegheny River, this would be the first of several spans of 160-feet each carrying 2K tons of water via two(2) seven-inch diameter wire cables. Costing $62K/ea, these aqueducts demonstrated the cost-effectiveness and ability of suspension bridges supported by wire cables to carry great weights safely. Transformed from an aqueduct into a road-bridge, this is the only aqueduct suspension bridge by JAR still in existence.





Collapse of a suspension bridge over the Siene River, France

This bridge collapsed as a result of a troop of French soldiers marching across in lock-step/cadence. This set-up harmonic vibrations in the structure that caused it to fail. Well into the 20th century, it was taboo to march across a bridge in lock-step, break-step/cadence was the norm. In the 19th century, 25% of all suspension bridges failed as a result of an imperfect understanding by their designers of the static/dynamic forces acting upon them. A JAR suspension bridge never failed and he would be the only person considered to design the E. River bridge.



Wheeling Suspension Bridge **by Charles Ellet**

Ellet was JAR's only real rival as a bridge builder. When this bridge was partially destroyed in a wind storm, JAR was hired to study the failure and rebuild it. JAR would add cable stays and stiffening trusses to stabilize the bridge in the wind. A Union naval officer, Ellet was killed-in-action at the Battle of Memphis.

"…was destroyed by the momentum acquired by its own dead weight, when swayed up and down by the wind…A high wind, acting upon a suspended floor, devoid of inherent stiffness, will produce a series of undulations…which will increase to a certain extent by their own effect, until by a steady blow a momentum of force may be produced, that may prove stronger than the cables. And although the weight of the floor is a very essential element of resistance to high winds, it should not be left to itself to work its own destruction. Weight should be simply an attending element to a still more important condition, viz: stiffness."

John Roebling, 1854 – excerpt from report on failure of the *Wheeling* bridge

"You drive over to Suspension Bridge and divide your misery between the chances of smashing down two-hundred feet into the river below, and the chances of having a railway-train overhead smashing down onto you. Either possibility is discomforting taken by itself, but, mixed together, they amount in the aggregate to positive unhappiness."

Mark Twain, 1855 – commenting on JAR's newly completed *Niagara* (a.k.a. *Suspension / International*) bridge

Begun in 1851 by Charles Ellet (he resigned over a pay dispute) and completed by JAR in 1855, *Niagara Bridge* put JAR on the map as a great bridge engineer. Because a boat could not be used (the river has treacherous currents), the first wire was carried across by kite. The bridge had two levels, the lower for carriages and the upper a single track for trains. The track had to be above since steam engines of the day released scaldingly hot steam from their boiler stack. Suspension bridges are not ideal for carrying heavy live-loads such as a train due to their inherent flexibility, a more rigid design such as an arch or cantilever works best. Trains crossing the Bridge had to move across slowly, never at full speed because of the excessive movement that would be introduced.

"My bridge is the admiration of everybody, the directors are delighted. The woodwork goes together in the best manner. The suspenders require scarcely any adjustment at all."

John Roebling, 1854 – RE: *Niagara* bridge

"The triangle is the only unchangeable figure known in geometry…"

John Roebling – referring to his trademark: *inclined cable stays*

"I have always insisted that a suspension bridge built without stays is planned without any regard to stiffness, and consequently is defective in a most important point."

John Roebling

The modern cable-stayed bridge is a variation of JAR's inclined cable stays for his suspension bridges. Unlike JAR's cable stays, in the modern version the cable-stays are the main support for the road-deck. JAR used cable stays for two auxiliary purposes; to act as a damper (to reduce movement of the suspender cables) and to assist in supporting the weight of the road deck. The wire main cables provide the primary support of the road deck in a JAR suspension bridge.

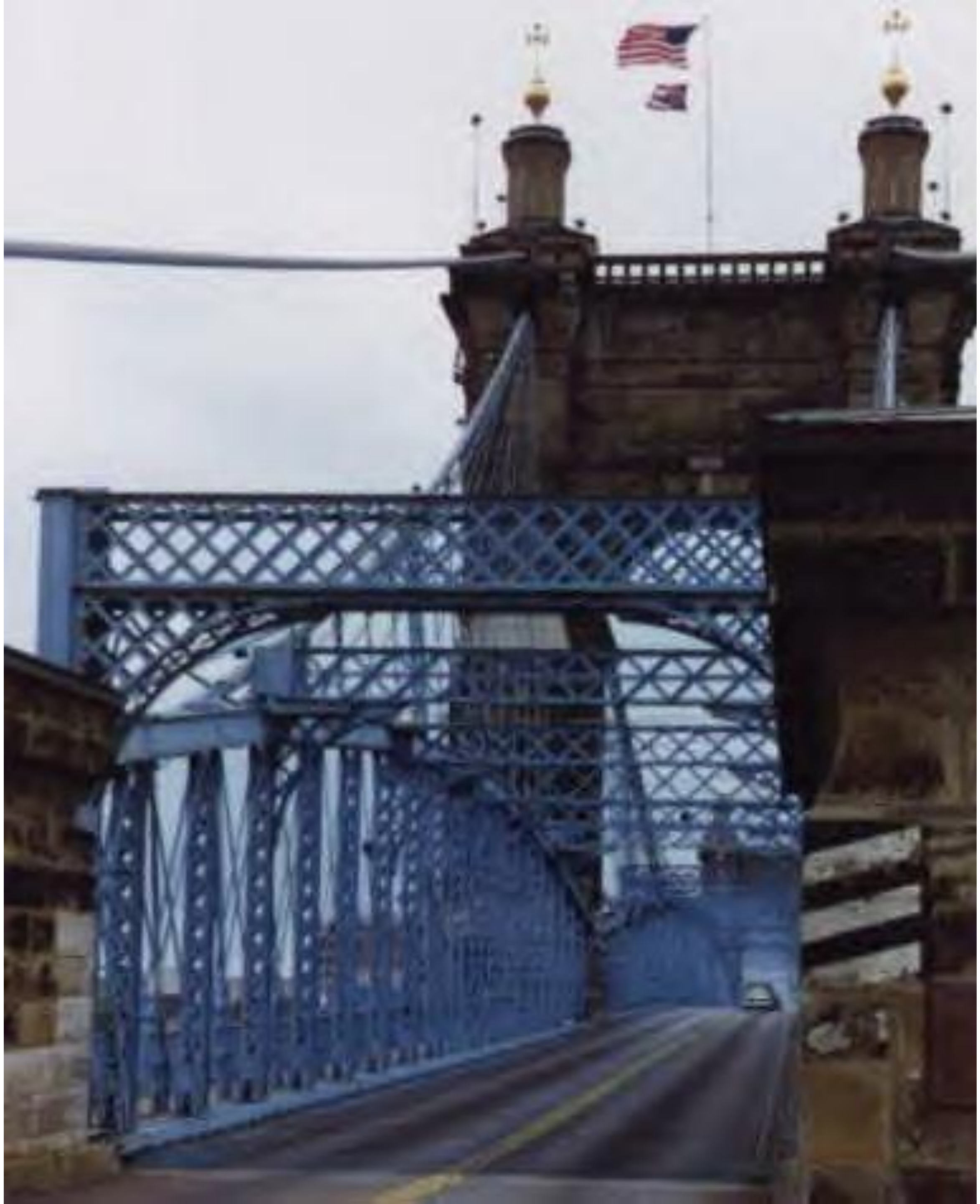
Sunshine Skyway **cable-stayed bridge**

Tampa, Florida

Modern cable-stay bridges are subject to tremendous vibrational forces acting on the cable-stays and require dampers below the roadway to reduce - but not eliminate entirely, this effect (akin to a guitar string being plucked). JAR got the idea for cable stays by studying the rigging of the sailing ship he came to America on in the early 1830s. He saw that a rope hanging eccentrically would move unhindered in the wind. To reduce this movement, sailors ran a rope across it and the movement was dramatically reduced. If the suspender cable is moving, so is the road-deck. By stabilizing the suspender with the dampening effect of the cable-stay, movement of the deck in the wind is dramatically reduced.

***Allegheny River Bridge*, 1857 by JAR**
Pittsburgh, PA

The *Cincinnati-Covington Bridge* was begun before the Civil War and completed in 1867. It still connects Cincinnati, Ohio with Covington, Kentucky spanning the Ohio River. It was in many respects the forerunner of the Brooklyn Bridge from a design, construction and aesthetic perspective and it was the first bridge father and son – John and Washington Roebling, worked on together. By 1867, Washington Roebling was an experienced bridge builder having built several railroad bridges serving as an engineering officer in the Union Army during the Civil War. His father realized his abilities as an engineer and leader from working with him on this bridge. He was quoted as saying: "*Leave bridge building to the younger folk*" – JAR was 63yo in 1869, the year work on the Brooklyn Bridge would begin.



Statue of JAR
Covington, Kentucky

Now He Belongs to the Ages

"Invaluable to this enterprise in its infancy"

W.C. Kingsley

RE: the untimely death of JAR (Kingsley paid for JAR's Funeral). JAR's foot was crushed on a piling when it got caught and a ferry (traveling too fast) ran into the piling. JAR was a believer in water cures and refused any treatment other than water poured onto the wound. Lockjaw was the result and he died a horrible, needless and premature death in June 1869 – at the outset of the surveying work, for the Brooklyn Bridge.

"He who loses his life from injuries received in the pursuit of science or duty, in acquiring engineering information or carrying out engineering details, is as truly and usefully a martyr as he who sacrifices his life for a theological opinion, and no less honor should be paid to his memory. Henceforth we look on the great project of the Brooklyn Bridge as being baptized and hallowed by the life blood of its distinguished and lamented author."

***The Brooklyn Eagle*, 1869**

"He spoke our language imperfectly, because he had not the advantage of being born on our soil, but he spoke the genuine language of America at Cincinnati, Pittsburgh and Niagara..."

The Brooklyn Eagle

"You will build that bridge"

JAR, June 1869

RE: Suffering terribly from halucinations and incredible pain, JAR had a lucid moment, sat up in his bed and looked his eldest son Washington in the eye and made this deathbed directive to his able heir, then he collapsed backwards and died.

Part 7

Pontifex Maximus

"That terrible treadmill of facing an avalanche of figures and facts into young brains not qualified to assimilate them as yet…I am still busy trying to forget the heterogeneous mass of unusable knowledge that I could only memorize, not really digest."

Washington Roebling – commenting on his formal education at RPI

Washington A. Roebling

When he was a student at *Rensselear Polytechnic Institute* (RPI)

(ca. 1858)

“With their close ties to private industries, their willingness to design their curricula to meet industrial needs, such schools fostered specialization of functions”

RE: RPI. The *U.S. Military Academy* at West Point, NY was the main source of engineering graduates in the mid-19th century - they were in high demand by both the military and private industry. Engineering was a well-paying and socially respected occupation, especially at the height of the industrial revolution.

Rensselear Polytechnic Institute (RPI)

Troy, NY

Washington Roebling's curriculum at RPI;

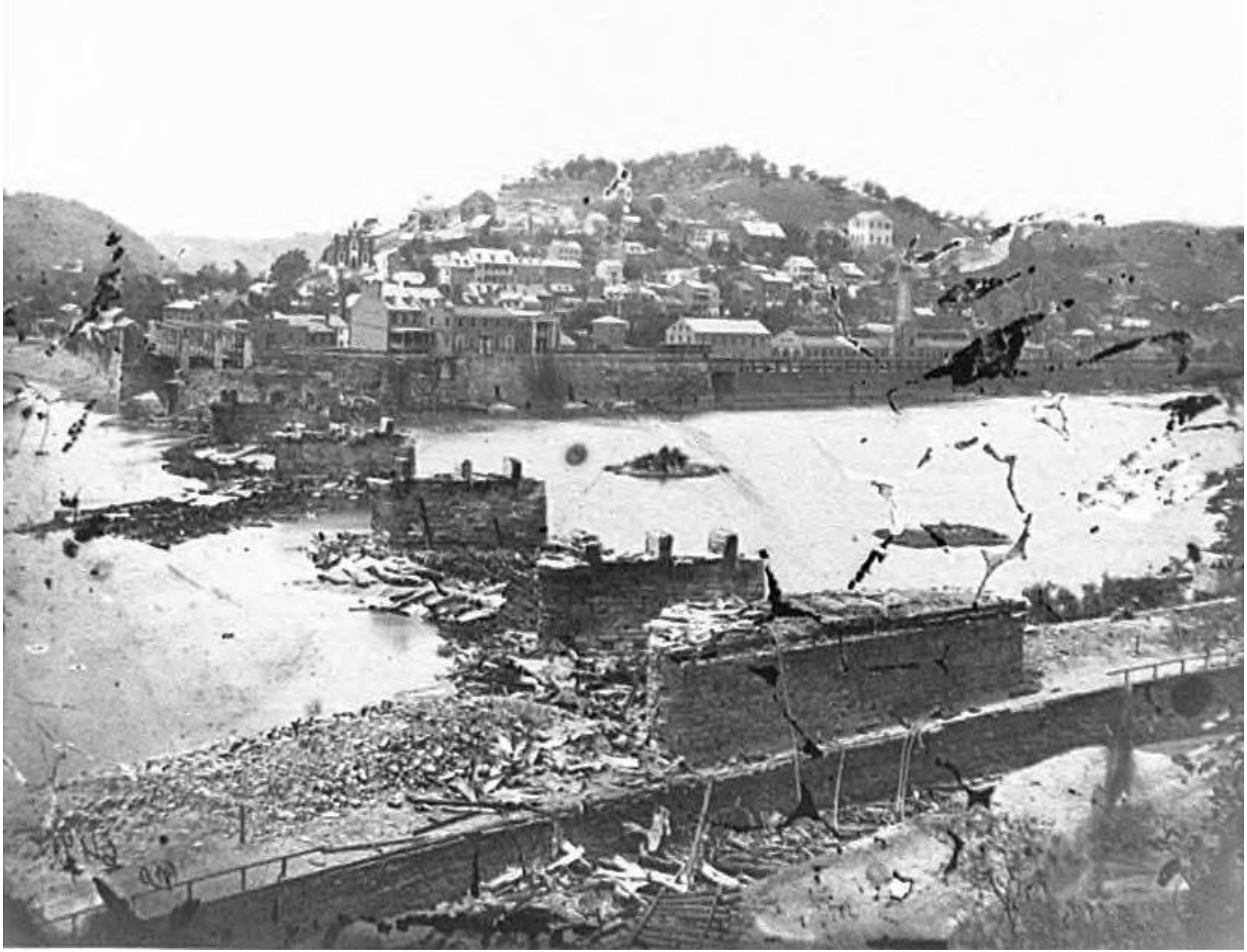
- Geometry of Three-Dimensions
- Differential & Integral Calculus
- Calculus of Variations
- Qualitative & Quantitative Analysis
- Determinative Mineralogy
- Higher Geodesy
- Logical & Rhetorical Criticism
- French Composition & Literature
- Orthographic & Spherical Projections
- Acoustics
- Optics
- Thermotics
- Geology of Mining
- Paleontology
- Rational Mechanics of Solids & Fluids
- Spherical Astronomy
- Kinematics
- Machine Design
- Hydraulic Motors
- Steam Engines
- Stability of Structures
- Engineering & Architectural Design & Construction
- Intellectual & Ethical Philosophy

"They must put fresh steam on the man factories up North, the demand down here for killing purposes is far ahead of the supply; thank God for this consolation that when the last man is killed the war will be over."

Washington Roebling – Civil War letter to Emily Warren

"The bridge has turned out more solid and substantial than I at first anticipated, it is very stiff, even without a truss railing, and has been pretty severely tested by cavalry and by heavy winds…the Harper Ferry bridge met the same fate as the others. When Lee came up for Gettysburg the suspenders were cut and the floor dropped into the river, but I rebuilt it completely and the army in part marched over it. The following year, Jubil Early destroyed it absolutely."

Washington Roebling – commenting on the bridges he built during the Civil War



Harper's Ferry Bridge
(Destroyed)

JAR was an abolishonist who would not allow democrats to work on his bridges since they were the pro-slavery party at the time. At the outset of the Civil War, JAR insisted WAR join the Union Army and so he did as his father wished. He entered as a private in 1861 and left the army a full colonel in 1864. His letters to Emily Warren, his future wife and the younger sister of his commanding officer; General G.K. Warren, are one of the best records of the Union Army's campaigns in the east. He served as engineering officer on the General's staff but took part in combat in several major battles, including Gettysburg.

Civil War RR Bridge

built by Washington A. Roebling (WAR)

"I was the first man on Little Round Top. There is no special credit attached to running up that little hill, but there was some in staying there without getting killed."

Washington Roebling – RE: Gettysburg, 1863

Apprentice to Genius

"It might be argued if a man inherits everything he deserves no credit for it. That would be so in a life of universal monotony, but with each generation in turn totally different conditions and environments arise. These have to be met by the new individual who must develop his powers to adapt himself to them; to overcome; to overcome them and use them as his tools."

Washington Roebling

"The size and magnitude of this work far surpass any expectations I had formed of it. It is the highest thing in this country; the towers are so high a person's neck aches looking up at them. It will take me a week to get used to the dimensions of everything around here."

Washington Roebling, Assistant Engineer – *Cincinnatti-Covington* bridge

“Your Kind offer…I accept with pleasure”

WAR, 1867

RE: JAR’s offer to Washington and Emily Roebling to go to Europe in the summer of 1867 at JAR’s invitation/expense. Pneumatic caissons were to be used for the foundations of the bridge towers and JAR wanted WAR to become as familiar with the technique – invented in France, as possible. The trip was a great success and WAR became one of only two engineers in America with expertise on the subject – the other being *James Buchanan Eads*, design engineer for the St. Louis RR bridge over the Mississippi (a.k.a. *Eads* bridge) then under construction which used very deep pneumatic caissons.

"Not long since , before the accident, which led to his death, Mr. Roebling remarked to us that he had enough of money and reputation. And he scarce knew why, at his age, he was undertaking to build another and still greater bridge. His son, he added, ought to build this Brooklyn Bridge – was as competent as himself in all respects to design and supervise it; had thought and worked with him, and in short was as good an engineer as his father."

Thomas Kinsella, *The Brooklyn Eagle*, 1869

"**First** – *I was the only living man who had the practical experience to build those great cables, far exceeding anything previously attempted, and make every wire bear its share.*

Second – *Two years previous I had spent a year in Europe studying pneumatic foundations and the sinking of caissons under compressed air. When the borings on the New York tower site developed the appalling depth of 106 feet below the water level all other engineers shrank back…*

Third – *I had assisted my father in the preparation of the first designs – he of course being the mastermind. I was therefore familiar with his ideas and with the whole project – and no one one else was.*"

Washington Roebling, 1869

"On motion of Mr. Jenks, it was resolved that Colonel Washington A. Roebling be appointed Chief Engineer; that the Executive Committee have power to fix his compensation, and that he have power to employ such assistance as he may deem proper, subject to the approval of the Executive Committee"

New York Bridge Company, August 3, 1869

Washington A. Roebling, ca. 1870
At about the time he assumed the position of Chief Engineer of the Brooklyn Bridge

"Confidence on the part of the public and of those whose money was to be invested in the undertaking would best be insured by employing the Engineer who had achieved the most successful results, and who was thus most likely to accomplish this great enterprise."

New York Bridge Co. – from their records on why JAR was chosen as Chief Engineer

"…He is too good a son of his father not to wish to identify his own name and fame with the building of the structure his sire designed, and he could hardly be blamed for not quarreling with the powerful superintendent and Executive Committee of the Company by which he was employed."

***New York World*, 1872**

“Nothing lasts forever. The most unforeseen circumstance will swamp you and baffle the wisest calculations. Only vitality and plenty of it helps you.”

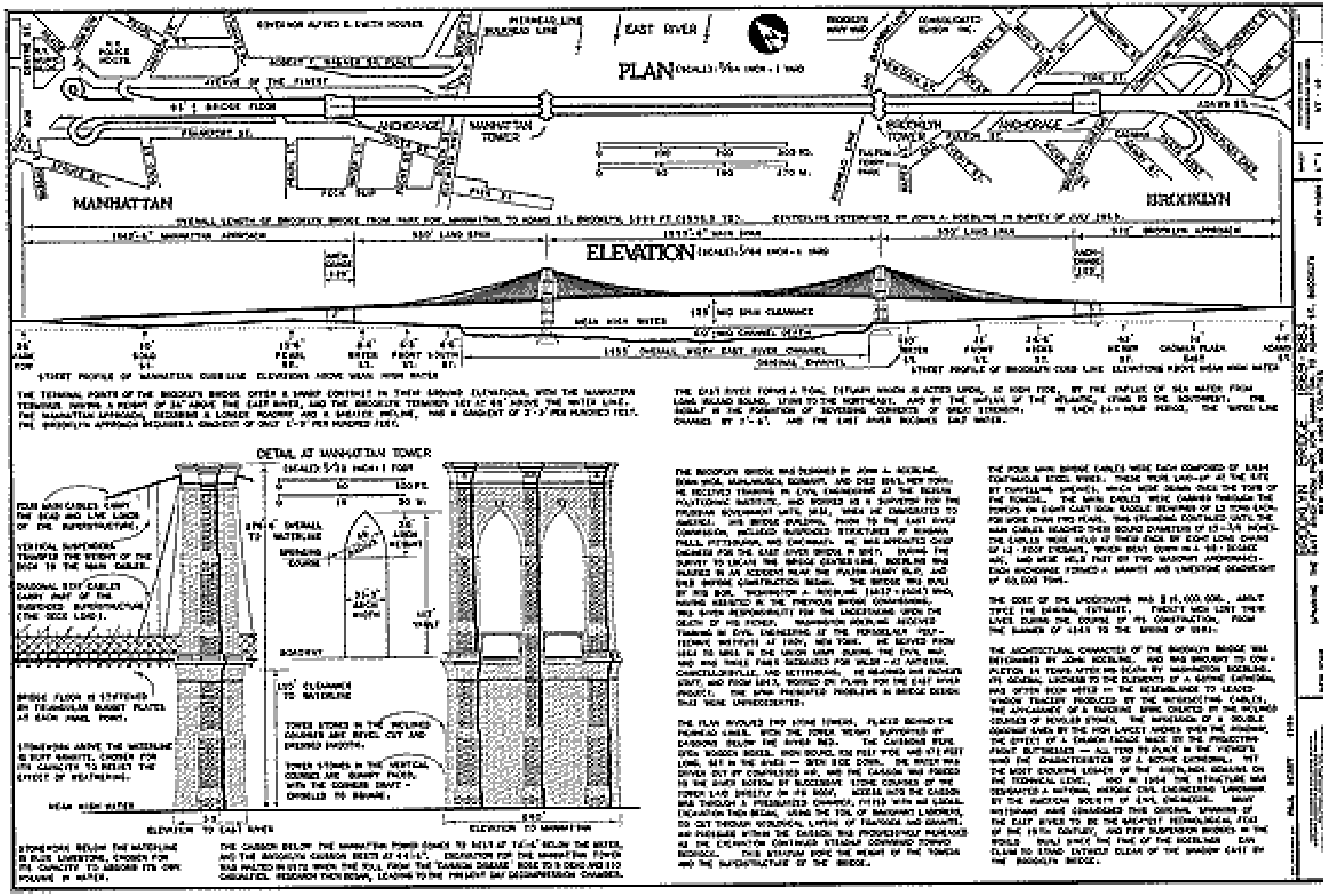
WAR

“There must be someone at hand to say ‘yes’ or ‘no’, and it often makes a great difference which word they use.”

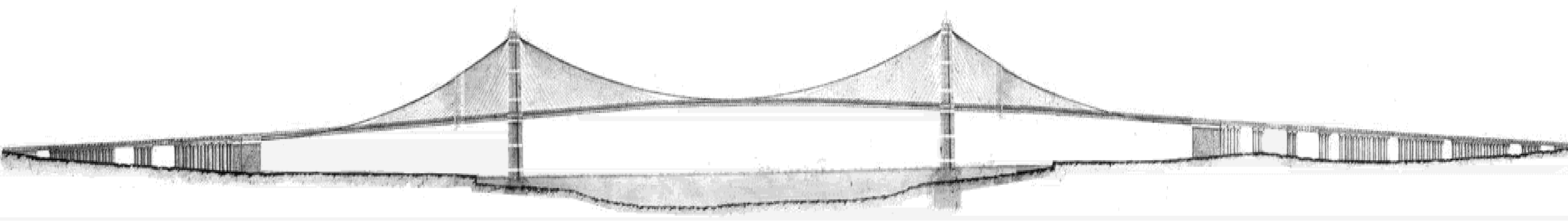
WAR

"The details not having been considered"

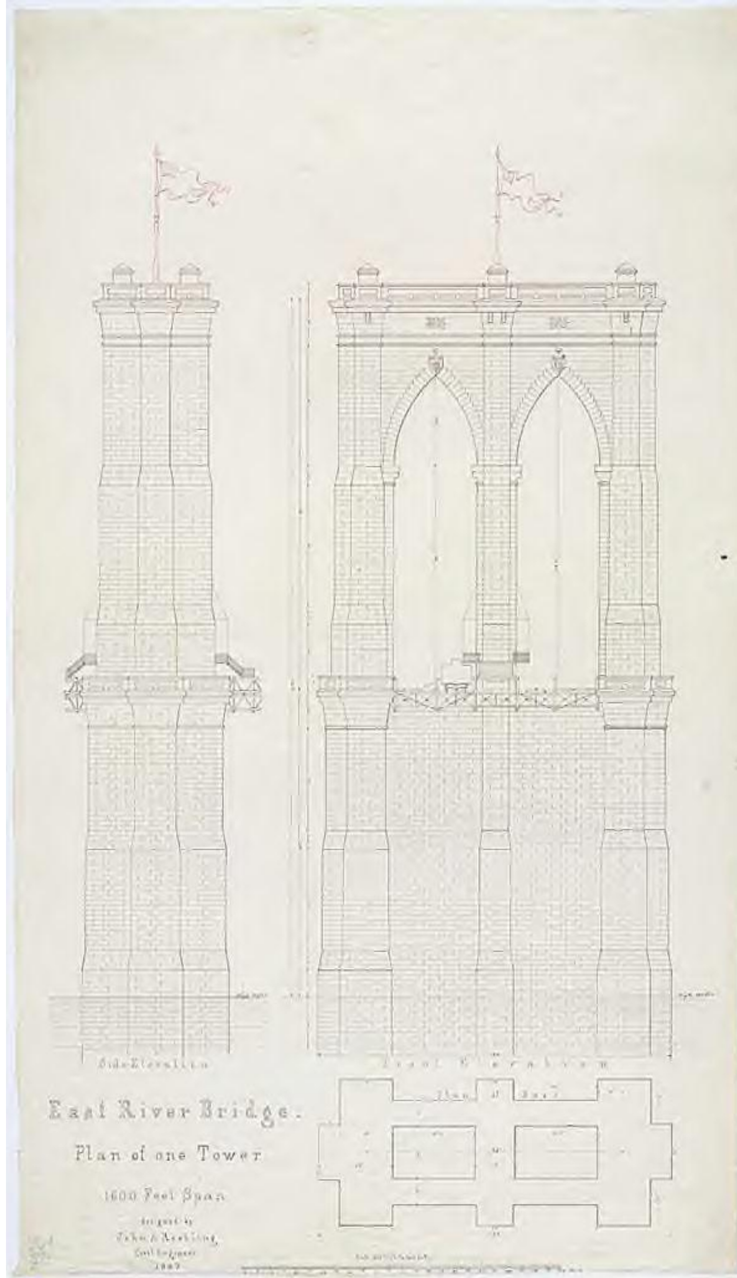
WAR – comment upon the fact that his father had completed only the general design work at the time of his death, but not the details by which the bridge would actually be constructed



General Plan & Elevations by JAR



Bridge Elevation by JAR



Bridge Tower/s Plan & Elevation by JAR

"…It took Cheops twenty years to build his pyramid, but if he had had a lot of trustees, contractors, and newspaper reporters to worry him, he might not have finished it by that time. The advantages of modern engineering are in many ways over balanced by the disadvantages of modern civilization."

Washington Roebling, 1883

Part 8

Behind Every Great Man

"At first I thought I would succumb, but I had a strong tower to lean upon, my wife, a woman of infinite tact and wisest council"

Washington Roebling

"Mrs. Roebling is a tall and handsome woman, strikingly English in style and shows not only in her face, but in her graceful carriage, an aristocratic ancestry."

Newspaper description of EWR

Emily Warren Roebling

EWR was the unsung hero of the drama that was the building of the Brooklyn Bridge. Liked by all, she was given the honor of being the first person to cross the bridge as a passenger in an open carriage. She held a rooster – a symbol of victory, to the cheers of the bridge workmen and spectators all the way across. When WAR was suffering from the lingering effects of *Caisson's Disease*, Emily served as his nurse, secretary and envoy. Without her, he could not have remained as Chief Engineer.

"I like her very much and I have no doubt that your union with her will be a happy one."

JAR

RE: excerpt from a letter to WAR after meeting Emily Warren

Emily & Washington

“The name of John Augustus Roebling must ever be identified with you and your works, but with a mother’s pride and fond hopes for her first-born I trust my boy may not prove unworthy of the name…”

EWR, 1867

RE: excerpt from a letter to JAR while in Germany (w/WAR) where their son – *John Augustus Roebling II*, was born

"There is a popular impression that Colonel Roebling has been for years a helpless paralytic. This is a mistake as he has never been paralyzed for even one moment and there never has been a time when he has not had full use of every member of his body."

EWR, 1875

“The Man in the Window”

A newspaper’s depiction of WAR as a paralytic observing the bridge’s construction from his home in Columbia Heights.

WAR was not present on-site for most of the substructure work while suffering from the after-effects of *The Bends*, he was in Trenton, NJ - at his home, or traveling to spas in Europe seeking treatment. By the summer of 1876, the bridge's towers and anchorages were complete and aerial spinning of the wire cables – his favorite part of the work, was about to begin and WAR was feeling well enough to return to Brooklyn. It was then that he observed the balance of the remaining work (until 1883) from his window with Emily acting as his emissary. Emily was highly intelligent and mastered much of the complex engineering principles involved in the bridge's design.

"…probably no great work was ever conducted by a man who had to work under so many disadvantages. It could never have been accomplished but for the unselfish devotion of his assistant engineers. Each man had a certain department in charge and they worked with all their energies to have the work properly done according to Colonel Roebling's plans and wishes and not to carry out any pet theories of their own for their own self-glorification."

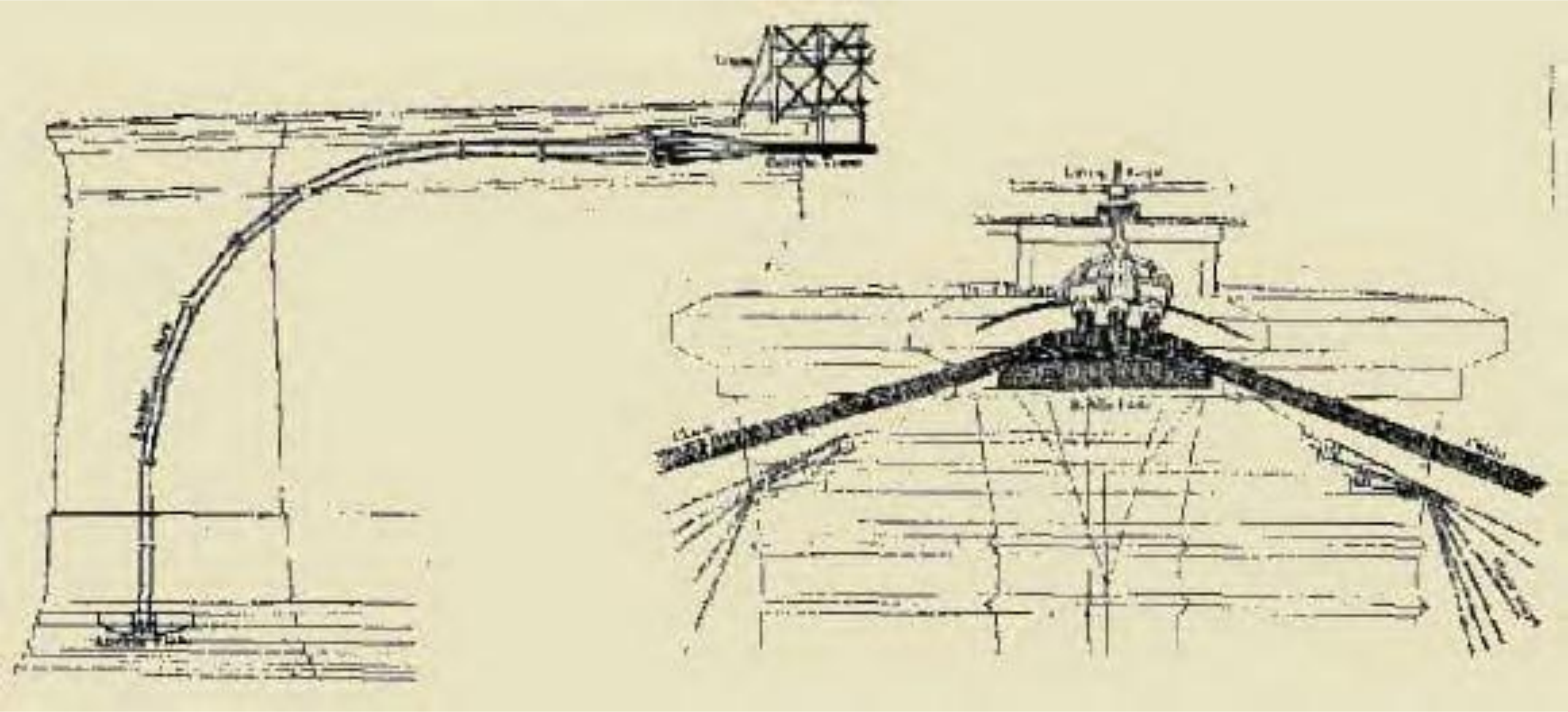
Emily Roebling

"One thing is certain, the Bridge Company have been exceedingly fortunate in securing the services of professional gentlemen who are without peer in their respective fields and whose talent and genius have enabled them to surmount every obstacle."

***The Brooklyn Eagle*, Fall, 1876 – RE: Engineering Staff**

"It has pleased the average penny-a-liner, to remark that there is nothing new in the East River Bridge and that Colonel Roebling only copied his father's plans. The fact is there is scarcely a feature in the whole work that did not present new and untried problems."

Emily Roebling



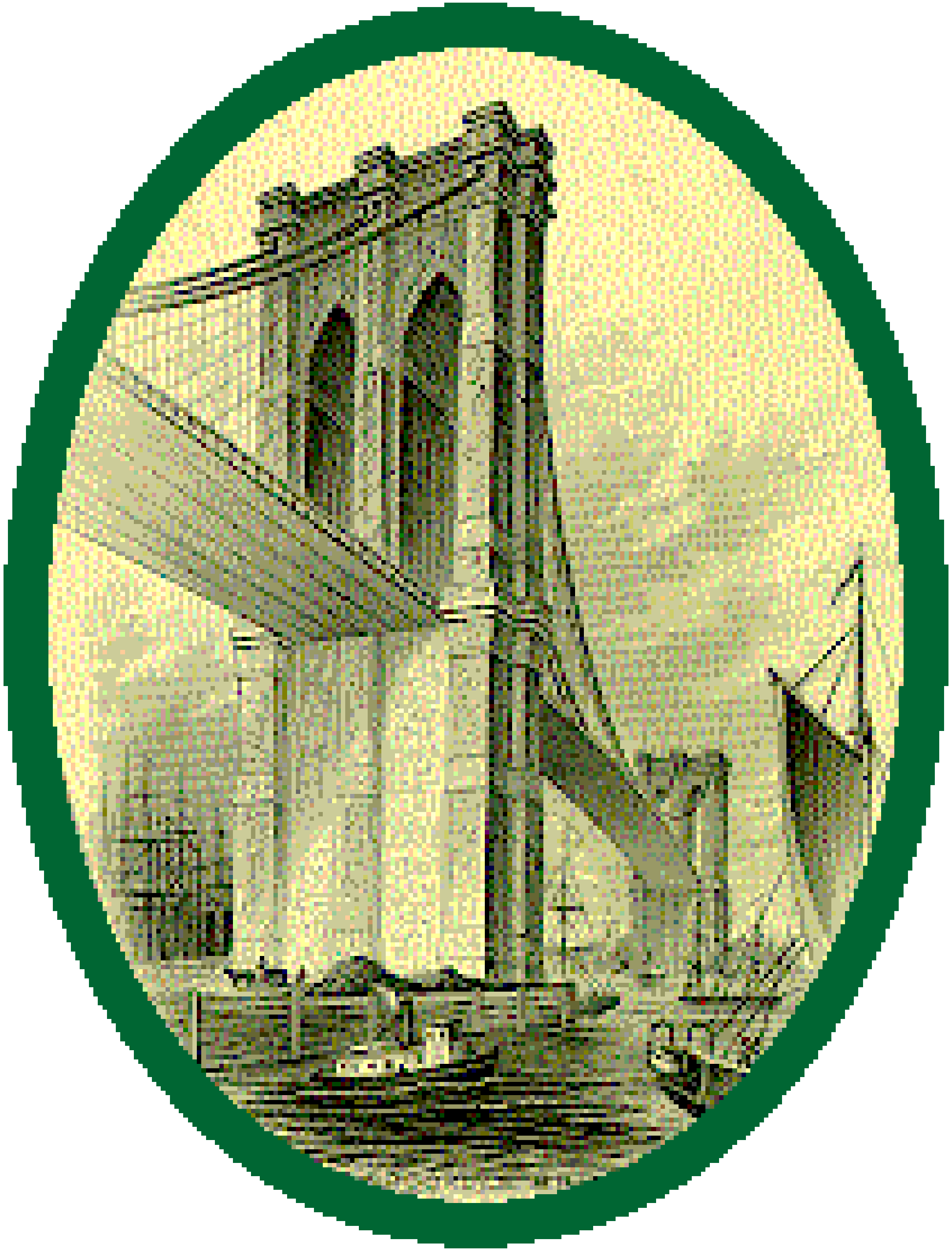
Anchorage Chain & Cable Saddle Details
(designed by WAR)

Emily Warren Roebling

1843-1903

Part 9

A Spiritual Conception



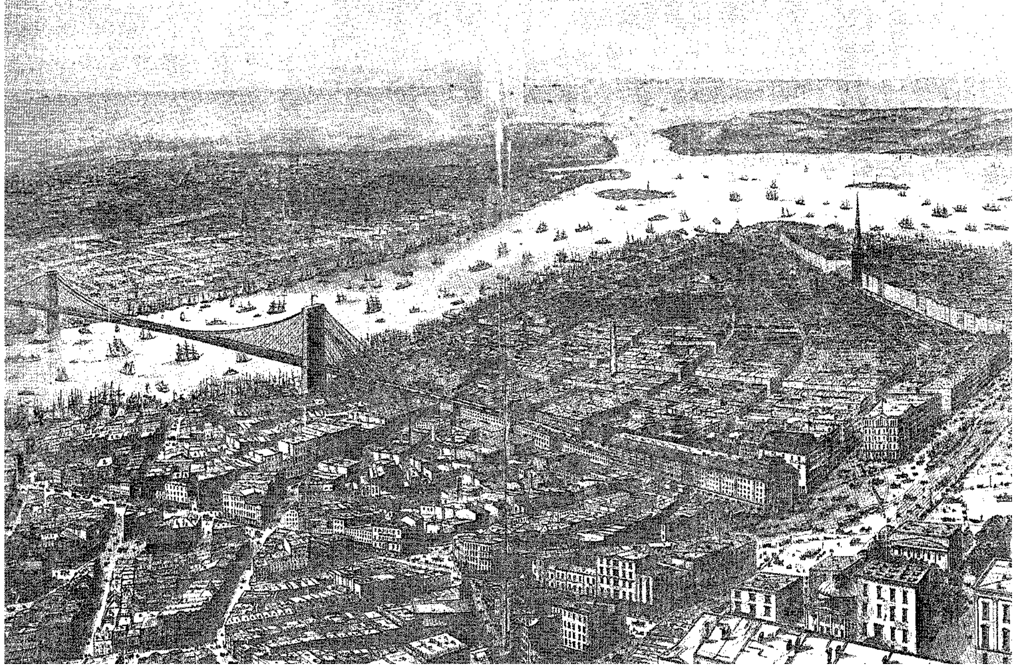
"Then and there saw a bridge in his mind's eye"

RE: WAR recalling a trip to Brooklyn in 1853 when he was 15yo. They were probably going to Brooklyn to visit the Turkish baths his father was fond of when they got stuck, mid-river, on an ice-bound ferry. JAR had a "flash of genius" at that moment, envisioning a bridge overhead in that very same spot.

"A wire suspension bridge crossing the East River by one single span at such an elevation as will not impede the navigation"

JAR, 1857

RE: Excerpt from a letter to Horace Greely proposing a bridge across the East River. Clearance at mid-span was set at 130-feet (at spring high-tide) by JAR, but the Army Corps of Engineers later changed that to 135-feet. This additional five-feet of clearance added significantly to the bridge's cost since it required design changes (i.e. longer approaches) to achieve the greater height. Ultimately, the federal government had the final say on the bridge's design since it was above navigable waters (plus nine-feet in depth) and the bridge was a "post-road" (the mail traveled over it).



Bird's eye view of the future Brooklyn Bridge

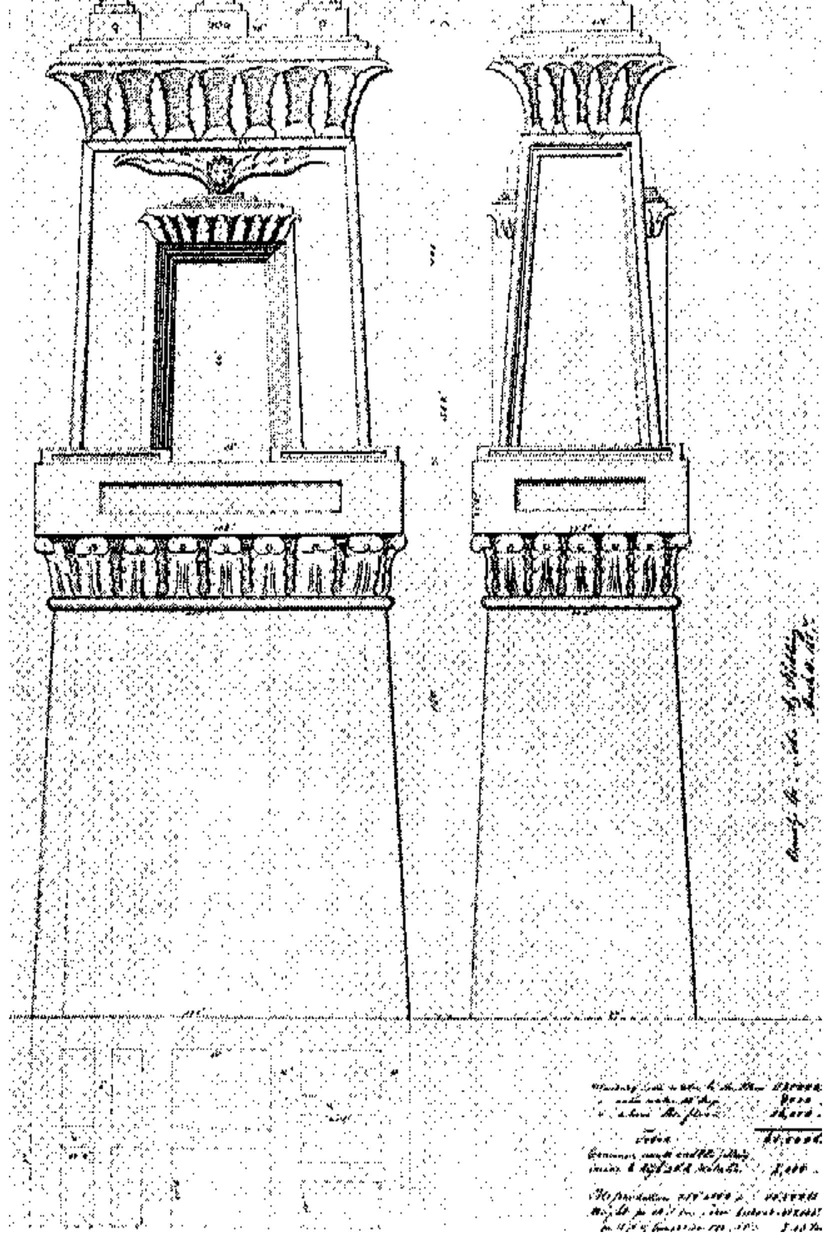
Because of the low-lying shores on both the NY and Brooklyn sides of the river, the approaches and land/side-spans (combined) were greater in length than the main/river-span (between the two towers). In fact, most of the Brooklyn Bridge is above land rather than water. The steeple of *Trinity Church* – at the foot of Wall Street on lower Broadway, can be seen in the upper-right. Until the towers of the bridge were completed in 1876, it was the tallest structure in NYC.

Man of Genius

"The completed work, when constructed in accordance with my designs, will not only be the greatest bridge in existence, but it will be the greatest engineering work of the continent, and of the age. Its most conspicuous features, the great towers, will serve as landmarks to the adjoining cities and they will be entitled to be ranked as national monuments. As a great work of art, and as a successful specimen of advanced bridge engineering, this structure will forever testify to the energy, enterprise and wealth of that community which shall secure its erection."

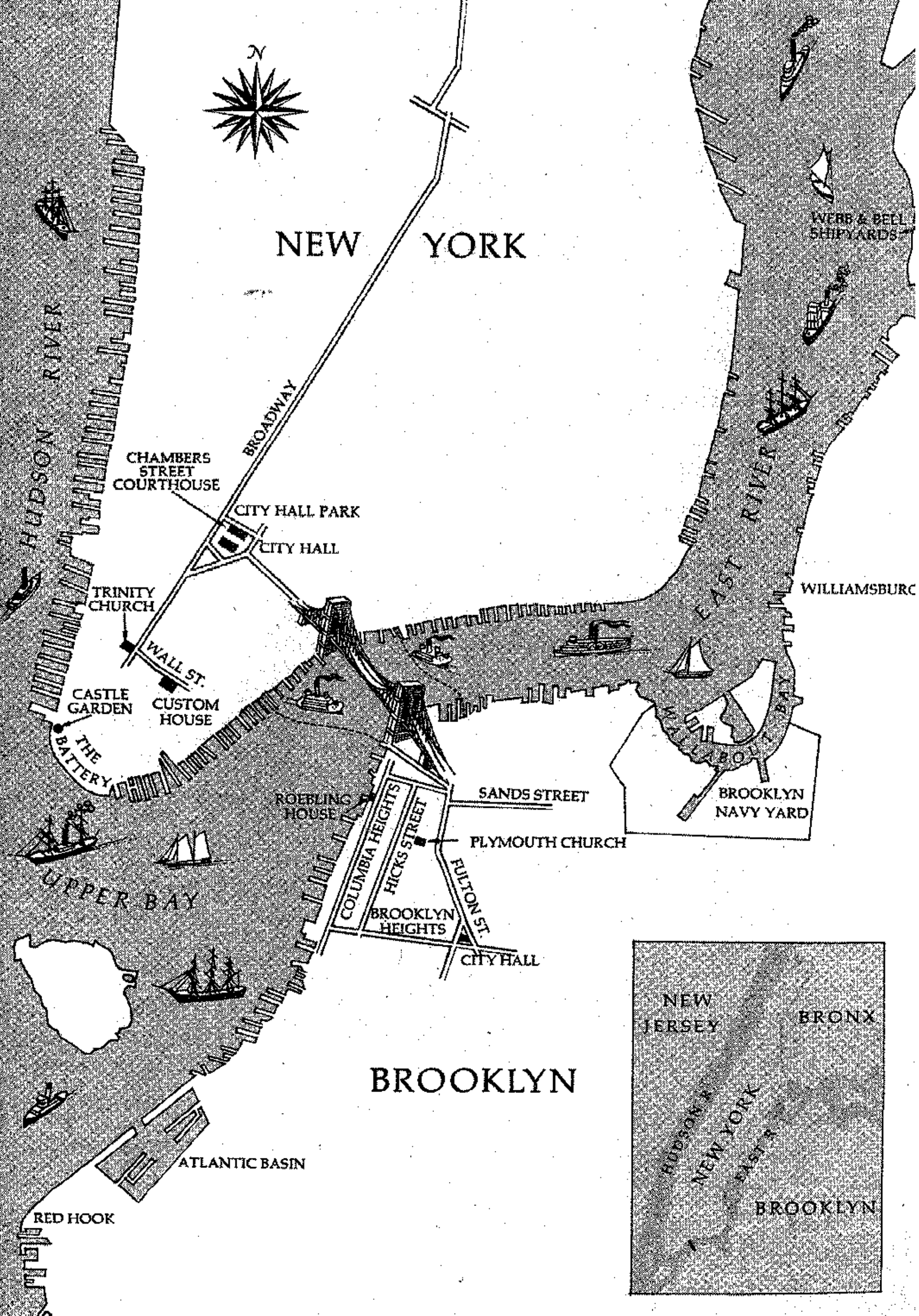
JAR, 1867

RE: excerpt from report to the bridge company

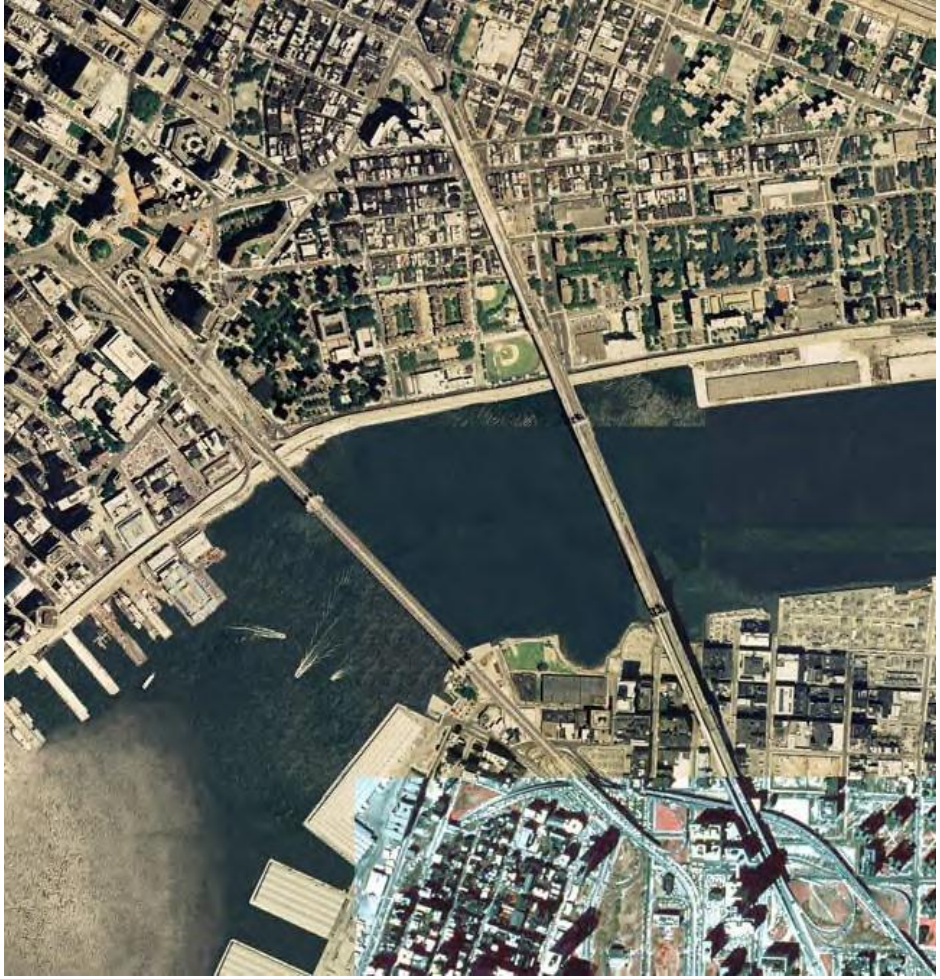


JAR’s first concept for the Brooklyn Bridge’s towers

(an Egyptian motif, then in fashion)



The bridge was to be located at the "second bend" of the river, the first bend being *Wallabout Bay* – the home of the Brooklyn Navy Yard. Adjoining the Fulton Ferry Landings, the idea was to link City Hall Manhattan with City Hall Brooklyn. NY and Brooklyn were two separate cities, each with their own municipal governments. Not until 1898 would the unified *City of New York* – including Brooklyn, become a reality. It could not have happened without the first physical link the Brooklyn Bridge provided.



Satellite view of the Lower East River

The *Brooklyn Bridge* (1883) at left and the *Manhattan Bridge* (1909) at right. Further upstream, just past the Brooklyn Navy Yard at *Wallabout Bay*, the *Williamsburg Bridge* (1903) would be built.

“A public work, to be constructed by the two cities for the accommodation, convenience and safe travel of the inhabitants…”

RE: May 1875 act of the NY State legislature whereby the *New York Bridge Company* was dissolved and the bridge project redefined as a “Public Work”

Teddy Roosevelt’s “Great White Fleet”

The Brooklyn Navy Yard was home port to the Atlantic Fleet and the center of capital ship construction and repair. It reached its height of activity during WWII, but went into decline after the war. The demise of the battleship coincided with the rise of the super-carrier whose antenna apparatus was too tall to clear the Brooklyn and/or Manhattan bridges (135-foot clearance).

U.S.S. Iowa (Battleship)

U.S.S. Maine (Battleship)

Bridge Party

To end the debate over whether or not a bridge could/should be built across the East River and/or the safety of such a bridge, in the spring of 1869, JAR led a "Bridge Party" visiting his completed bridges in Cincinatti, Pittsburgh and Niagara Falls. Twenty-one people set out from Jersey City, NJ on April 14, 1869 including JAR, WAR, army and consulting engineers and a group of Brooklyn businessmen, politicians and newspapermen. W.C. Kingsley paid out-of-pocket the $7K cost of the tour. It worked, all were thoroughly impressed including those previously in opposition to JAR and his grand plan for a suspension bridge for Brooklyn.

Bridge Party
(JAR at lower right)

"It then broke upon us all at once, the stateliest and most splendid evidence of genius, enterprise and skill it has ever been my lot to see"

Thomas Kinsella, *The Brooklyn Eagle* – member of the *Bridge Party* – comments upon seeing JAR's *Cincinnatti-Covington* bridge for the first time

"He is an extraordinary man and if you people in Brooklyn are wise you will interfere with his views as little as possible. Give the old man his way and trust him."

Amos Shinkle, 1869 – Cincinnati coal dealer & organizer for the creation of the *Cincinnati-Covington* bridge – advice to the *Bridge Party*

"A great future is opening before our city"

***The Brooklyn Eagle*, 1869**

Part 10

Caissons

"The foundations for the support of these large masses of masonry must be unyielding"

JAR, 1867

RE: JAR emphasizing the importance of a strong, stable foundation for the massive weight of the bridge towers, without which the bridge would fail. In a suspension bridge, tension in the cables is transferred to the top of the towers as a compressive force which is then transmitted through the towers to the foundation and into terra firma (solid ground).

“We have no precedent, just like this bridge”

WAR, 1869

RE: WAR commenting on the lack of previous experience concerning pneumatic caissons of such great size and weight. Pneumatic caissons were first used in France and later in England and Germany. In 1831, Lord Thomas Cochrane – a British admiral, invented an air-lock allowing workers to enter and/or leave a chamber filled with compressed air. In 1851, pneumatic caissons were used for the first time to construct the piers of a bridge over the Medway River in Rochester, England. In 1858, Brunel went to a depth of seventy-feet with a pneumatic caisson for the *Royal Albert* RR bridge over the Tamar River in Saltash, Cornwall, England. WAR understood that the sub-structure consisting of two extremely large pneumatic caissons would be the most difficult engineering problem to be encountered since, albeit on a smaller scale (i.e. *Cincinatti-Covington* bridge), all else had been done before (masonry towers/anchorage, wire cables etc.)

"…Creating a great sensation among all whose good fortune led them to view one of the wonders of the 19th century…to be hidden from the gaze of mortal eyes…it came down the river as placidly as a swan upon the bosom of an inland lake…of course, everyone was anxious to be able to say in future years that they had been upon the monster"

Newspaper Report – May, 1870

RE: The launching of the Brooklyn caisson from the *Webb & Bell* shipyard in Greenpoint, Brooklyn and floatation down river to its position just off the shoreline on May 3, 1870

Construction of the Brooklyn Caisson had begun in the fall of 1869 and when it was launched in the early spring, it was launched sideways just like a ship (though it was a giant rectangular box measuring 168-feet long by 102-feet wide and weighing 3K-tons or six-million pounds). It was more than one-half the size of a city block (about three tennis courts) in overall area. It contained 110K cubic feet of timber and 230-tons of iron and it was larger (by +1K-tons) than the largest ship ever built on the East River up to that time. *Caisson* is a French word meaning *Chest.*

Brooklyn Caisson
(at launching on May 3rd 1870)

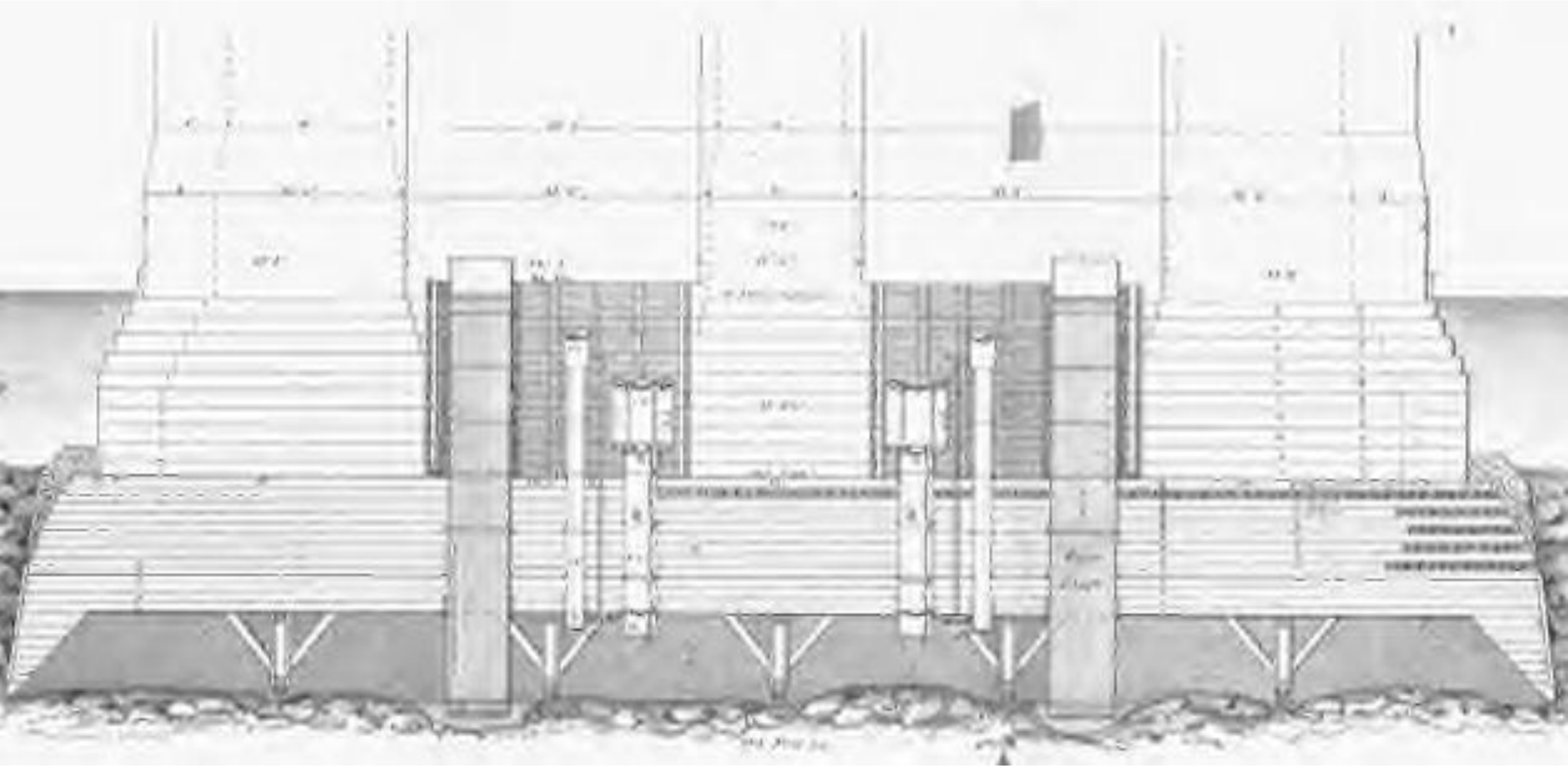
Akin to a diving bell, with a heavy nine-inch thick roof and strong V-shaped sides (inside slope of 45-degrees), fourteen and one-half feet high (overall) with nine and one-half feet of headroom (for the workmen inside the work chamber). It would slowly descend below the waterline until it hit the river bottom and then, filled with compressed air (to keep the river out and for the workmen to breath) below the carefully undermined river bed within and around its perimeter, all by the dead-weight of the masonry courses (limestone below, granite above the waterline) laid atop it. When the caisson "founded," it would be abandoned and all void spaces filled with concrete. To help support the great weight (until the void spaces could be filled solid), WAR constructed ten strategically placed support piers throughout the interior of the work chamber. [175]

"A pile which was sixteen inches in diameter below the mud, perfectly sound and free from worms, would be found eaten away to a thin stem of three inches just above the mud, and all timber was affected alike. This shows the necessity of going below the top of the riverbed with our timber foundation, and also proves its entire safety in that position."

Washington Roebling, 1870 – remarks upon examining removed dock piles

"The extreme rise and fall is seven & one-half feet. If the inflated caisson is just barely touching the ground at high water, it will press upon the base with a force of 4,000 tons at low tide, all of which has to be met by the strength of the shoe and the frames."

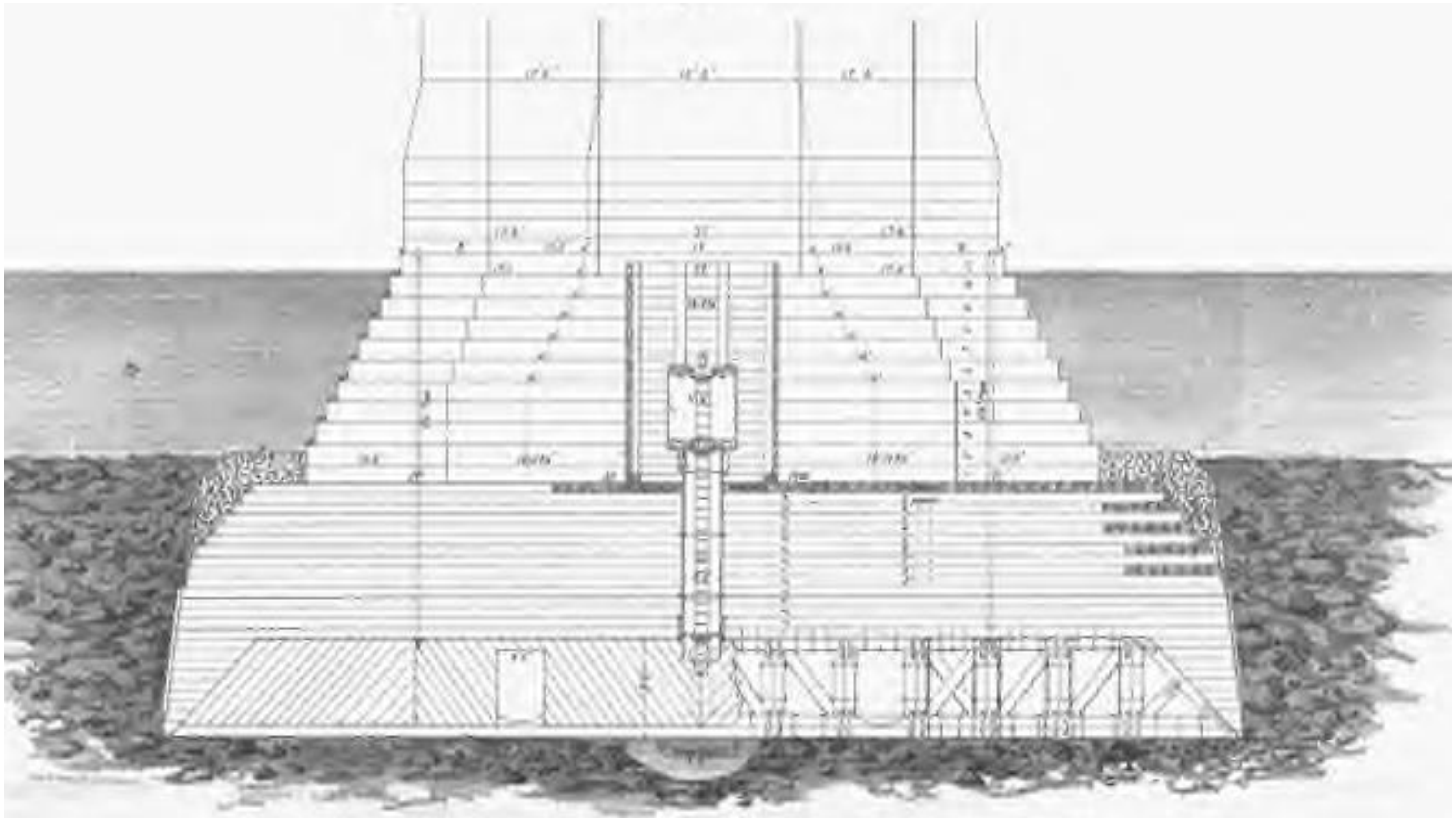
Washington Roebling, 1870



Longitudinal Section through the Brooklyn Caisson

Here, the “cutting edge” of the V-shaped sides is clearly seen as are the five “frames” (creating six sections) and the arrangement of the set of shaft openings (supply, air, water)

The cutting-edge or “shoe” tapered to just eight-inches and was clad with a heavy iron casting and sheathed with boiler plate extending three-feet up the interior side (the exterior sides were completely sheathed with tin plate). The V-shaped sides were affixed to the roof structure with heavy angle-irons. WAR added five “frames” that were not in JAR’s original design. Made of heavy timber and clad with diagonal wood bracing, openings were made to allow the workmen to pass through. Two-foot square solid oak blocks would be placed below the shoe and frames to support the weight of the caisson while the river bottom was undermined, then they would be carefully knocked out of place (in sequence) and the caisson would settle to a new position further below the river’s bottom.



Transverse Section through the Brooklyn Caisson

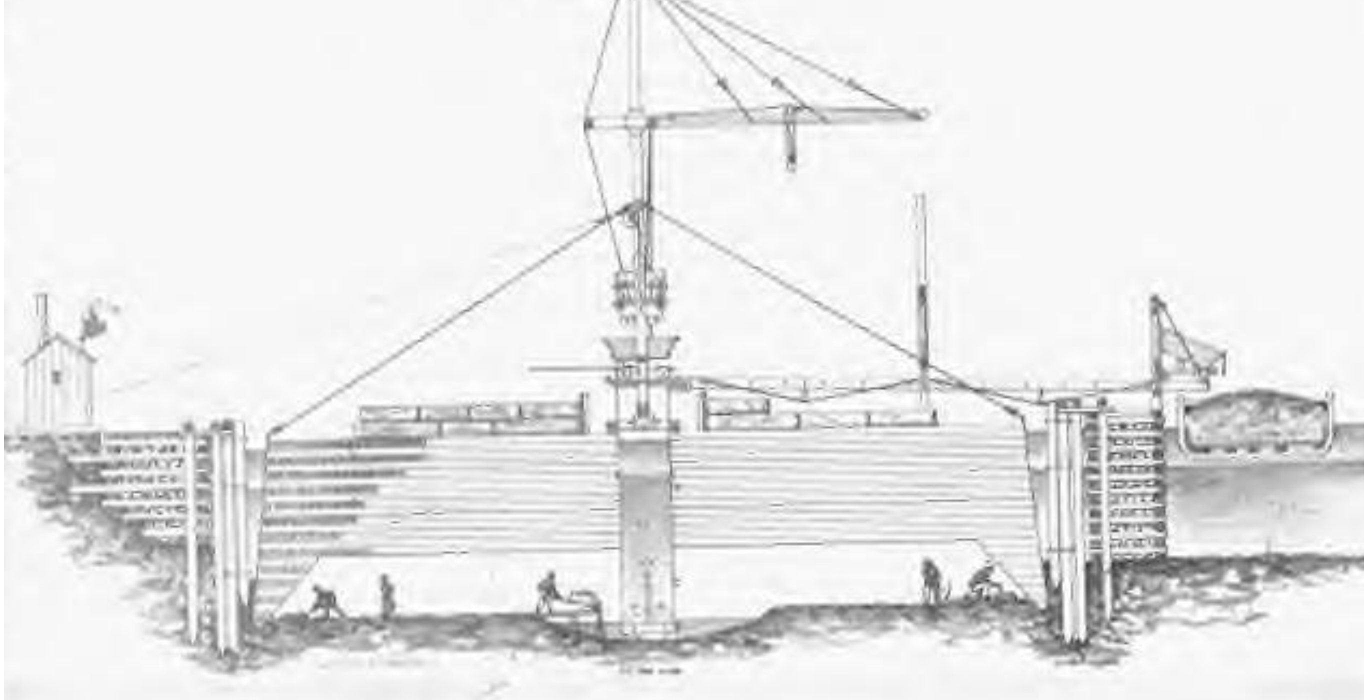
Offering a good front elevation and sectional view of a frame (with its two openings and diagonal cladding). Also in view are the masonry courses atop the caisson (always several feet above the waterline). It also provides a good sectional view of the roof structure and one (of two) air-lock/s and shaft/s (w/ladder) and the "pool" below a water shaft (water shaft/s not in view).

The roof structure was composed of solid timber courses five-feet thick (made of one-foot square "sticks") laid side-by-side and bolted both vertically and horizontally. For reinforcement of the corners, the timber was interlocked by "halving" and strapped together. Drift-bolts, screw bolts and wood-screw bolts were used to fasten and secure the timber frame. WAR carefully chose yellow pine from Georgia and Florida because of its inherent "pitchiness" (it wouldn't even float). Across the entire top and along all four sides of the caisson tin sheathing was applied. Spaces between timbers were filled with hot pitch. For air-tightness, oakum was used between the fourth and fifth courses of roof timber to a depth of six-inches inside and out. A specially formulated varnish was applied through-out the interior of the work chamber.

"The material now became sufficiently exposed to enable us to arrive at the conclusion that it was of a very formidable nature, and could only be removed by slow, tedious and persistent efforts."

WAR, 1870

Built into the timber roof of the caisson were a set of air-locks/shafts, supply shafts and water shafts. The water shafts were the brainchild of WAR and provided an ingenious, but dangerous, method by which excavated material could be removed without undermining the integrity of the compressed air environment in the work chamber and/or without having to move the "spoil" through an air-lock. A seven-foot square opening penetrated through the roof of the caisson and then extended the height of the work chamber plus an additional two-feet below the caisson's shoe. Made of boiler plate, it was filled with water to a sufficient level and maintained to lock-in the compressed air in the work chamber, this equilibrium of water/air pressure had to be carefully monitored lest the air pressure become greater[183] **than the water pressure causing a "blowout."**



Two masonry courses laid atop the Brooklyn Caisson

For every two-feet the caisson descended, one PSI had to be added above normal atmospheric pressure (14.7 PSI). Thus, for every one PSI increase in pressure the water column was forced two-feet higher in the water shaft. At the base of the extended shaft a water-filled pool was dug-out and excavated material dumped in to be removed by a steam-driven clamshell dredge. It was akin to a thermometer with the cistern at the base being the pool and the water shaft the tube filled with mercury.

Atop the Brooklyn Caisson

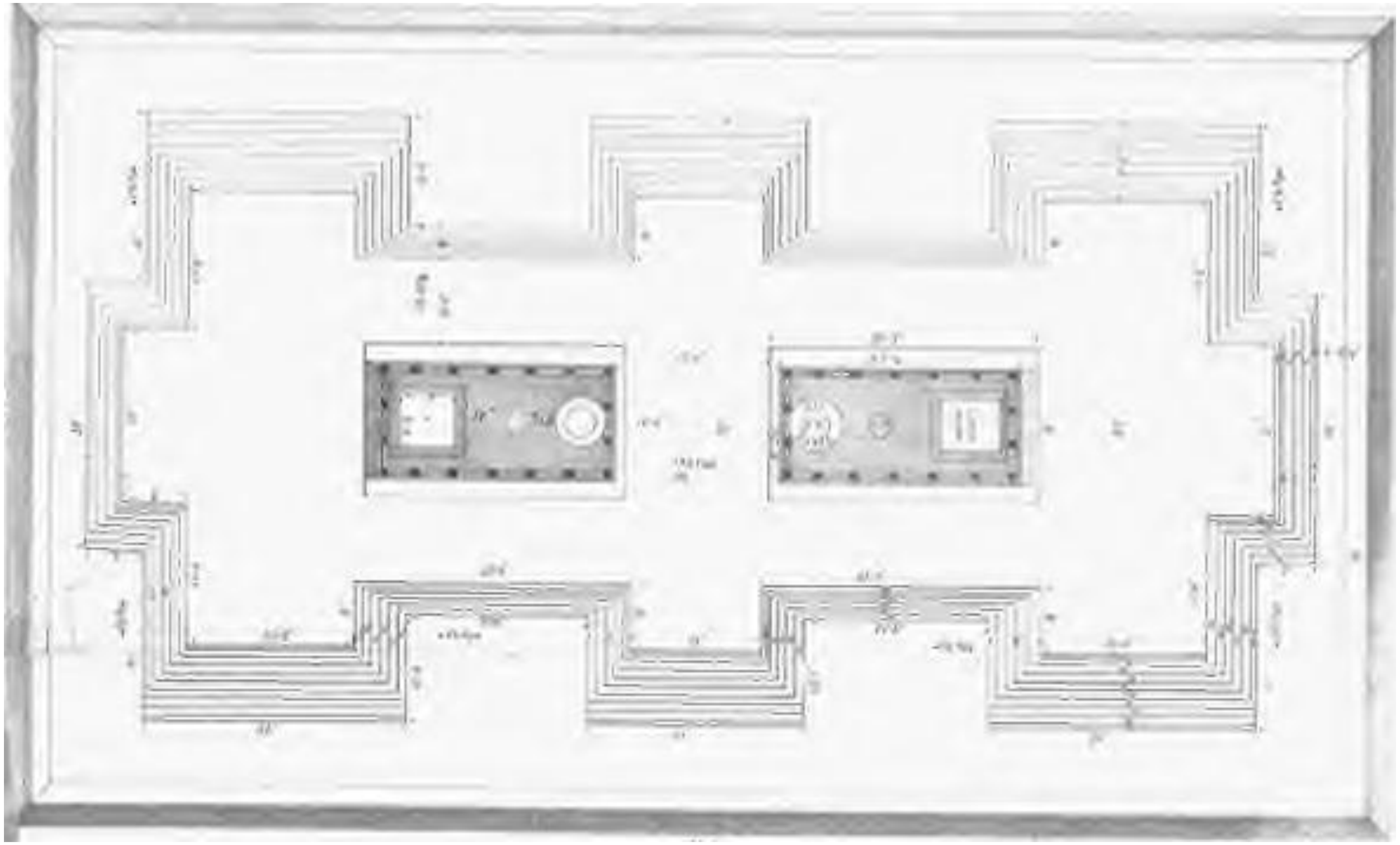
Steam-driven derricks did the heavy lifting of excavated material from inside the caisson. The spoil was loaded onto barges and removed from the site. Rifle powder was used to deal with the many large rocks and boulders unexpectedly encountered.

"Moreover, a settling of the caisson of six inches or a foot would bring to light an entirely fresh crop of boulders in new positions, and very often half without and half within the caisson."

Washington Roebling, 1870

"Levels were taken every morning on the masonry above, a copy furnished the general foreman…if the caisson were level, the usual method followed in lowering was to begin at the central frame, and loosen the wedges regularly from the center towards the ends. The two frames next to these were then treated in like manner, and finally the outer two. When no obstructions occurred, the blocks would all be gone over several times in the course of a day, and the caisson would settle easily, at a rate of three to four inches in 24 hours."

Francis Collingwood, Jr., 1870 (Engineering Staff)



Plan of the Brooklyn Caisson

Showing the set of shafts (air, supply & water). These shafts as well as the entire volume of the work chamber would be filled with concrete and abandoned upon founding. The square shape of the water shaft/s proved problematic for the clamshell dredge (the bucket jammed very often) so a cylindrical (round) water shaft was used to good effect on the Manhattan caisson.

"For three weeks past, a gang of forty men have been at work in the caisson for eight hours every day, under the charge of Mr. Young, principally in leveling off and removing boulders which happened to lie under the frames and the edges. A deposit of dock mud, from two to three feet deep, has made this work exceptionally unpleasant. The dredges, which are now beginning to work, will remove it in short time. This removal of large stones from under the shoe, some of them 100 cubic-feet, is a matter requiring considerable skill and perseverance."

WAR – June 12, 1870

RE: excerpt from a report to the Bridge Company

Dante's Inferno

"Inside the caisson everything wore an unreal, weird appearance. There was a confused sensation in the head…The pulse was at first accelerated, then sometimes fell below the normal rate. The voice sounded faint unnatural, and it became a great effort to speak. What with the flaming lights, the deep shadows, the confusing noise of hammers, drills and chains, the half-naked forms flitting about, with here and there a Sisyphus rolling his stone, one might, if of a poetic temperament, get a realizing sense of Dante's Inferno."

E.F. (Frank) Farrington – Master Mechanic, 1870

RE: Commenting upon the deplorable working conditions inside the Brooklyn Caisson

A total of 2,500 men worked in the two caissons, many new immigrants desperate for work. Most couldn't handle the extraordinary difficulties involved in hard physical labor while working in compressed air and excessive heat and humidity that made for horrific working conditions. The Manhattan Caisson, unlike Brooklyn, was whitewashed on all interior surfaces to make the visibility and atmosphere somewhat more bearable. It was also better ventilated.

"For night is turned into day and day into night in one of these bridge caissons, and when the steam tugs, with their red & blue lights burning from their wooden turrets go creeping along the bosom of the river like monstrous fireflies, then do these submarine giants delve and dig and ditch and drill and blast…The work of the buried bridge-builder is like the onward flow of eternity; it does not cease for the sun at noonday or the silent stars at night. Gangs are relieved and replaced, and swart, perspiring companies of men follow each other up and down the iron locks, with a dim quiet purpose…"

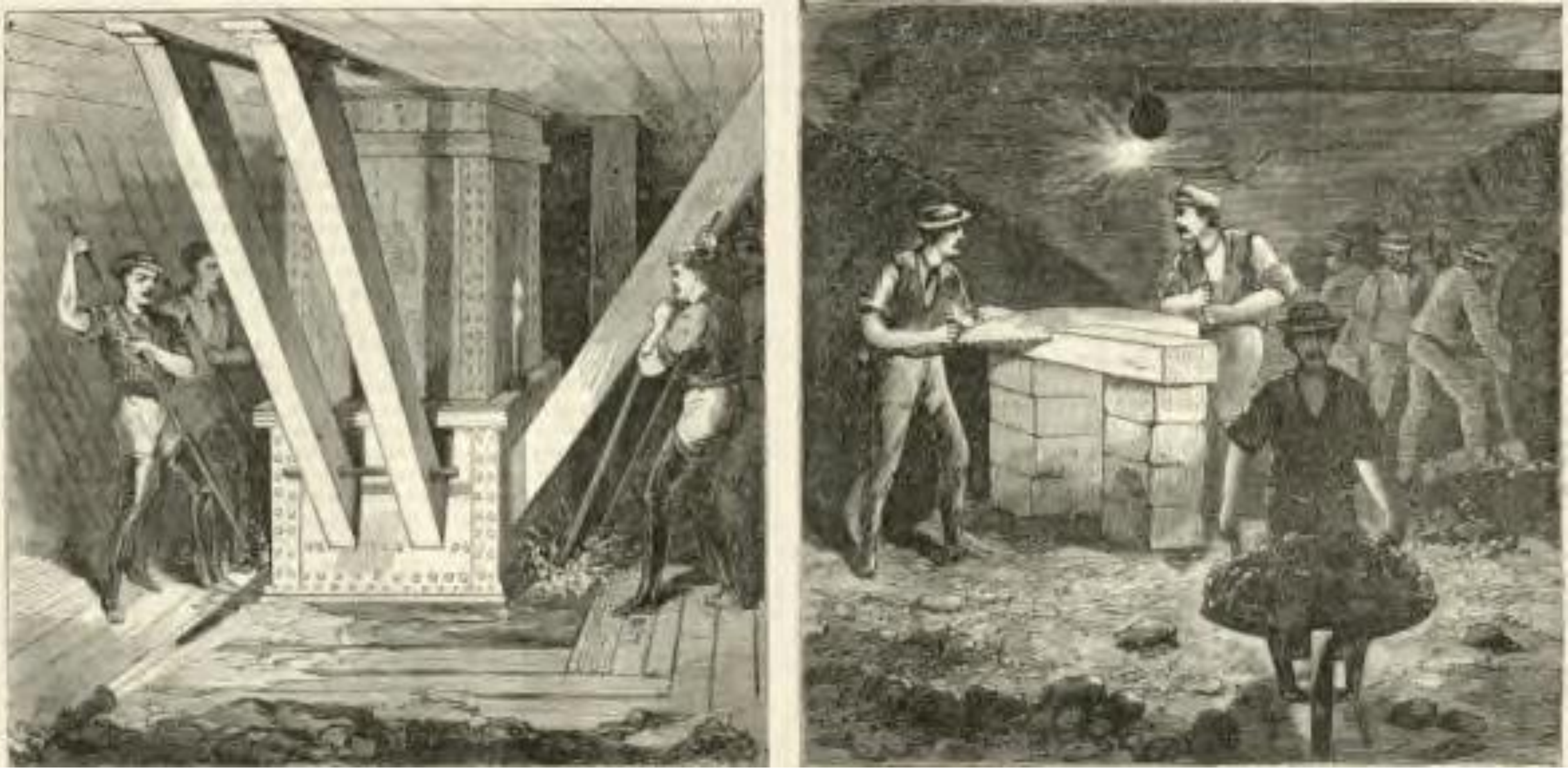
The Herald, 1870

<u>Left</u>: Inside the air lock (waiting for the air pressure to be equalized). Note the circular glass skylights for illuminating the chamber and the ladder for entering/exiting the air- lock. An attendant operated the air pressure apparatus.

<u>Right</u>: Workmen moving wheelbarrows full of excavated river bottom along planks laid on the riverbed and workman exiting/entering the air-lock shaft-way via a ladder

Left: Workman passing a wheelbarrow full of “spoil” through an opening in a support frame

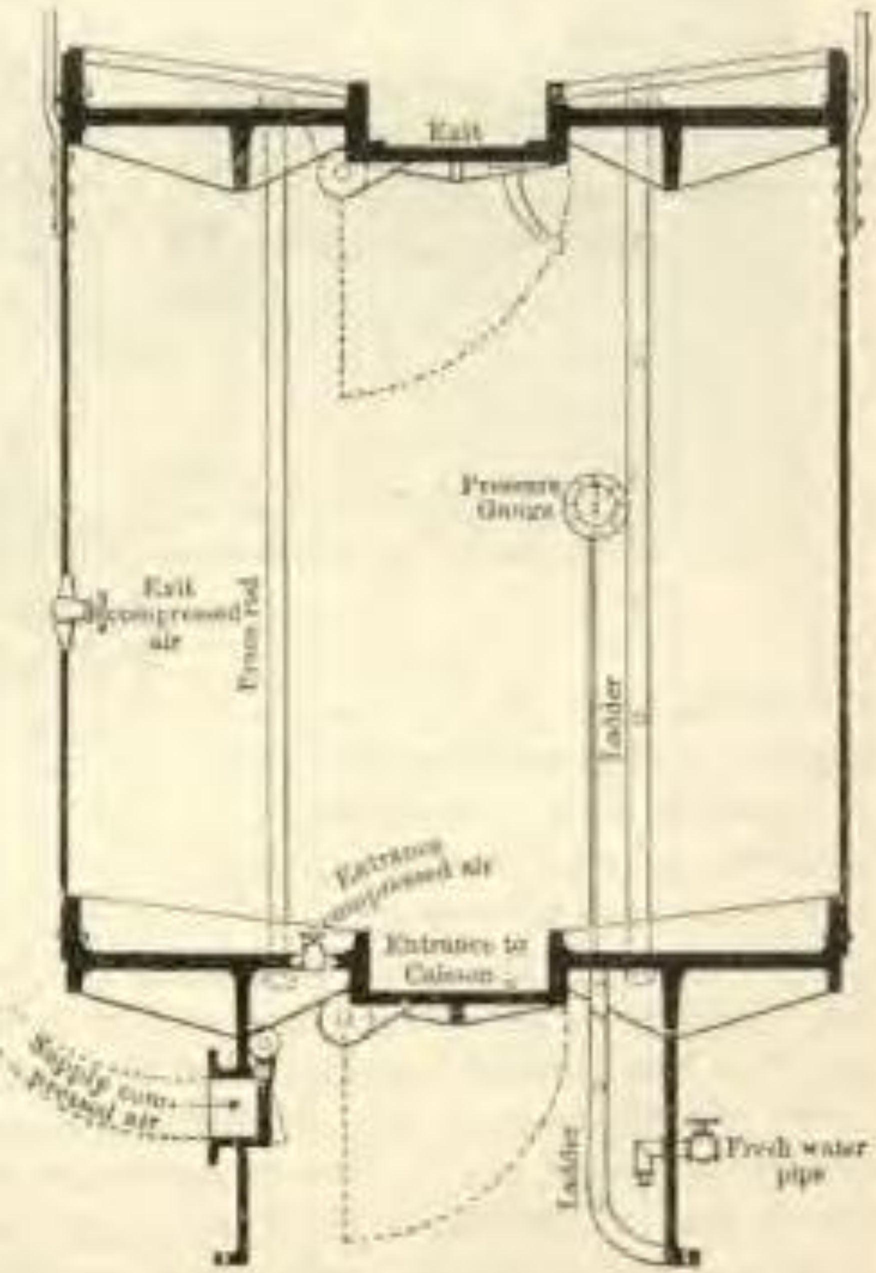
Right: Workmen using a *Sisyphus* and sledge hammers to break boulders



Left: Workmen dumping excavated material into the water pool (at the base of the water shaft) for removal by the clamshell dredge
Right: Workmen sawing an oak block (used as wedges below the shoe and/or frames)

"An unearthly and deafening screech, as from a steam whistle, is the immediate result, and we instinctively stop our ears with our fingers to defend them from the terrible sound. As the sound diminished we are sensible of an oppressive fullness about the head, not unaccompanied with pain, somewhat such as might be expected were our heads about to explode."

Visitor, 1870 – describing the air-lock experience



AIR LOCK.

Cross-section thru Air-Lock

The air-locks were cylindrical in shape; 6.5-feet in diameter and 7-feet high (about twelve men could fit inside) and were made of one-half inch thick boiler plate. Entry was from above via a manhole-size hatch. Upon securing the hatch, the attendant opened a valve near his feet which released compressed air from the work chamber below into the air-lock. The pressure gauge indicated when both the air-lock and the work chamber were at equal pressure.

Once equalized pressure was achieved in the air-lock, the floor hatch was opened and workmen descended a ladder inside a three and one-half foot diameter iron shaft extending a few feet below the roof of the work chamber and into the work chamber itself via a wooden ladder. At any given time, the volume of compressed air lost was no greater than the volume of the air chamber (whenever a gang of workmen entered or exited). For egress, the process was reversed. Air was released from the lock and when the pressure gauge showed 14.7 PSI (normal atmospheric pressure), the top hatch was opened and the occupants exited into fresh air.

"The noise made by splitting blocks and posts was rather ominous, and inclined to make the reflecting mind nervous in view of the impending mass of 30,000 tons overhead."

Washington Roebling, 1870

BLOWOUT!

The supply shaft/s were twenty-one inches in diameter and were used to lower supplies such as sand and gravel into the work chamber. Like the air-lock, there were hatches top and bottom and when one was open the other had to be closed lest a "blowout" occur (rapid escape of compressed air). When a load got stuck in the shaft, a bundle of bricks tied to a rope was dropped down the shaft to free the obstruction. Such a technique was being used to clear an obstruction but, unfortunately, without a means to communicate effectively both hatches were open simultaneously after the obstruction was cleared and a blowout ensued. Fortunately, WAR was present in the caisson at the time and realized quickly what needed to be done to remedy the dangerous situation.

"I was in a remote part of the caisson at the time, half-a-minute elapsed before I realized what was occurring and had groped my way to the supply shaft, where the air was blowing out. Here I joined several firemen in scraping away the heaps of gravel and large stones lying under the shaft, which prevented the lower door from being closed."

WAR – December, 1870

RE: *Supply Shaft Blowout* – mid-December, 1870.

"The question naturally arises, what would have been the result if water had entered the caisson as rapidly as the air escaped. The experience here showed that the confusion, the darkness and other obstacles were sufficient to prevent the majority of men from making their escapes by the air locks…Now it so happens that the supply shafts project two feet below the roof into the air chamber; as soon, therefore, as the water reaches the bottom of the shaft it will instantly rise in it, forming a column of balance and checking the further escape of air. The remaining two feet would form a breathing space sufficient for the men to live, and even if the rush of water were to reduce this space to one foot, there would be enough left to save all hands who retained sufficient presence of mind."

WAR

RE: December 1870 supply shaft blowout

The Great Sunday Blowout

***The Great Sunday Blowout* was caused by attendants not maintaining a higher water level in one of the water shafts (to maintain pressure balance). During the work week, a lower water level could be maintained due to the density of silt in the water column. No work was performed on Sundays, thus there was less silt in the water shaft due to settling. A higher water level should have been maintained via a hose feeding a small stream of water into the shaft (about a ten-foot differential between active and inactive was req'd.). Fortunately, nobody was in the caisson at the time of the blowout. Debris was sent flying 500-feet into the air landing all around. The caisson withstood a ten-inch drop totaling 17,675-tons thus, the caisson carried 23-tons/SF (it was designed to carry five-tons/SF). This proved the caisson to be +4x as strong as specified.**

"The total settling that took place amounted to ten inches in all. Every block under the frames and posts was absolutely crushed, the ground being too compact to yield; none of the frames, however, were injured or out of line. The brunt of the blow was, of course, taken by the shoe and the sides of the caisson. One sharp boulder in No. 2 chamber had cut the armor plate, crushed through the shoe casting, and buried itself a foot deep into the heavy oak sill, at the same time forcing in the sides some six inches. In a number of places the sides were forced in to that amount, but in no instance were they forced outward. The marvel is that the airtightness was not impaired in the least."

Washington Roebling, 1870 – report to the Bridge Company's Board of Directors regarding the Sunday blowout's internal damage to the caisson's work chambers

"To say that this occurrence was an accident would certainly be wrong, because not one accident in a hundred deserves the name. In this case it was simply the legitimate result of carelessness, brought about by an overconfidence in supposing matters would take care of themselves."

WAR

RE: The Great Sunday Blowout

FIRE!

The Friday, Dec. 2nd 1870 fire in the Brooklyn Caisson was akin to a mine disaster. A workman named McDonald held a candle too close to a seam of exposed, flammable *oakum* which ignited (the seam had not been properly pointed with cement) and burned through undetected in overhead areas. Eighty men were in the caisson when the fire was discovered and panic ensued. Wet rags, mud etc. was stuffed into the fist-size hole but inside the flames were spreading. WAR arrived and noticed a violent draft of compressed air feeding the fire. He ordered exploratory holes be drilled to determine the extent of the fire. This was a terrible mistake. The new holes provided draft tunnels that fed the fire, making it much worse.

"Everybody was there, and there was considerable lively calculations going on. Persons in every walk of life wandered about the spot, senators, merchants, laborers. To most of them the whole thing was a mystery."

The Brooklyn Eagle

RE: The Friday, December 2nd 1870 fire in the Brooklyn Caisson

At 8:00am on Saturday, Dec. 3rd, an exhausted WAR, believing the fire had been suppressed, was informed that it was spreading through the roof timbers. A boulder sitting under a water shaft was removed and all workmen were evacuated before WAR ordered the caisson flooded. On Monday, Dec. 5th, air pressure was restored and all the water was pumped out in six hours. One major benefit of the fire was to saturate and swell the wood timbers which were getting too dry. To prevent a similar event in the NY Caisson, the entire interior was covered with boiler plate.

"Men, muddied by splashing liquid clay, dampened by the streams of bursting hose, made their difficult way over all obstacles, climbed upon the elevation whence the water shaft is accessible, and looked down, only to see the unrevealing surface of the column of muddy water, with which the shaft is filled. Others again, climbed upon the platform about the air lock, up and down in which the huge rubber pipes go, and in pursuit of knowledge under difficulties, climbed down as far as they might."

***The Brooklyn Eagle*, December 3, 1870**

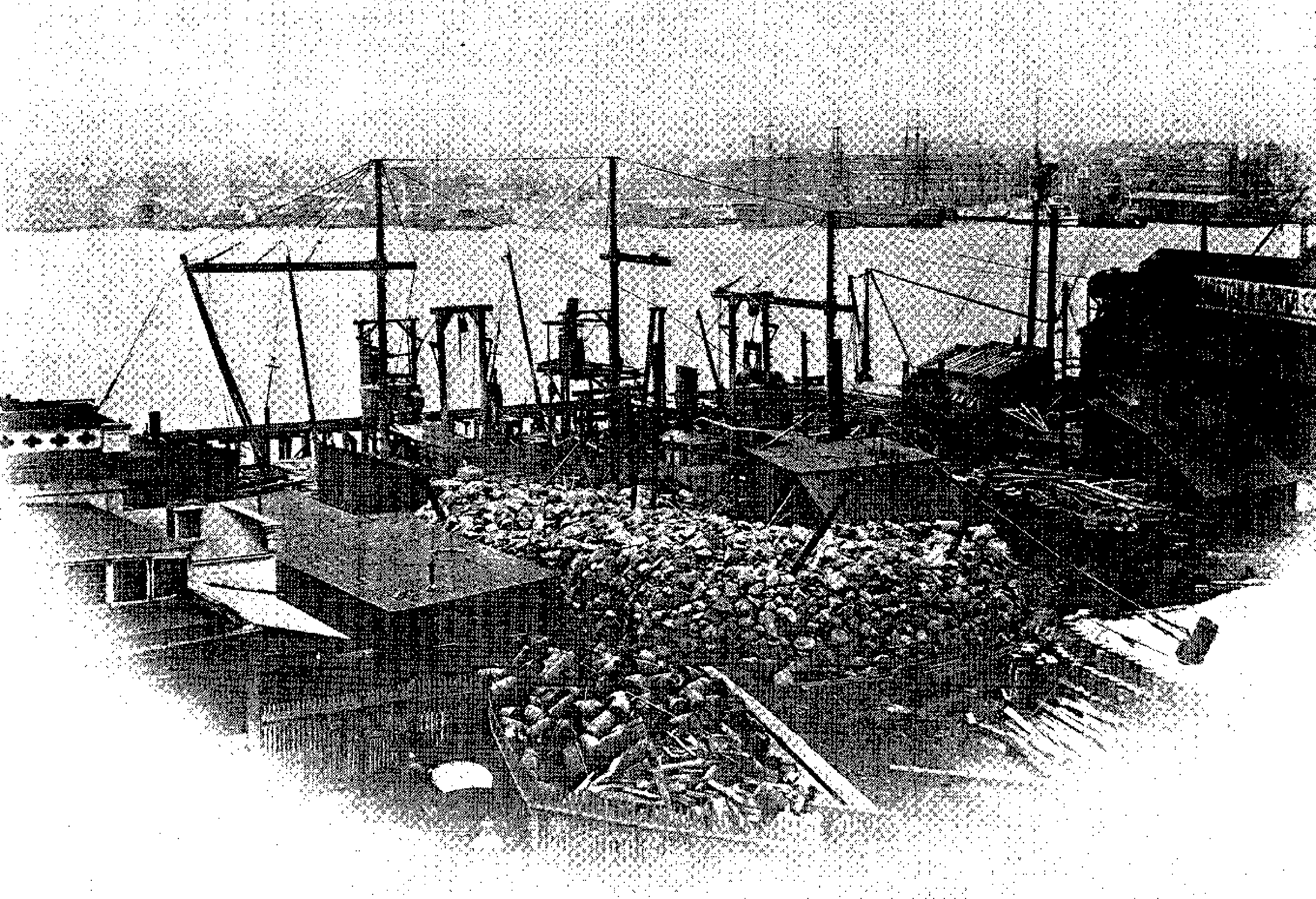
"All that the fire has done is to burn little spaces between the beams, very probably very small ones which will not in that mass of timber affect the stability of the structure in the slightest."

C.C. Martin (Engineering Staff), December, 1870

"From the faithful manner in which the work was done it is certain that the burnt district is fully as strong, if not stronger than the rest of the caisson."

WAR, 1871 – RE: extensive repairs to the Brooklyn caisson's roof timbers after discovering the full extent of the damage caused by the December, 1870 fire

Repairs to the Brooklyn Caisson due to fire damage cost about $50K and delayed the completion of the work for about three months, but on March 6, 1871, repairs were complete. On December 24th 1870, the work chamber began to be filled with concrete and the long process of filling the void with concrete was completed on March 11th 1871. By mid-March, the air chambers were removed and all shafts were drained of water and filled with concrete – the Brooklyn Caisson was complete.



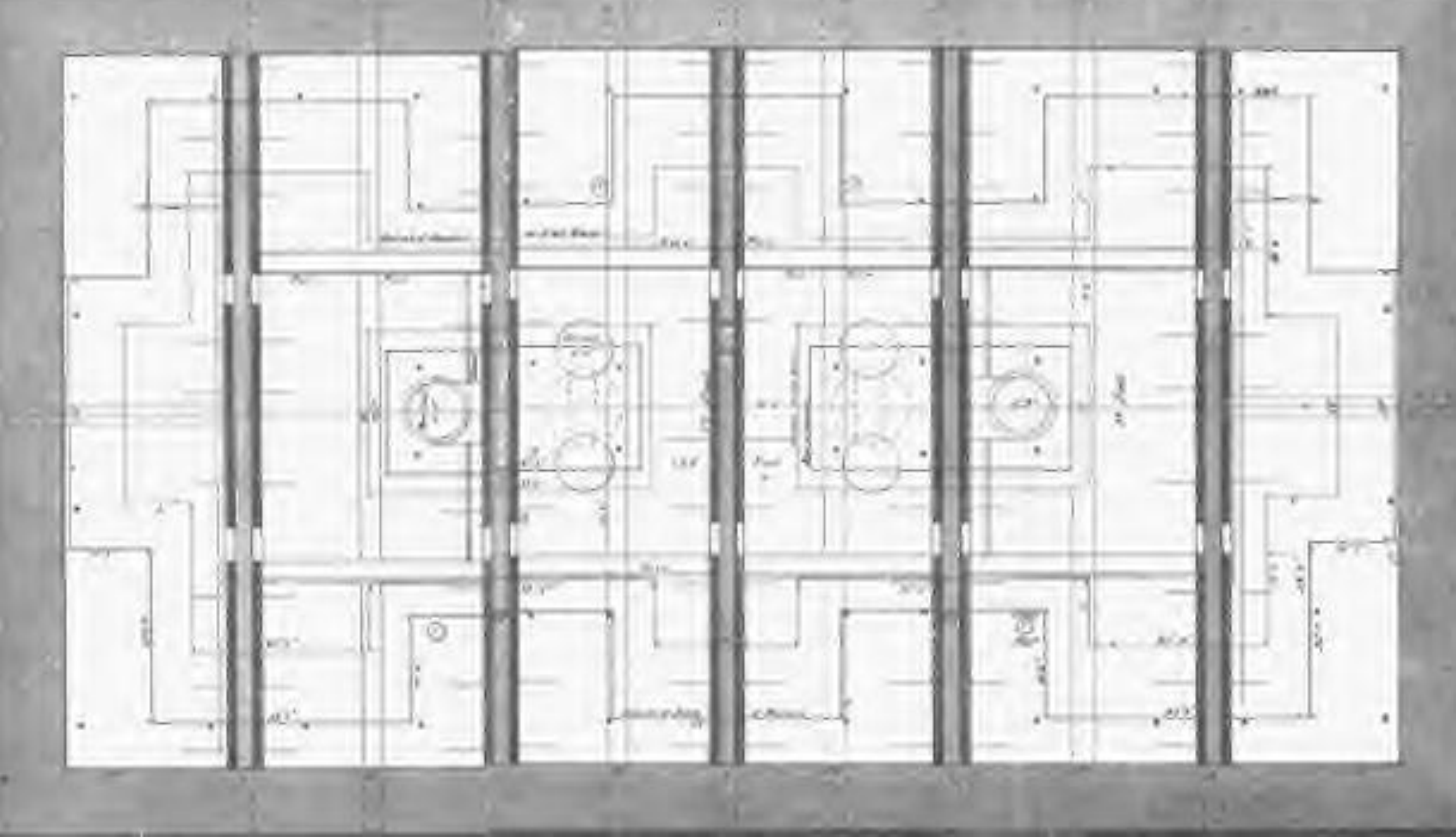
Debris from the Brooklyn Caisson fire

To save time, money and material, the shoe/cutting-edge around the perimeter of the caisson was allowed to sink three-feet deeper than planned thus creating six and one-half feet of headroom (at the tail-end of operations). This *value engineering* idea allowed for one-third less concrete to be used (the work chamber was nine and one-half feet high). For all the problems and difficulties encountered, there were no deaths and/or serious injuries while working on the Brooklyn Caisson. Things would be different on the NY side of the river.

We Are Now On Foreign Soil

The hard lessons learned from sinking and founding the Brooklyn Caisson would be applied to the NY Caisson. As in Brooklyn, WAR added five “frames” (with two openings per frame) that divided the work chamber into six distinct sections. The NY Caisson was launched on May 5th 1871 and floated into place in mid-September, 1871 (it filled the space of two ferry slips). The river bottom had to be dredged to a depth of thirty seven-feet and one hundred-feet of Pier 29 removed to make way for a trestle connecting the caisson to the Manhattan shore.

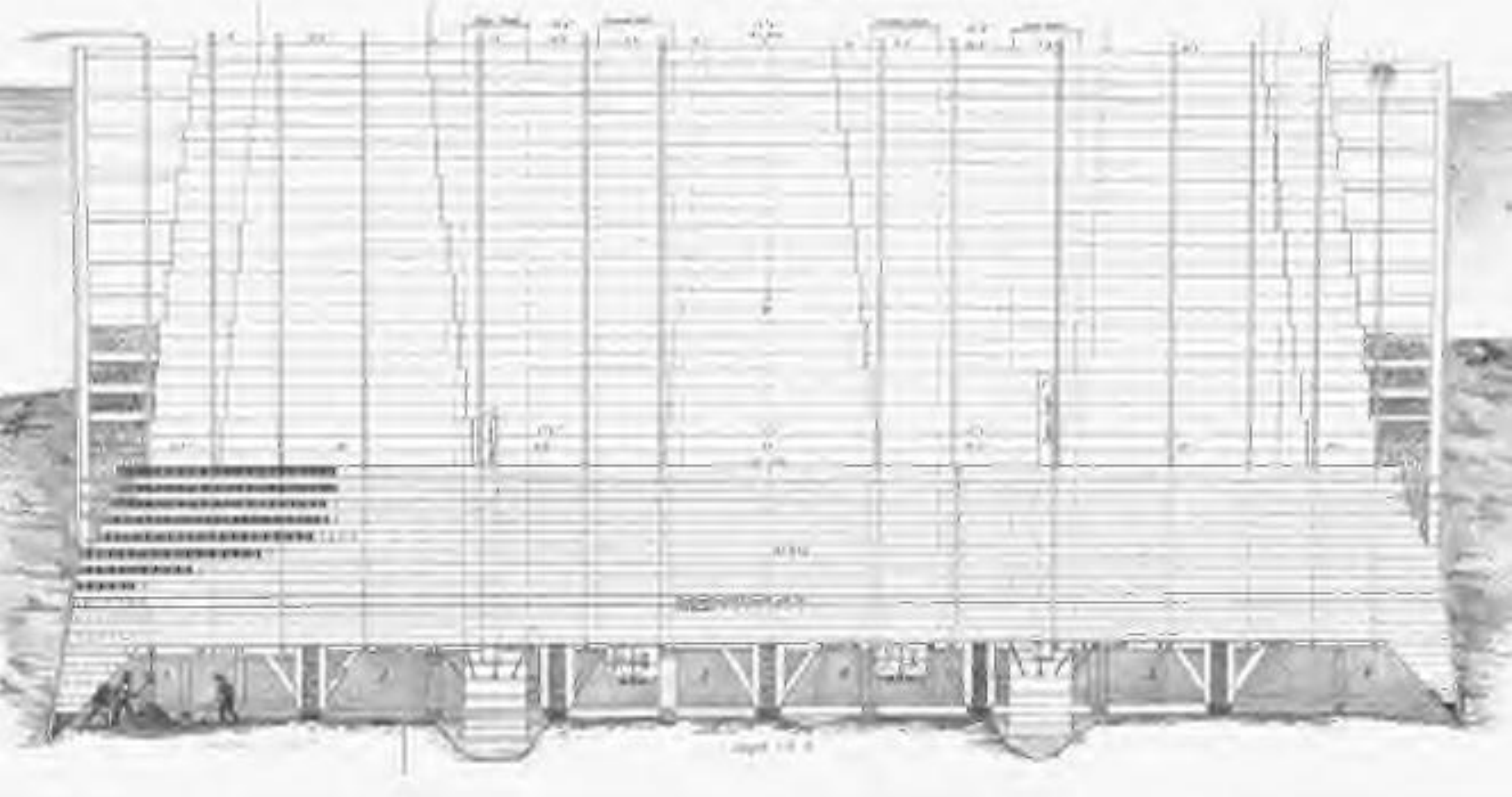
The current on the NY side of the East River was/is considerably stronger so planks were used to construct a square enclosure at the caisson's ends (to break the force of the six-knot tidal current). Because the NY Caisson would have to be sunk much deeper than Brooklyn (therefore carrying more weight), it was four-feet longer measuring 102-feet by 172-feet and 31-feet high. The Brooklyn Caisson contained fifteen-feet of solid timber in its roof whereas the NY Caisson had twenty-two feet – seven more courses, making the NY caisson nearly 2x as strong as its sister caisson in Brooklyn.



Plan of the NY Caisson

Note the cylindrical water shafts (rather than square, as in Bklyn)

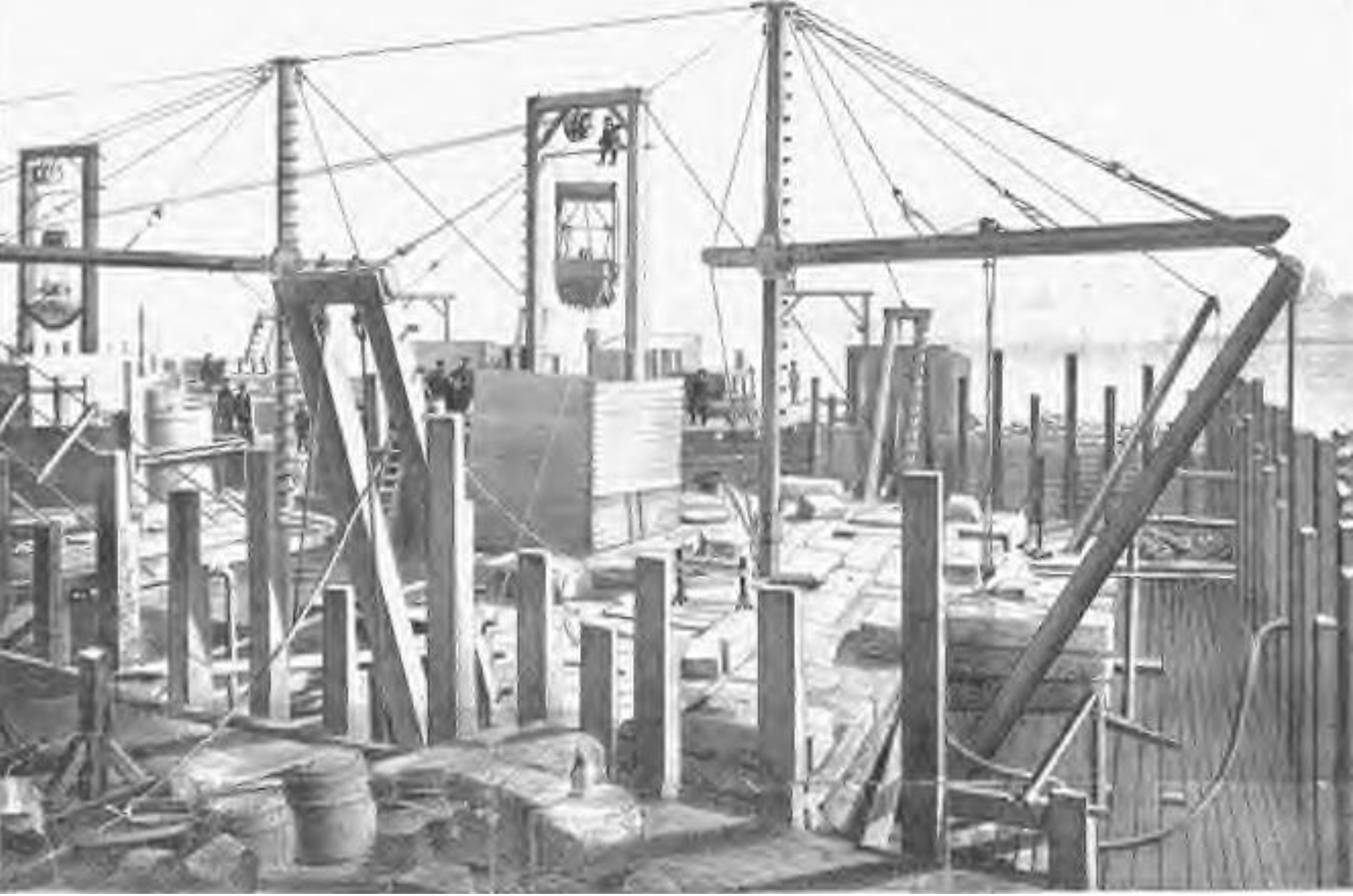
Though there were many similarities to the Brooklyn Caisson, there were important differences as well. Fifty(50) four-inch diameter iron pipes were installed for removing sand (the NY side of the riverbed was mostly sand, unlike Brooklyn which was mostly rock). These pipes ran though the roof of the caisson and extended nearly to the floor, there was no closure thus a vacuum effect (caused by compressed air escaping) sucked out sand shoveled at the base of the pipe by workmen. At top, it was diverted into a barge and removed from the site.



Longitudinal Section – NY Caisson

Note the structure on either side of the caisson (to break the force of the tidal current) and the additional courses of timber in the caisson's roof. The multiple sand pipes running from the work chamber to the top of the caisson are also in view

The force at which the sand traveled through the pipe/s was so great that it cut through iron pipe in a matter of minutes and through granite blocks (placed on top of the pipes to divert the sand into the barges) in a matter of days (one man had a finger taken off by the force of the sand). Danger aside, it was a very efficient method for removing the sandy river bottom and relieved the pressure on the clamshell dredge/s as the sole means of removing excavated material from inside the caisson. It also provided much needed ventilation since the NY Caisson was much more airtight.

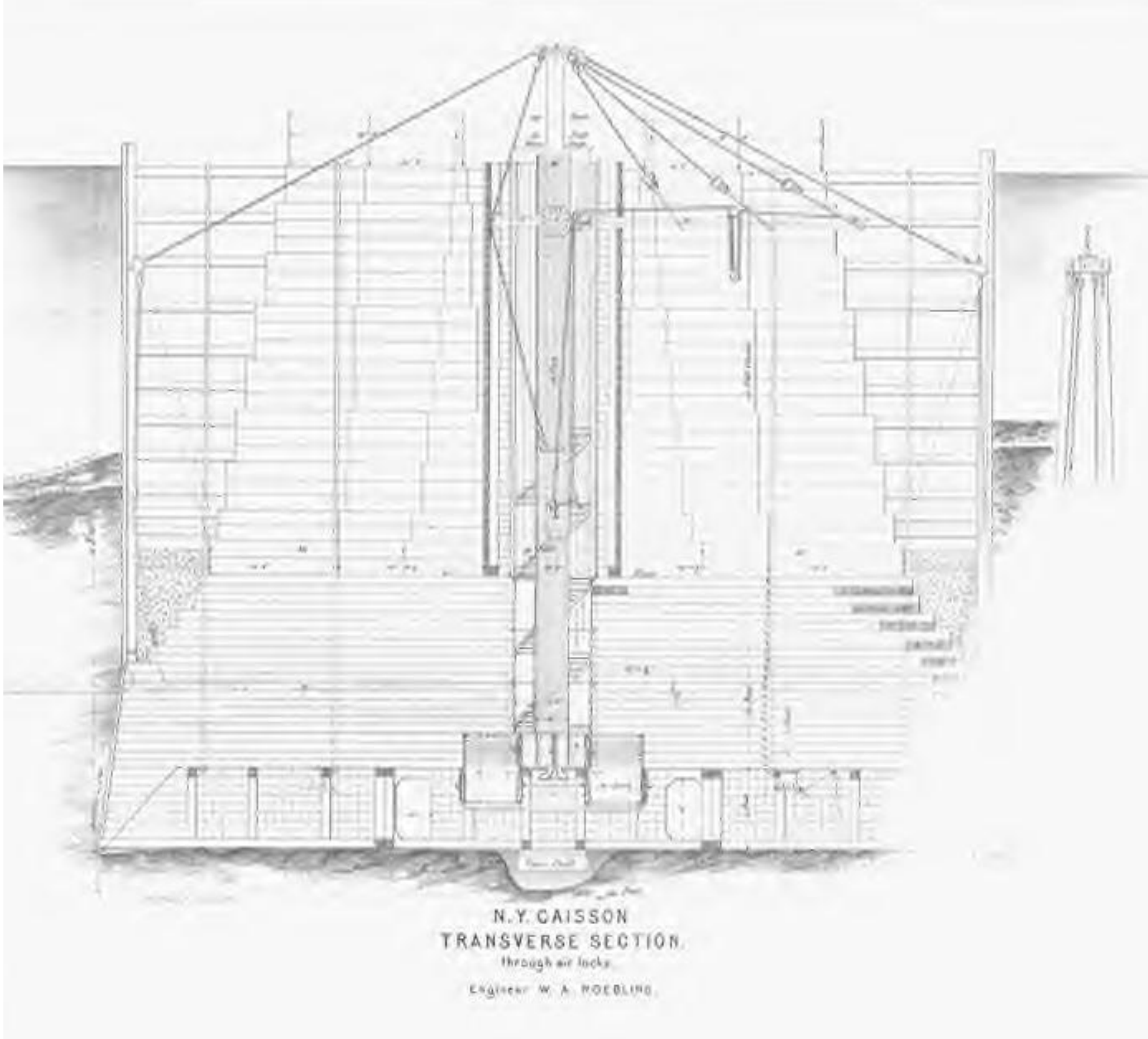


Atop the NY Caisson

Note the clamshell dredge bucket (center top) above water shaft

***Colonel Thomas Paine*, former chief cartographer of the Union Army during the Civil War, was placed in charge of the bridge's superstructure. He was a very capable man and contributed greatly to the Bridge's success. Using one of the fifty sand pipes (running through the top of the caisson to the work chamber below), he devised a mechanical signaling system (i.e. *stop* / *start* / *bucket is caught* etc.) that allowed for communication between the surface and the work chamber. It worked flawlessly eliminating the need for someone to enter or exit the caisson to "see what's happening" (as was done in Brooklyn).**

One major change WAR made on the NY Caisson was to the air-locks (he would come to regret this). The locks were now “double-locks” holding thirty men each thus, one-hundred and twenty men could leave and/or enter the work chamber at one “locking.” After visiting the St.Louis Bridge Caisson, WAR decided to use the same configuration as Capt. Eads had since the NY Caisson had to go very deep in sand to hit bedrock, as was the case in St. Louis. He built the air locks into the roof of the work chamber and a spiral staircase above connected the chamber to the surface.

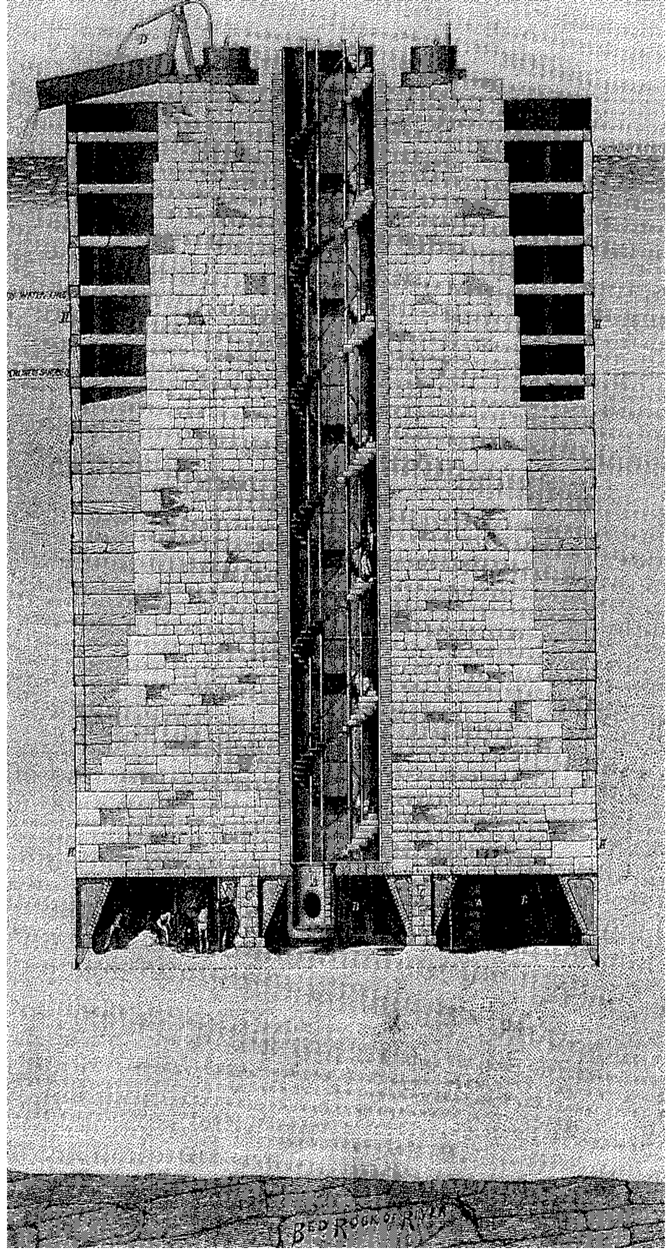


Transverse Section - NY Caisson

Note the double air-lock and spiral stair configuration

It was thought by WAR that men entering the air-lock first, decompressing and then climbing the stairs to exit (the stairs got higher as the caisson descended) would be preferable to the reverse arrangement in Brooklyn (there was a ladder from the work chamber to the air-lock which was located nearer to the surface). Decompressing caused fatigue and, with diminished strength and/or *The Bends*, the men had to climb up the spiral staircase to exit. It was better to climb stairs before decompressing since the debilitating effects of decompression were not in effect until the men were closer to the surface and fresh air.

Ultimately, a steam-driven lift had to be installed to remedy the situation of fatigued men unable to ascend the spiral stairs to the surface. The other problem this change caused concerned Capt. Eads directly, he took personal umbrage at the fact that WAR had copied his air-lock design, this despite the fact that Eads had personally invited him to see it. Litigation ensued and, to his annoyance but relief, WAR settled out of court.



St. Louis Bridge Caisson

Note the air-lock (at the caisson's base) and spiral staircase

"Its perusal has left only the one prominent impression on my mind, that his skill in blowing his own trumpet is only surpassed by his art in writing abusive and unjust articles about other people."

Washington Roebling, 1873 – response to Capt. Eads' claims in *Engineering* that WAR had not given him due credit for placement of the air locks at the bottom of the caisson (NY tower only)

"The love of praise is, I believe, common to all men, and whether it be frailty or a virtue, I plead no exception from its fascination"

Capt. James Buchanan Eads, 1874

RE: Excerpt from his speech made at the opening ceremonies for the Mississippi River Bridge at St. Louis

St. Louis Bridge (a.k.a. *Eads Bridge*)

"I am willing to accede to the proposition of Captain Eads in order to settle this matter. I give my consent more as a matter of expediency than from conviction. I am not in a frame of mind to stand any further worry about a lawsuit."

WAR, 1876

RE: WAR paid Eads $5K to settle the matter of the air-lock design once and for all.

Sewage Abominations

"This is a wise provision of nature, because foul odors certainly have their home in a caisson"

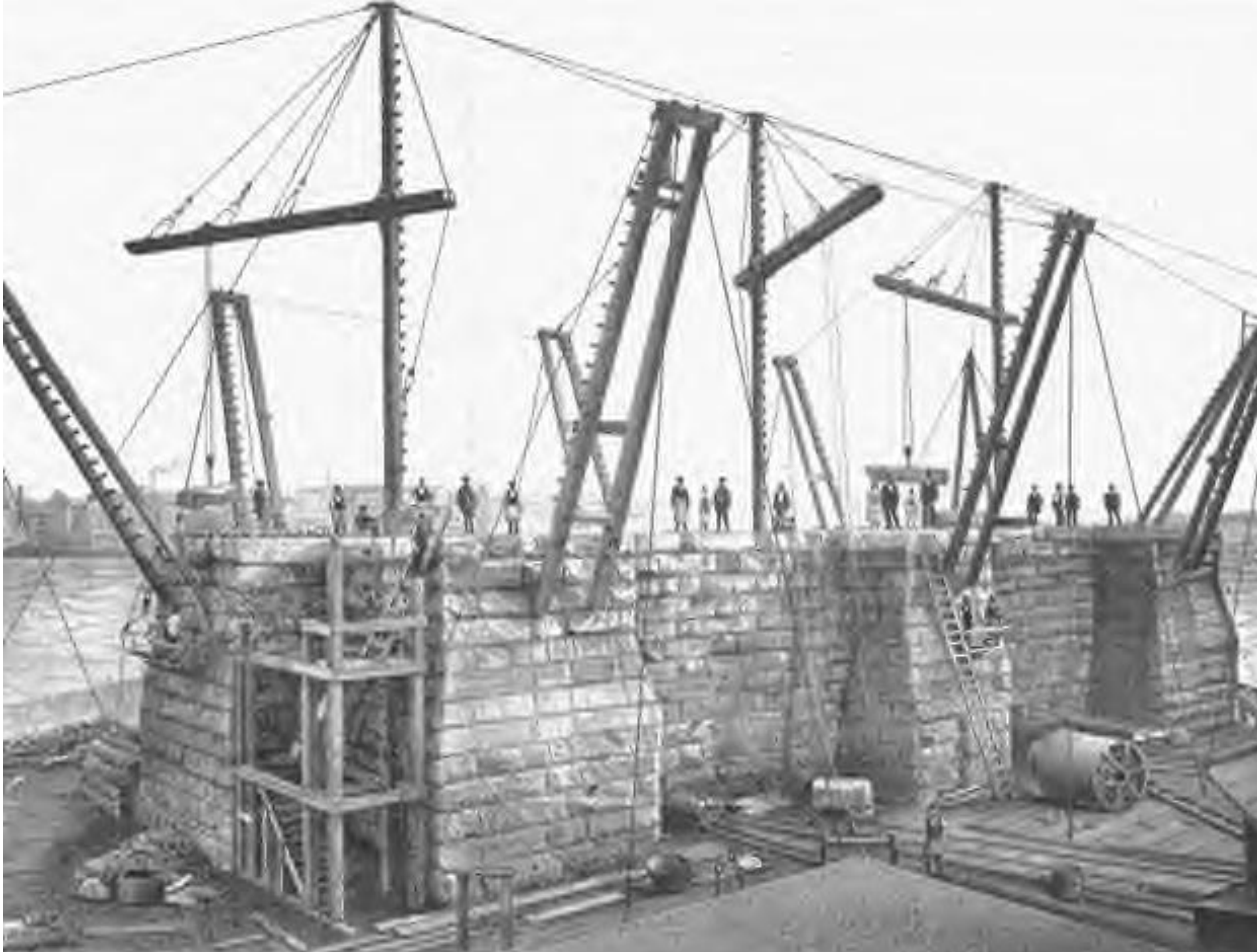
WAR, 1871

RE: Commenting upon the fact that the sense of smell is lost in a compressed air environment. Unbeknownst to all, the NY Caisson was sited adjacent to an open sewer. Even though compressed air reduces the sense of smell, it is not completely absent and the stench of the riverbed from the raw sewage was nauseating. A thin (one-inch) film of water was maintained over the entire floor of the river bed (below the caisson) to help reduce the foul odors.

"The downward movement of the caisson has been under perfect control."

Washington Roebling, 1872

With much more favorable soil conditions and the ever increasing weight of the masonry above, the caisson descended steadily. What took ten months in Brooklyn (to reach forty-five feet below the river bed), took only one month in NY. By contrast, only eight-feet of masonry penetrated the riverbed at this depth (45-feet) on the NY side (bedrock was expected to be found at 106-feet). At this depth, the air pressure needed was twenty-one PSI and, as in Brooklyn, signs of pain and discomfort among the workmen began to appear, things would take a turn for the worst past fifty-feet (+24 PSI). Initially the workday was divided into two shifts with a two-hour interval, 50-125 men during the day and 15-30 at night. At 45-feet, WAR changed this to two shifts, seven and one-half hours each and at 50-feet, two shifts, seven hours each.



Atop the NY Caisson

"good enough to found upon, or at any rate nearly as good as any concrete that could be put in place of it."

Washington Roebling, May, 1872 – RE: decision to stop New York caisson's decent atop compacted gravel & sand – not bedrock

“The great timber foundation was now complete! It contains twenty-two feet of solid timber above the roof of the air chamber, seven courses more than the Brooklyn caisson, and since strength of such structures varies as the square of the depth, we may consider it to be nearly twice as strong as its Brooklyn brother.”

WAR, September 1872

"…He gave the work his unremitting attention at all times, conspicuous for his presence and exertions."

W.C. Kingsley

RE: WAR

WAR ca. 1872

Note the change in his physical demeanor

His youth was gone and the debilitating effects of *The Bends* had taken their toll on both his physical and mental health. WAR suffered more than anyone else the long-term effects of *Caissons Disease* since he was the person most often entering and/or exiting. In particular, the December 1870 fire whereby he entered and exited the caisson many times in a short period was most detrimental. It was a wonder how he even survived at all.

"Regarding your health my council would be sit down and keep quiet…Above all don't let a fake ambition lead you on to undertaking tasks that will only break you down all the more. You are no doubt beginning to find out, as I have found out long ago, that nervous diseases are as intractable as they are incurable and only through mental rest of all the faculties and especially the emotions can they even be palliated in the slightest degree."

Washington Roebling, 1874 – excerpt from letter to Francis Collingwood

"My health has become of late so precarious a nature, that I find myself less and less able to do any work of any kind. I am therefore reluctantly compelled to offer my resignation as Engineer of the East River Bridge. The hopes that time and rest would effect a change have been in vain, rest being simply impossible."

Washington Roebling, December, 1875 – at his lowest point, letter dictated to Emily – never received a reply – questionable if she ever sent it

"We are not partial to long official reports, but this one is exceptional in the thrilling interest of the story."

The Brooklyn Eagle*, June 5, 1871 – RE: WAR's annual report to the Bridge Co. published in the *Eagle

"The adventures of Colonel Roebling and his 2,500 men under the bed of the East River are as readable, as he tells them, as any story of romance which has issued from the imagination of the novelist."

***The Brooklyn Eagle*, 1871 – RE: comparing Jules Verne's 1870 English publication of *20,000 Leagues under the Sea* with the drama of sinking the Brooklyn caisson**

Part 11

The Bends

Caissons Disease (a.k.a. "The Bends") is caused by nitrogen (a major component of the air we breath) coming out of solution under pressure (like a compressed-air work chamber or diving to great depths) and forms small bubbles in the bloodstream. Egress from this pressure environment too quickly (not allowing the nitrogen bubbles to dissolve back into the bloodstream) causes the bubbles to coagulate and block the flow of blood. Deprived of blood, a "heart attack of the joints" literally occurs.

"When it is severe, local numbness, weakness, and faintness resemble the sickening pain of a blow on the testicle."

Medical Textbook Description of Caisson Disease – 1870's

It was long believed that, unlike humans, marine mammals such as whales and dolphins could ascend and descend the depths of the ocean at will without any harm caused by the great pressure to their bodies, that no longer appears to be so. Autopsies performed on beached whales reveal nitrogen bubbles in their bloodstream. Sonar from ships and acoustic bombs (used to search for oil below the ocean floor) cause incredible pain to marine mammals who communicate via sound. In pain from the alien noise, they are believed to ascend to the surface too quickly and the result is *The Bends*. In unbearable pain and with no options other than ending the pain by killing themselves, they commit mass suicide by stranding on the nearest beach. That is the theory at least for the ever increasing frequency of these events around the world.

Beached Pilot Whales - Tazmania

"Knowing from reports of other similar works that compressed air was liable to affect some men unfavorably, every known precaution was taken to guard against this danger"

William C. Kingsley

"That the system struggles against this abnormal state of affairs, is shown by the fact that the number of inhalations per minute is involuntarily reduced from thirty to fifty percent. It follows, therefore, that the shorter the period of exposure to compressed air the less risk."

Washington Roebling, 1870

"He is strictly temperate and regular in all his habits, and is none the worse for his long service in compressed air."

W.C. Kingsley, 1870 – RE: Mike Lynch who worked the first shift through to the last in the Brooklyn caisson

The Heroic Mode

"…by applying the heroic mode of returning into the caisson at once as soon as pains manifested themselves."

Washington Roebling -- RE: returning to work chamber to alleviate pain caused by "the bends"

"It frequently happened under my observation that pains not sufficiently severe to deter men from returning to work were promptly dissipated on entering the caisson, to return again on coming into the open air. Indeed, I do not remember a single exception to the rule, that any pain which may have been felt before, disappeared almost immediately on going down."

A.H. Smith, 1873 – Surgeon to the Bridge Company – report to Bridge Company

"As it is now demonstrated that the method of compressed air is applicable to a great range of engineering operations, and offers many peculiar advantages, it is extremely desirable that the principal objection to its employment, viz., the discomfort and danger to the workmen, should be reduced to a minimum. To this end I offer the following suggestions…"

A.H. Smith, M.D.

1. **Never enter the caisson with an empty stomach**
2. **Use as far as possible a meat diet, and take warm coffee freely**
3. **Always put on extra clothing on coming out, and avoid exposure to cold**
4. **Exercise as little as may be during the first hour coming out, and lie down if possible**
5. **Use intoxicating liquors sparingly; better not at all**
6. **Take at least eight hours sleep every night**
7. **See that the bowels are open everyday**
8. **Never enter the caisson if at all sick**
9. **Report at once at the office all cases of illness, even if they occur after going home**

A.H. Smith, 1872 – Surgeon to the Bridge Company

Case 11 – E. Riley. Taken sick February 16th, one hour after leaving the caisson. Pressure 26 PSI. Epigastric pain and pain in the legs. No loss of sensibility. Profuse cold perspiration. Pulse, when I saw him, two hours after the commencement of the attack was 96. The pain, which at first was very severe, had by this time become much less. Gave him an ounce of brandy and a teaspoonful of fluid extract of ergot. In ten minutes the pulse had fallen to 82. Was able to resume work the next day.

A.H. Smith – Surgeon to the Bridge Company, Case Notes

<u>Case 12</u> – Joseph Brown, foreman, American, aged about 28. Taken on the 28th of February, about an hour after coming up from a three hours watch. Excessive pain in left shoulder and arm, coming on suddenly, *"like the thrust of a knife."* Pain continued until he went down again for the afternoon watch, when it ceased immediately…

A.H. Smith, 1872 – Surgeon to the Bridge Company, Case Notes

"Experience teaches, that the ill effects are in proportion to the rapidity with which the transition is made from the compressed air to normal atmosphere"

M.B. Pol, 1854 – French Mining Engineer

Dr. Smith took a dog into the caisson for seven hours and then killed it with prussic acid. He took a blood sample and observed bubbles in the bloodstream but did not make the connection with nitrogen coming out of solution under pressure (in later years he would invent the hyperbaric chamber as a result of his experiences as surgeon for the bridge company). Though it was suspected exiting too quickly was a probable cause by Dr. Smith and others (such as mining engineer M.B. Pol seventeen years earlier), there were other theories such as an odorless, colorless gas emitted from the riverbed causing the symptoms or the blood leaving the extremities and moving to the center of the body under pressure.

Dr. Smith ordered that for every three(3) PSI greater than 14.7 PSI (normal atmospheric pressure), one minute more in the air lock was required. Thus, when at 65-feet and a pressure of 30 PSI, five(5) minutes were required. in the air lock. At 75-feet/33 PSI, six(6) minutes were required etc. The men resisted and though armed with a pistol, the attendant was no match for thirty men wanting to get a drink at the nearest tavern after a hard day's work. Smith studied Dr. Jaminaet's notes and research for the St. Louis Bridge Caisson and he personally made careful notes and observations on every case. He concluded that a man's physical condition and even their ethnicity played a part in the severity and/or lack of symptoms. Men who were fat and heavy drinkers suffered the most while a lean man of medium height in his 20s or 30s fared best.

"Indeed, it is altogether probable that if sufficient time were allowed for passing through the lock, the disease would never occur."

A.H. Smith, 1872

A strong cup of coffee was given to all exiting the air-lock. In worst case scenarios (to alleviate the great pain), ergot in quantity, whiskey and ginger, injections of atrophine (an antisposmodic) were adminmistered. If all else failed and as a last resort, morphine was given to the patient. Typically, an attack of *The Bends* lasted for several hours. Altogether, Smith recorded 110 cases including those of the engineering staff. However, it will never be known how many actual cases there were for many went unreported out of fear of losing their job. It is very likely that some of the 2,500 men who worked in the caisson went home to die and were never seen or heard from again.

“The natural impatience of the men to reach their homes, makes the delay in the lock irksome, and great firmness is required on the part of the lock tender to prevent the escape cocks being opened more widely than is consistent with safety”

A.H. Smith, 1872

Andrew H. Smith was a former army surgeon and a throat specialist. He was appointed *Surgeon to the New York Bridge Company* on January 25, 1872 and served in this position until May 31, 1872. In 1881, he performed the autopsy on President Garfield.

Lunch Break

Part 12

A Likeable Scoundrel

“The spectacle is appalling. We live in an atmosphere of hypocrisy throughout”

Walt Whitman

RE: The endemic corruption of the late 19th century. In the post-Civil War era, corruption was being institutionalized from the federal (i.e. Grant Administration) down to the state and, especially, local levels.

"All were disgusted, but they had to content themselves by turning their backs and going to work harder than ever on their railroads and foundries."

Henry Adams

“Who owns the City of New York today? The Devil!”

Henry Ward Beecher

RE: *William Marcy Tweed*.

William Marcy Tweed

The construction of the Brooklyn Bridge coincided with the height "The Tweed Ring" whereby corruption of the NYC government was institutionalized under the charismatic leadership of "Boss Tweed." Tweed got involved with politics when he served as a volunteer fireman. Though he was of Scottish ancestry, he won the favor of Irish immigrants (who became his base of support) by securing ferry service to Williamsburg where they had a large community. His fall came about partly due to his own excesses and the building of the bridge. A contractor in league with the ring would put a bid in on a public project covering all their costs (plus profit) and then the ring would tell them to add 50 to 65% on top of that which was required to be kicked-back. It was a simple but very effective extortion racket.

"Although the bridge from every element of its use and from the source of its finances, is considered a public enterprise, yet it is entirely a private corporation in which the public has no voice..."

Demas Barnes

The Bridge Company issued $500K worth of stock; Brooklyn bought $300K and NY $150K worth of the capital stock at $100/share (Brooklyn won the honor of having the bridge named "Brooklyn Bridge" since it bought 2x as much stock as NY did). The balance of $50K was private stock mainly held by Tweed and his cronies and purchased at a significant discount. A person owning one share of private stock had as much to say about the way the bridge company operated as did the entire cites of Brooklyn and/or NY. After the collapse of the Tweed Ring, the bridge company would be reorganized as a public company with a Board of Trustees rather than a Board of Directors. Tweed had grandiose plans (he wanted to take over the entire United States), but his incarceration and death (in 1878) put an end to his plans.

Boss Tweed was born at No. 3 Cherry Street, next to the first presidential mansion located at No. 1 Cherry Street. Both structures were demolished to make way for the NY anchorage, where this plaque is permanently affixed.

"I don't care a straw for your newspaper articles – my constituents don't know how to read, but they can't help seeing those damn pictures!"

W.M. Tweed, 1869

RE: Response to Thomas Nast's cartoon attacks on the Tweed ring in *Harper's Weekly*. Tweed was as charming as he was corrupt and was extremely loyal and generous to his friends, though ruthless to his enemies whom he tried to subdue with pay-offs, most of the time he succeeded. He was also completely unbiased when it came to race, ethnicity etc., as long as you served his and/or the Ring's purpose, you were allowed in. With a large immigrant community desperate for work, *quid pro quo* was the path of least resistance for most, but NYC's gentry were, in general, appalled at the goings-on.

A typical Thomas Nast cartoon in *Harper's Weekly*

"Deftness in speech was supplanted by deftness in manipulation of votes; dexterity in argument made way for the dexterity which makes one count for two for your side. The deterioration of our political methods began then…"

The Brooklyn Eagle - RE: Tammany Hall

"THAT'S WHAT'S THE MATTER."

Boss Tweed. "As long as I count the Votes, what are you going to do about it? say?"

"Mr. Tweed was a power in New York then, and nothing could be done in the Common Council and hardly in Albany without his help. You know how he controlled everything at that time, and therefore he was the proper person to see, when anything was wanted in the way of legislation, to secure his influence for any measures that were to be passed."

Henry Cruse Murphy

"You just do as Jimmy tells you, and you will get your money"

Boss Tweed

RE: James Watson, NY County Auditor. Watson was killed in a carriage accident, this event would begin the rapid fall of *The Tweed Ring*. His replacement's background was not checked carefully, had they inquired they would have learned that he had a score to settle with the ring. As county auditor, he gave records of the corrupt dealings to reporters eager to sell newspapers and assist in the fall from grace of Boss Tweed and his Tammany Hall cronies.

"What a testimony of the loyalty, the royalty, and the abounding East Indian resources of Tammany Hall…Was there any Democracy to compare with thy Democracy, in glory, power, and equal rights, under the sun? Never! And it is just the beginning of the good time coming. Don't talk of Jeff Davis and his absurd Democracy; don't mention the democracy of the Paris commune as representing true Democratic principles; but come to the fountainhead of democracy, the old wigwam, and you will get it there - if you get within the lucky circle of the 'magic' ring."

The New York Herald, August 2, 1871 - commentary regarding the opulent wedding and gift-giving for Boss Tweed's daughter on May 31, 1871

“Our Boss” (Tweed)
(adorning the cover of a cigar box)

"Well, I don't think I'll do it, I made up my mind not long ago to put some of those fellows behind bars, and I am going to put them there."

Thomas Nast, *Harper's Weekly*, 1871 - RE: $500K bribe offer

"There is no power like the power of the people armed, aroused, and kindled with the enthusiasm of a righteous wrath!"

Judge James Emott, 1871 – Committee of Seventy

Q: ***"Now, how did you expect to be benefited by becoming one of the subscribers to this bridge?"***

A: ***"I expected that when the bridge was built by the citizens of New York & Brooklyn, and with their money, it would be a well-paying dividend stock. Then we expected to get employment for a great many laborers and an expenditure of the money for the different articles required to build the bridge"***

W.M. Tweed – interchange with interrogator

"This Company was chartered as a private Company, and although the cities of New York and Brooklyn subscribed to its capital stock, that fact did not change its character. There were scores of railroad corporations in this state to whose stock towns and cities have subscribed under authority of the law, and which retain their private character. We refer to this fact merely for the purpose of showing how natural, right and proper in itself it was for the Executive Committee, in the absence of all legal provisions to the contrary, to exercise their discretion in this respect in the same manner as other private corporations."

Executive Committee, 1872

"It is, no doubt, true that Mr. Kingsley, in connecting himself with this great work, looked to some pecuniary advantage. It is hardly to be supposed that anyone would spend so much time and labor and incur such pecuniary liability as he had done without some expectation of remuneration."

Executive Committee, 1872 – response to Committee of Investigation report

"Every man must have somewhere an objective in life with which a greater good than money allies him…My objective is to build the bridge."

W.C. Kingsley, 1872

"It has been alleged, that supplies have been furnished by members of the company, at prices prejudicial to the interests of the bridge. In all such cases I know that supplies have been furnished after a reasonable competition, and at rates lower than those of any other bidder…"

WAR – July 1, 1872

RE: Excerpt from a report to the Board of Directors

Throughout the course of the Tweed Ring debacle and subsequent mis-dealings, WAR remained entirely above the corruption surrounding him. Bridge company president Henry Cruse Murphy instructed him to let William C. Kingsley and his superintendent handle all material, equipment etc. purchases and/or labor dealings.

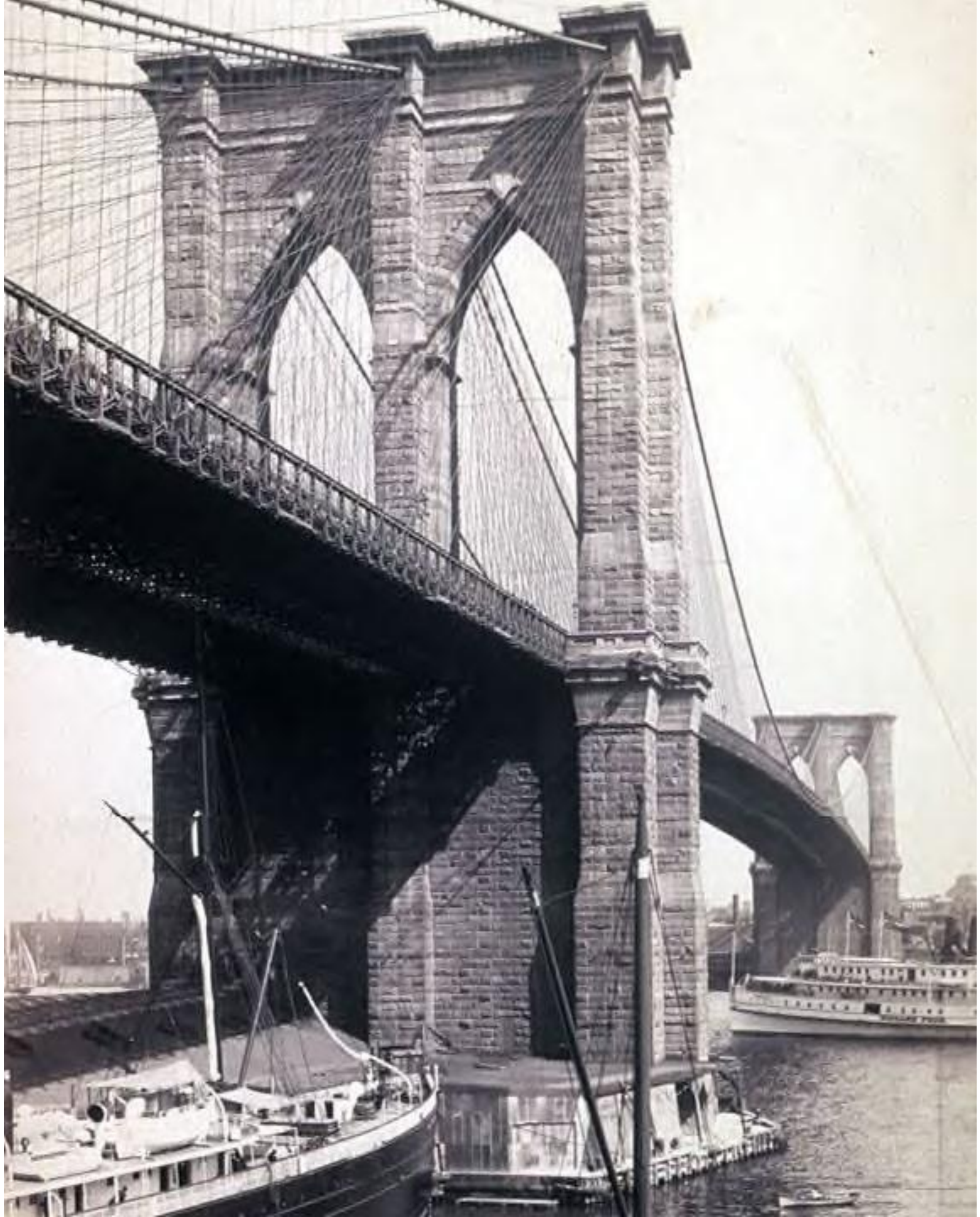
Part 13

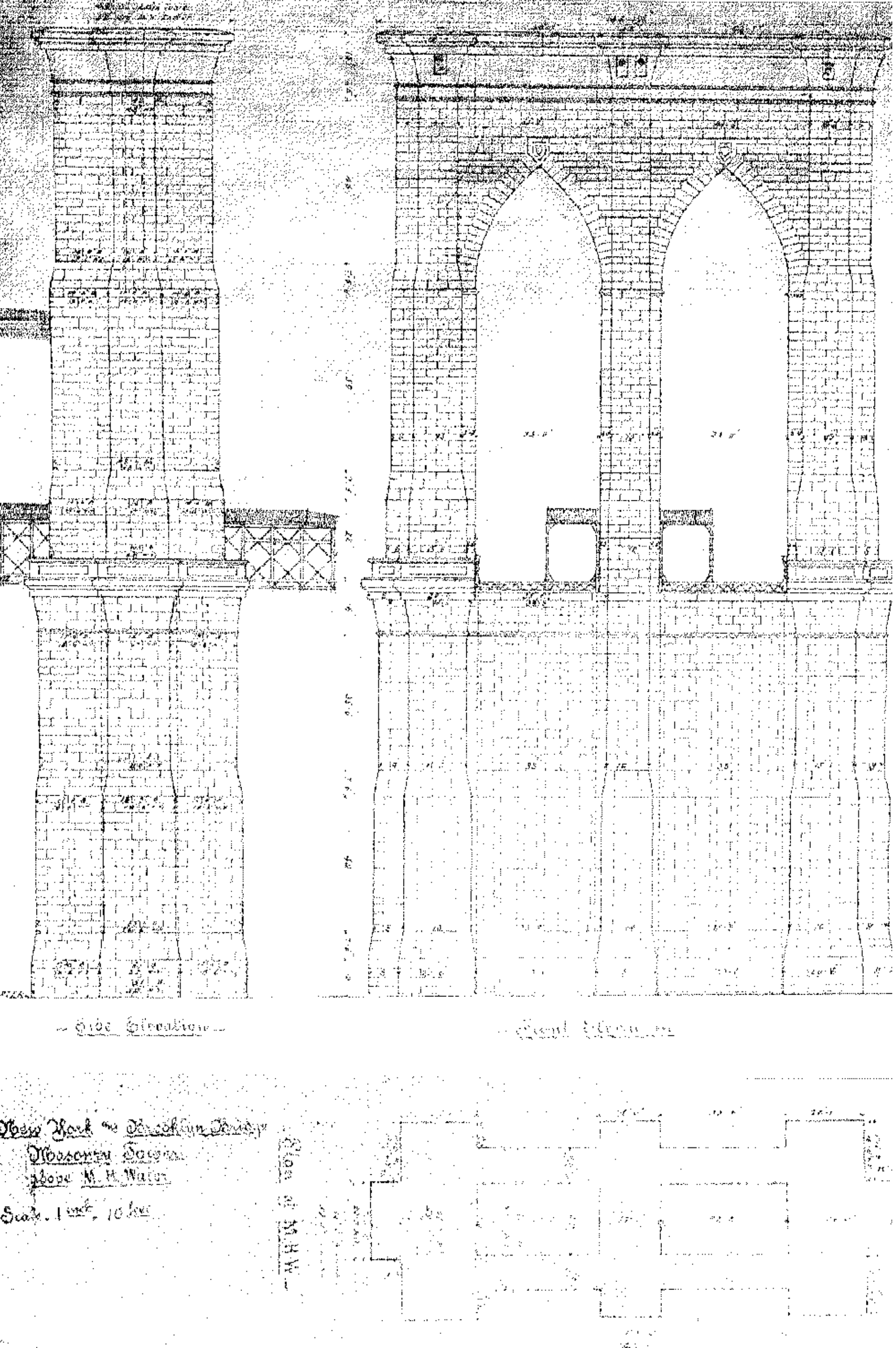
Most Conspicuous Features

The two towers of the Brooklyn Bridge rose to a height of two-hundred seventy-six-feet, six-inches (eight-feet, six-inches higher than JAR's original plan called for due to the mid-span height increase from 130-feet to 135-feet required by the Army Corps of Engineers). The towers would be made of solid masonry courses only where the four cables bore down above (buttressed), in between (below/above the arches) the masonry was hollow. It would be the last time such large masonry towers were built to support the cables of a suspension bridge. The new material – steel, would be used for future suspension bridges due to its strength and economy. JAR got the idea for the pair of gothic arches in each tower from the stained glass windows in the church he attended back in Saxonburg, PA.

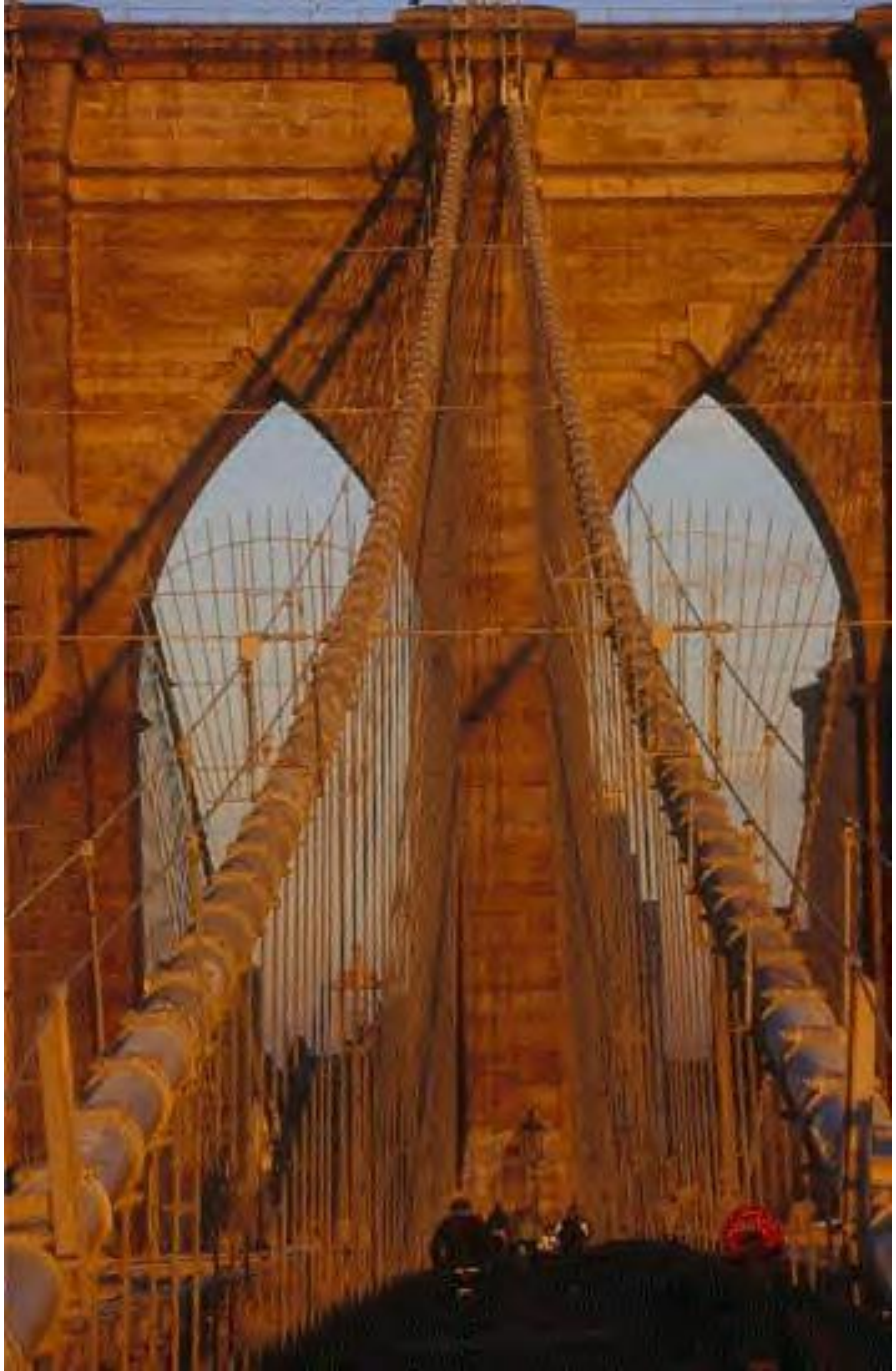
"Think of Trinity Church as big as the top of the Steeple as at the ground, and one solid mass all the way up, and we get some idea of what the great Brooklyn tower is to be…the fame of the Roeblings and the boast of Brooklyn forever will be that, where nature gave no facilities for a suspension bridge, and seemed indeed to place a veto upon the idea in these low and shelving shores, the genius of the father designed and the consummate inherited and acquired ability of the son executed, in spite of all obstacles, this most novel and unparalled masterpiece…"

Thomas Kinsella – Editor, *The Brooklyn Eagle*, 1871





The Towers are irregular rectangles with heavy buttresses at the side/s and cable bearing points. Measured lengthwise against the shore, each tower is 140-feet long by 59-feet wide. Because the NY Caisson needed to go much deeper than the Brooklyn Caisson, nearly as much masonry is below the river in NY as is above the river in Brooklyn. Each tower casts a shadow about one city block long and the west face/s often take on a beautiful pinkish-hue at sundown.



Forever Famous

"America has seen nothing like it…Even Europe has no structure of such magnitude as this will be. The most famous cathedrals of the historic Old World are but pygmies by the side of this great Brooklyn tower. And it is our own city which is to be forever famous for possessing this greatest architectural and engineering work of the continent, and of the age."

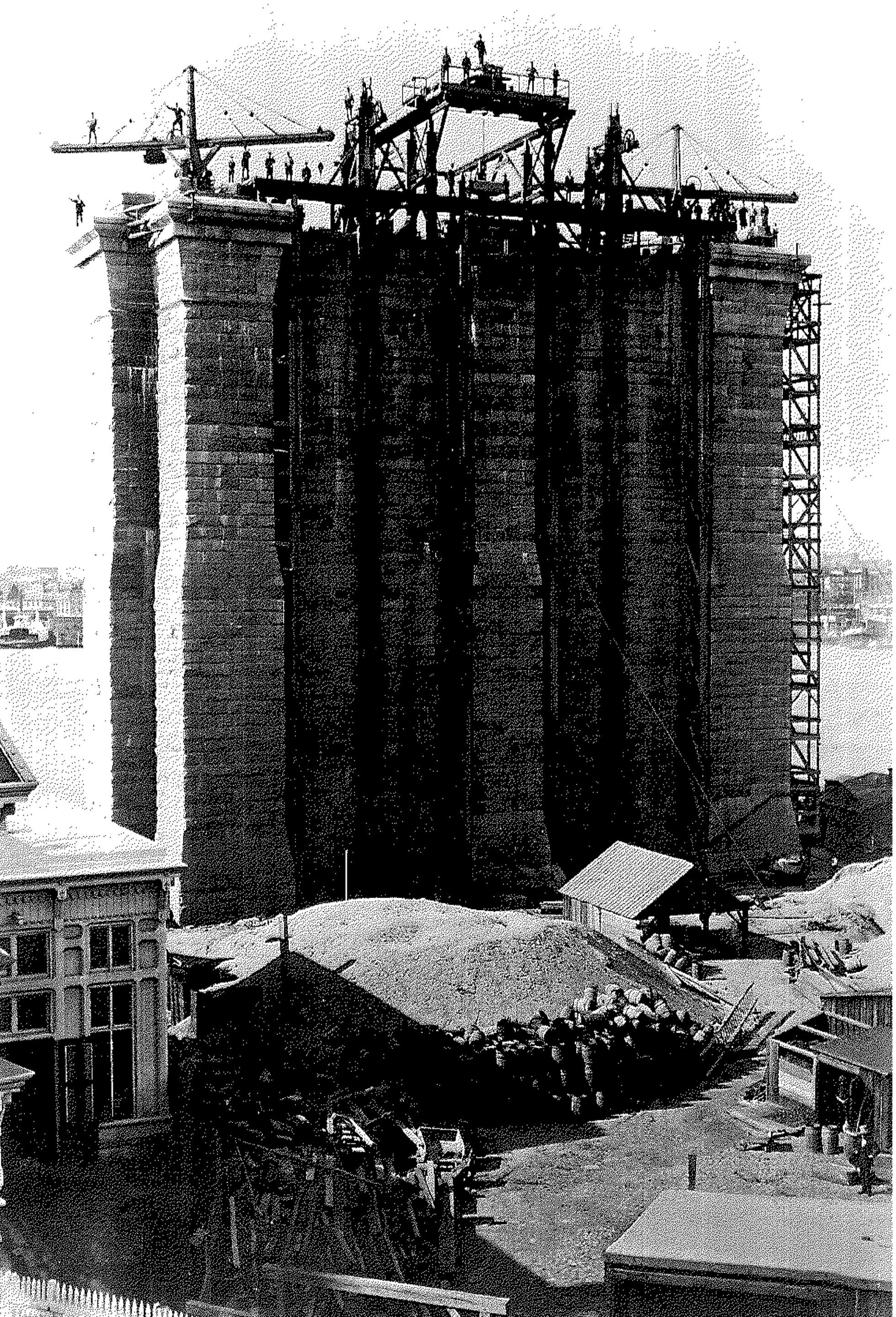
Thomas Kinsella – Editor, *The Brooklyn Eagle*, March 1871

RE: An editorial excerpt upon the completion of the Brooklyn Caisson and rising Brooklyn tower. Brooklyn was a backwater and among Brooklynites, none were more enthusiastic than *The Brooklyn Eagle* and its editor Thomas Kinsella when it came to putting Brooklyn on the map once and for all. Having the tallest man-made structure on the North American continent would do just that.

"To such of the general public as might imagine that no work had been done on the New York tower, because they see no evidence of it above water, I should simply remark that the amount of concrete and masonry laid on the foundation during the past winter, under water, is equal in quantity to the entire masonry of the Brooklyn tower visible today above the water line"

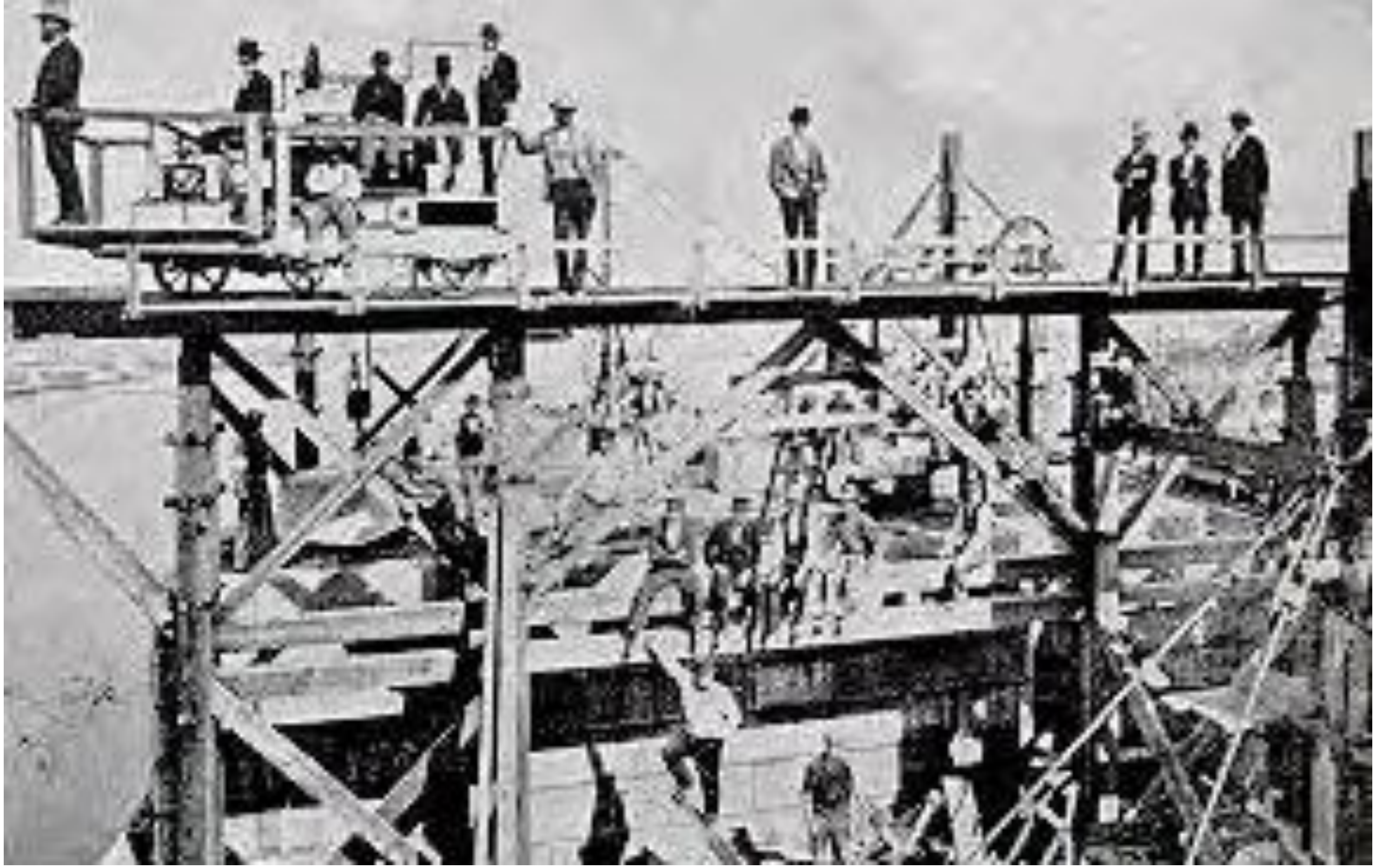
WAR, June 1872

RE: Excerpt from annual report to the bridge company. By mid-1872, the Brooklyn tower rose 100-feet above the river at high-tide and the NY Caisson rested 78-feet, 6-inches below the high-tide mark. A total of 14,500 cubic yards of masonry was in-place on the Brooklyn tower and 13,075 cubic-yards had been laid on the NY tower.

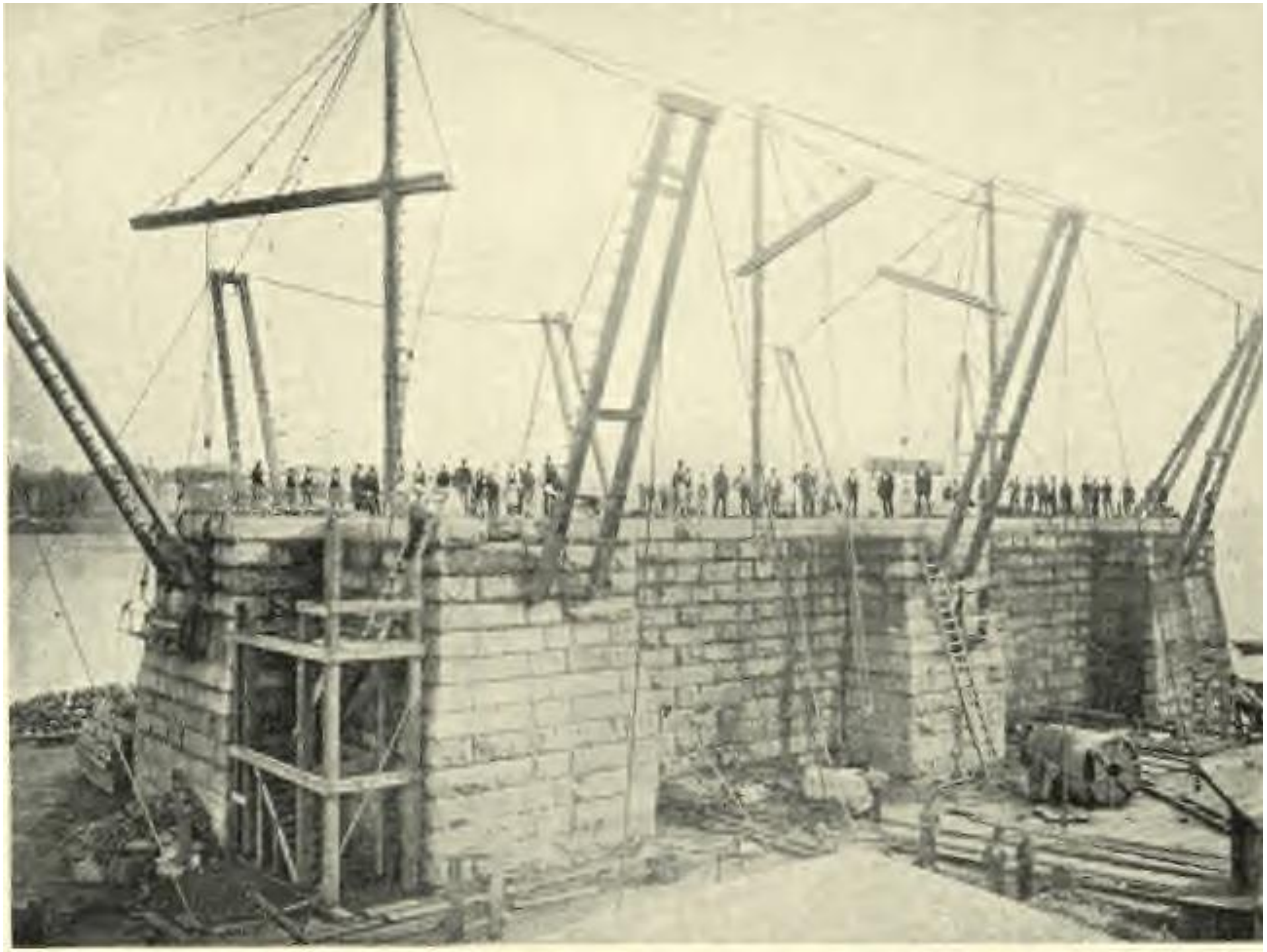


Projecting over the edge of each tower (at its center) were two large iron pulleys that were in-line with heavy timbers laid up like RR tracks for the full-height of the masonry. Hoisting engines using 1&1/2-inch diameter steel cable ran through the pulleys and lifted the heavy blocks of granite to the top of the tower via iron eyebolts set into the ends of each block. On only one occasion did a block come loose (it fell 200-feet). The keystones of each arch weighed eleven-tons and fit so precisely (direct from the quarry) that they needed no trimming.

Several men died building the towers; one had an epileptic fit and fell to his death while another fell while wheeling a wheelbarrow across a plank. Another man fell from the top of the tower landing inside an arch. Two men were killed by falling stones. The most gruesome death was that of a man named *Cope*, he died while guiding wire rope onto a drum and, when he kicked the drum, the rope caught his foot and his leg was crushed – he died instantly. By the time the towers were completed in the summer of 1876, twelve men are known to have died including JAR.

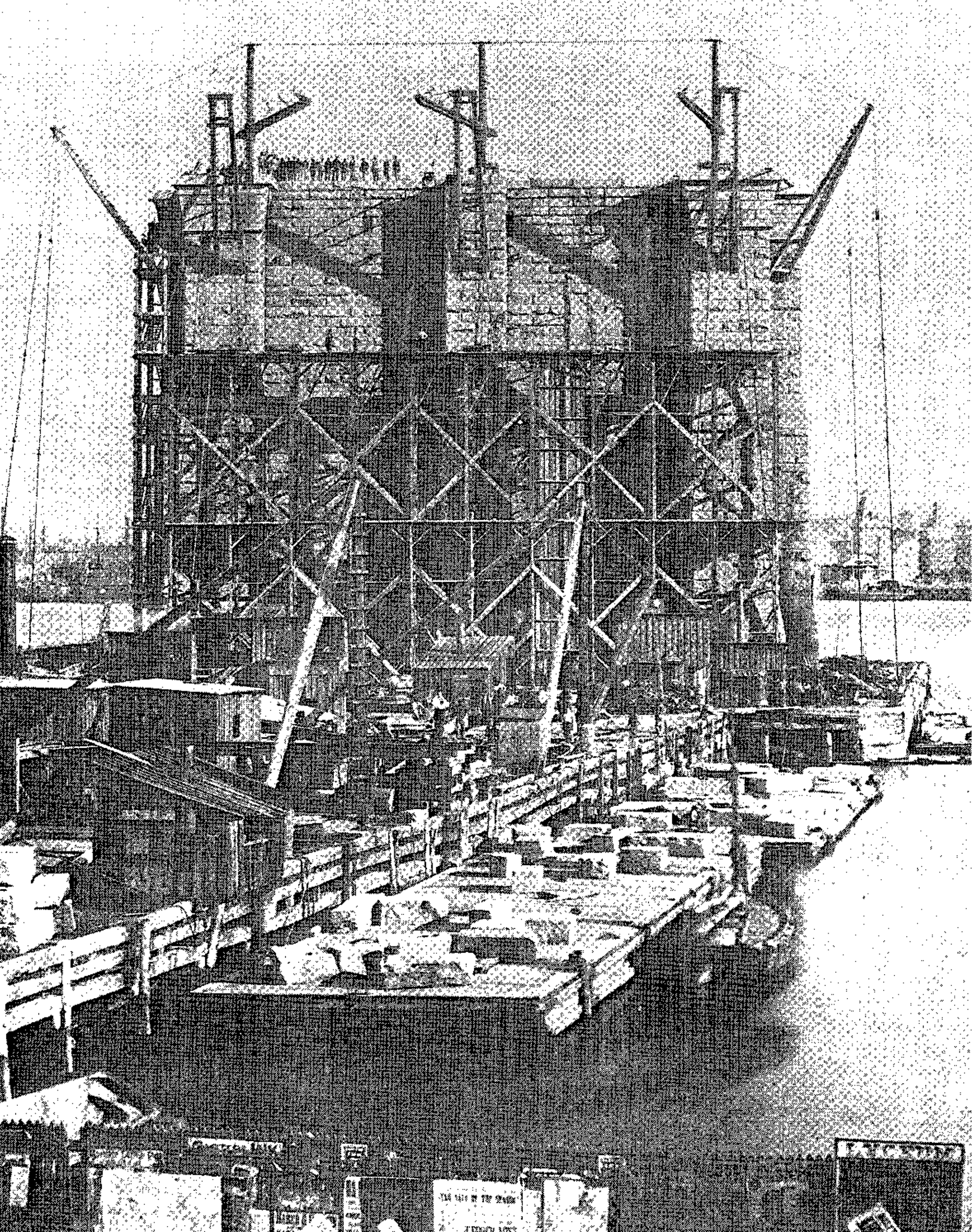


The top of each tower was a very busy, crowded and dangerous place with about eighty men working atop the tower/s at any given time. It was almost always windy and work had to be halted for the winter months. Communicating with the ground was done with signal flags and/or signal bells – shouting was another option, but not very efficient.

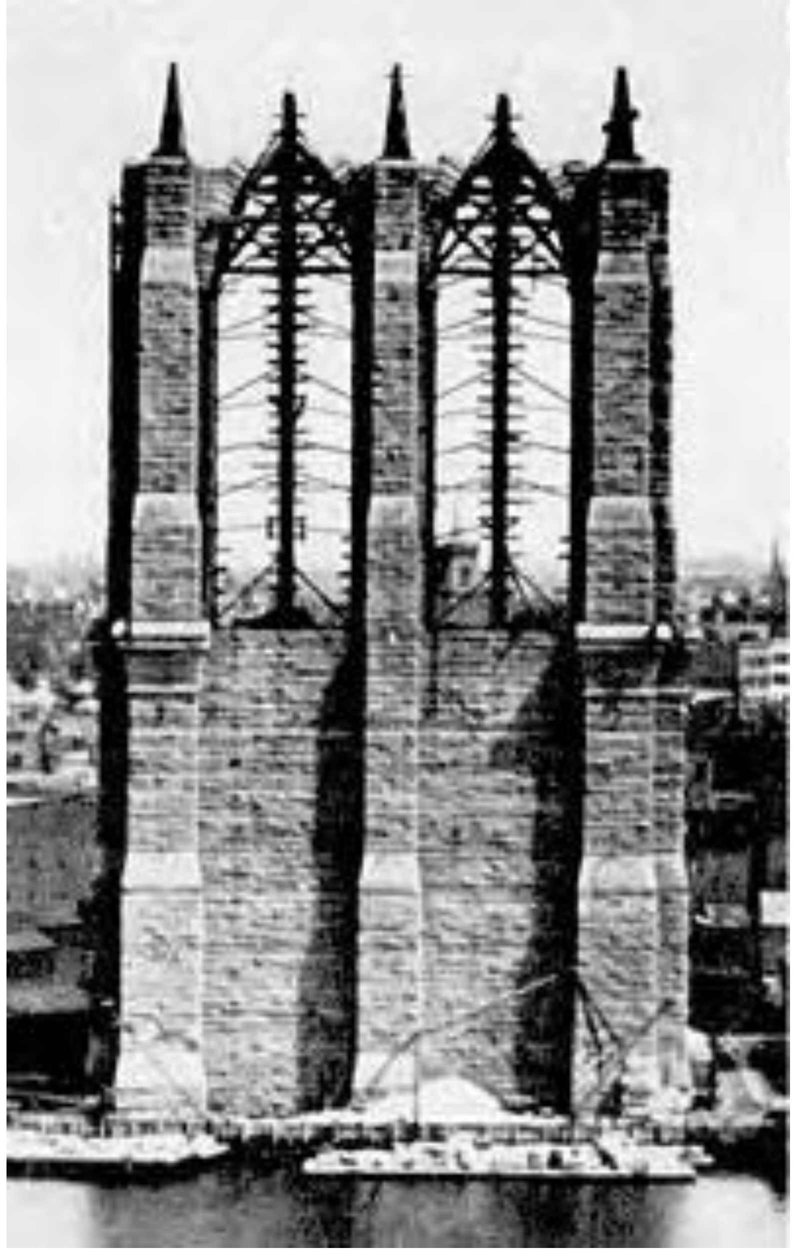


Fifty-foot boom derricks were used at first to hoist the blocks, but as the height grew the engine hoists and wire-rope/pulley system took its place. Once at the top, a block was placed on a flatcar that ran on rails atop wood supports. It was then moved into position where a boom derrick picked it up and swung it into place.

The Brooklyn tower was completed in June of 1875 and the NY tower in July of 1876. It was seen as a good omen that the towers were completed just in time for the nation's centennial celebration on July 4, 1876.



Stone for the towers came from twenty quarries and was delivered to a storage yard in Red Hook, Bklyn. From there, it arrived on-site via large scows which were tied to the tower's adjoining piers. Boom derricks then picked up each block, one-by-one, and placed them on flatcars which transported them to the foot of the tower/s where they could be lifted to the top.



Wooden “falsework” in-place
(for forming the Gothic Arches, Brooklyn Tower)

Magnificent Panorama

"When it is considered that one has to climb upward of 30 flights of winding stairway, the toil of the ascent on a close August day can be readily imagined, but all this is instantly forgotten when the picture from the summit spreads out at one's feet. What a splendid set of photographs could be obtained from this point…Doubtless some enterprising photographer will seize the chance."

***New York Herald*, 1876**

"…Above the arch is the spandrel-filling of varying thickness of courses, and covered by a broad band-course at the line of the keystone. The space between the keystone and the cornice is occupied by a recessed panel…The interior space above the spandrel-filling is not all solid, but consists of three parallel walls, separated by two hollow spaces. The middle wall is 4'-2" thick, the outer ones vary from 4'-2" to 5'-3" in thickness, and the width of the hollow spaces varies from 4'-3" to 4'-9"…"

Washington Roebling, Winter, 1874 – specification for NY tower granite: face stone, arch stone and spandrel courses. Written while convalescing in Trenton

It was critically important that the towers and anchorages be built and completed at or about the same time to ensure cable-spinning could begin on schedule. With a suspension bridge you can’t have one without the other, and so it was that the Brooklyn Anchorage (begun in 1873) was completed in 1875 and the NY anchorage in 1876.

NY Tower and Anchorage
(looking towards Brooklyn)

"...on a bridge that is not called for...very seriously damages a large part of commerce of this harbor, taxes the financial ability of these two cities to their utmost and cannot fail either to be taken down by the mandate of the courts or demolished by the wind"

NY Council of Reform, 1875 – commenting on how navy ships – such as the *Swatara*, could not pass under the bridge (135' above high water) when completed

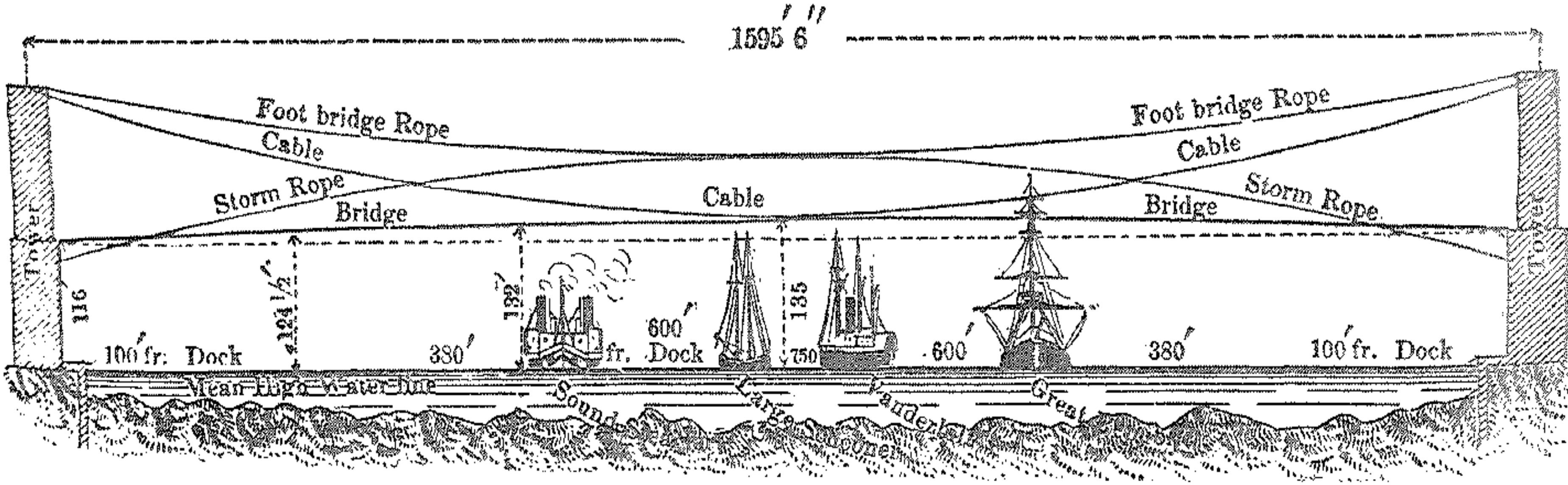
U.S.S. Swatara passes through the completed Towers, 1876.

Tall-masted ships would not be able to pass unhindered under the bridge once complete. This made many ship and warehouse owners very unhappy and much litigation ensued (even after the towers and anchorages were complete), but the die was cast and none succeeded in stopping the bridge to Brooklyn. Fortunately, the *Age of Sail* was giving way to the *Age of Steam* by the 1870s and steam-driven ships (lacking the need of tall masts for propulsion) were not hindered by the 135-feet of clearance at mid-span (nor were smaller ships, ferryboats etc.).

"There was some reason for the Cincinnati-Covington Bridge because it opened up immense tracts of land. That however is not the case with the Brooklyn Bridge because they could not travel more than five miles without hitting the ocean"

NYC Mayor Havenmeyer, 1873 – explaining why NYC refused to pay its share of the cost for the East River Bridge

The *catenary curve* of the main cable/s meets the bridge deck at mid-span achieving the 135-foot clearance (at spring high-tide) required by the Army Corps of Engineers. A “Foot Bridge Rope” was temporary and used to support the footbridge and cradles (during aerial spinning of the main cables), it would be removed upon completion of the bridge deck. A “Storm Rope” was also temporary and associated with the footbridge rope, it provided bracing to resist movement of the footbridge in heavy winds (as did temporary cable stays).



Bridge Cable Diagram

Note the main-span (a.k.a. *river-span*) between the two towers is 1,595-feet, 6-inches. Four ships of different types are shown with their associated clearances. Only the large, fully-rigged sailing ship (at right) would be unable to get past the bridge when completed.

Part 14

Anchorages

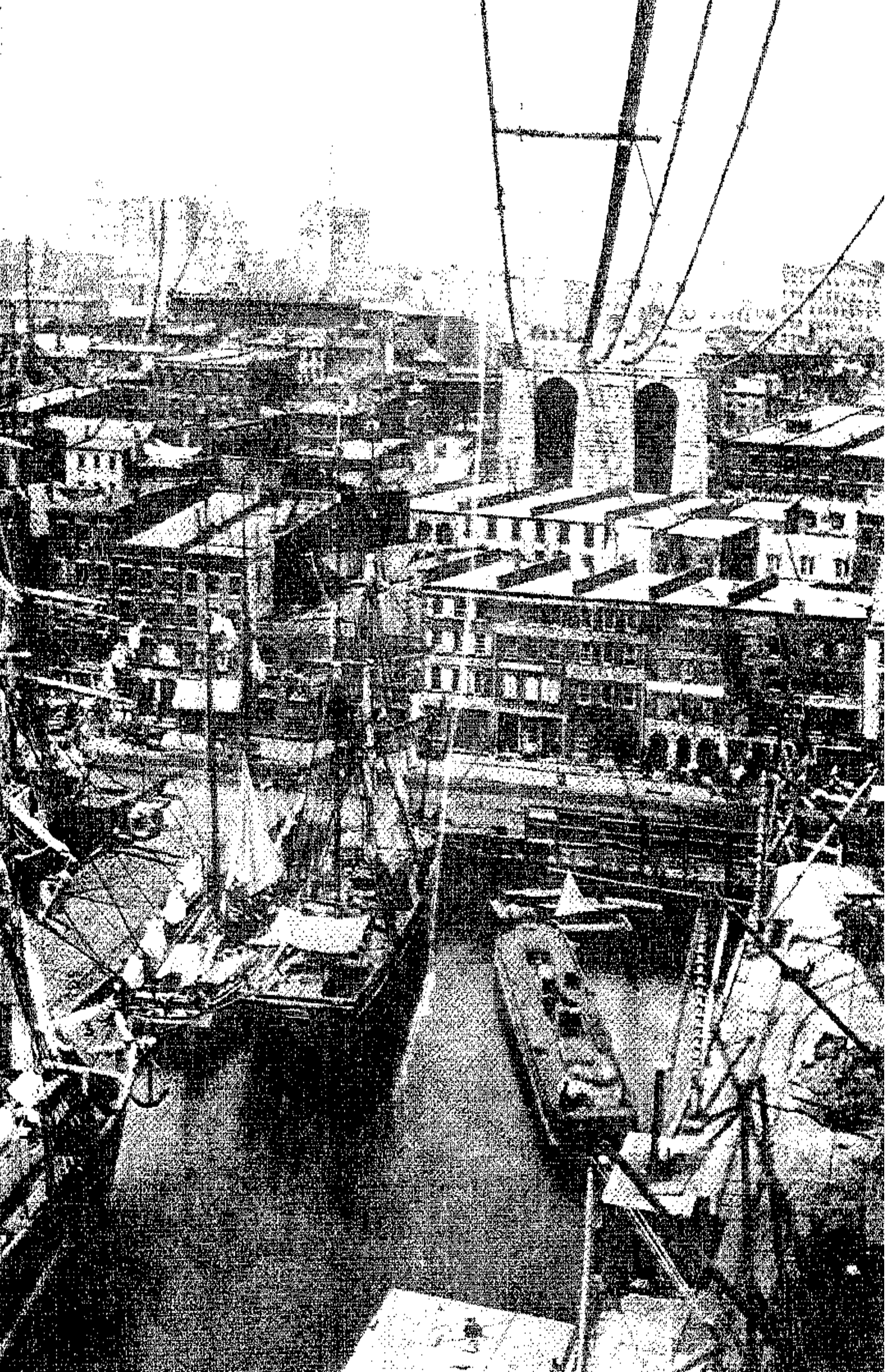
Each anchorage was set-back 900-feet inland and in-line with their respective towers. The span of the cable/s between the anchorage/s and tower/s was referred to as the "land-span" or "side-span." Each anchorage measured 119-feet by 129-feet at the base and 104-feet by 117-feet at the level of the roadway which was nearly 90-feet above grade. Each anchorage weighed 60K tons (120 million pounds). To withstand the tremendous "pull" of the cables, a double chain of wrought-iron eye-bars (akin to a bicycle chain) from each of the four cables tied in to four large cast-iron anchor plates which were embedded deep within the cocoon of granite (near street level).

"This, however, is contrary to the genius of the American people with whom everything has to look out for itself: hence, in the arrangement of this anchorage, the chains are inaccessibly preserved and are not entrusted to the neglect of posterity"

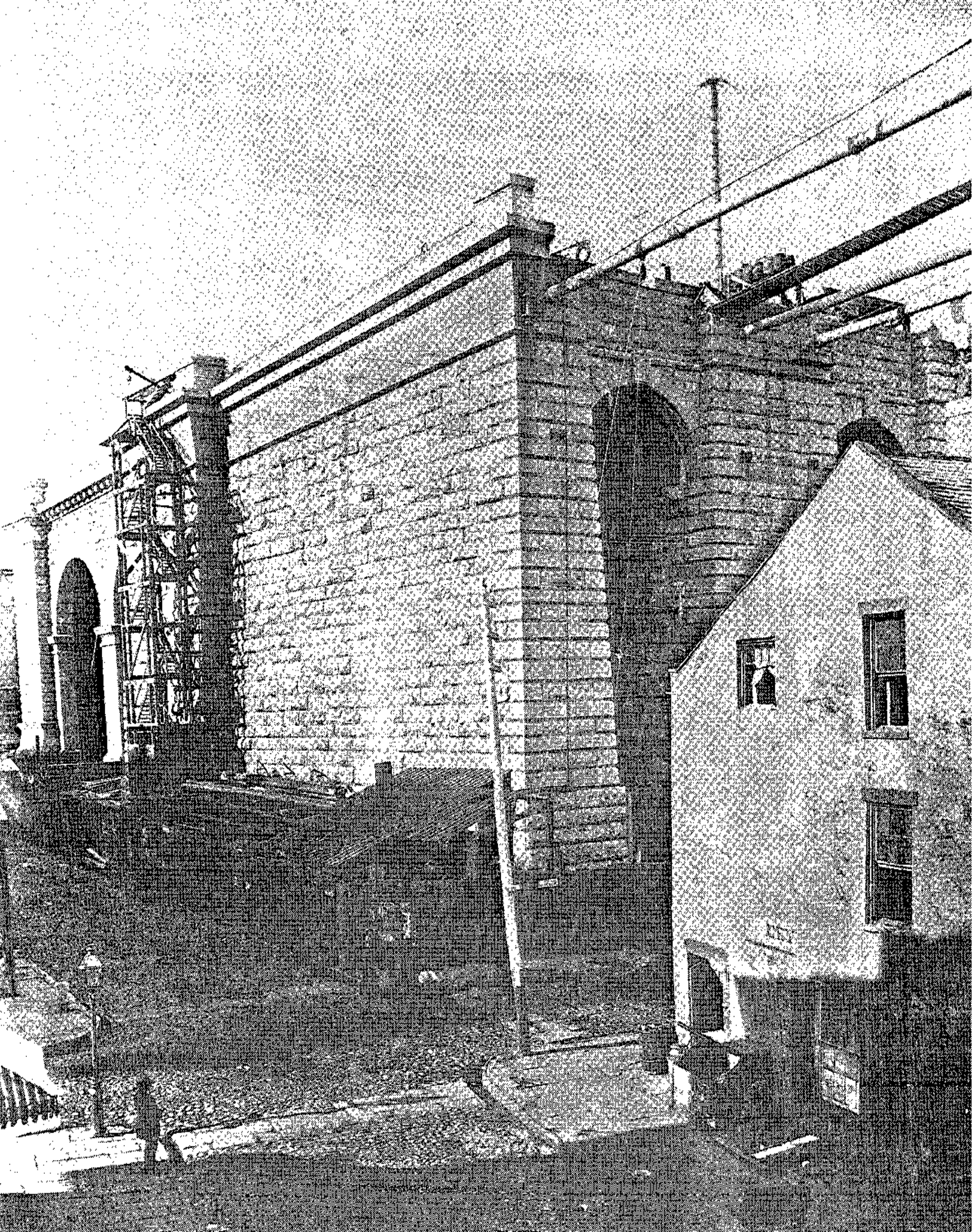
WAR – Chief Engineer, 1876

RE: Commenting in a report on the open access via tunnels of anchor chains in European bridges and his intent to make the Brooklyn Bridge maintenance free by encasing the cables in a stone tomb for all eternity

The cable saddles, eye-bars and anchor plates were the only structural components of the bridge not made from steel (the manufacturer could not perfect the castings in steel thus iron was used). The Brooklyn Bridge was the first edifice in the U.S. to use structural steel for its superstructure (main cables, suspenders, trusses etc.) and proved its worth as a safe, cost-effective building material. It remains a fact that, of all of NYC's many suspension bridges, the Brooklyn Bridge requires the least maintenance.



The face of the anchorage/s where the cables entered the anchorage was comprised of two very tall arches, very similar in style to that of a Roman Bathhouse. The cable/s entered the anchorage/s and were secured to the eye-bar chain 25-feet back from the face where the cable/s entered.



The anchor bar chain/s formed a gradual arc and grew with the masonry built-up around them. The eye-bar chain/s were aligned carefully with their respective cable and heavy pins secured them to one another.

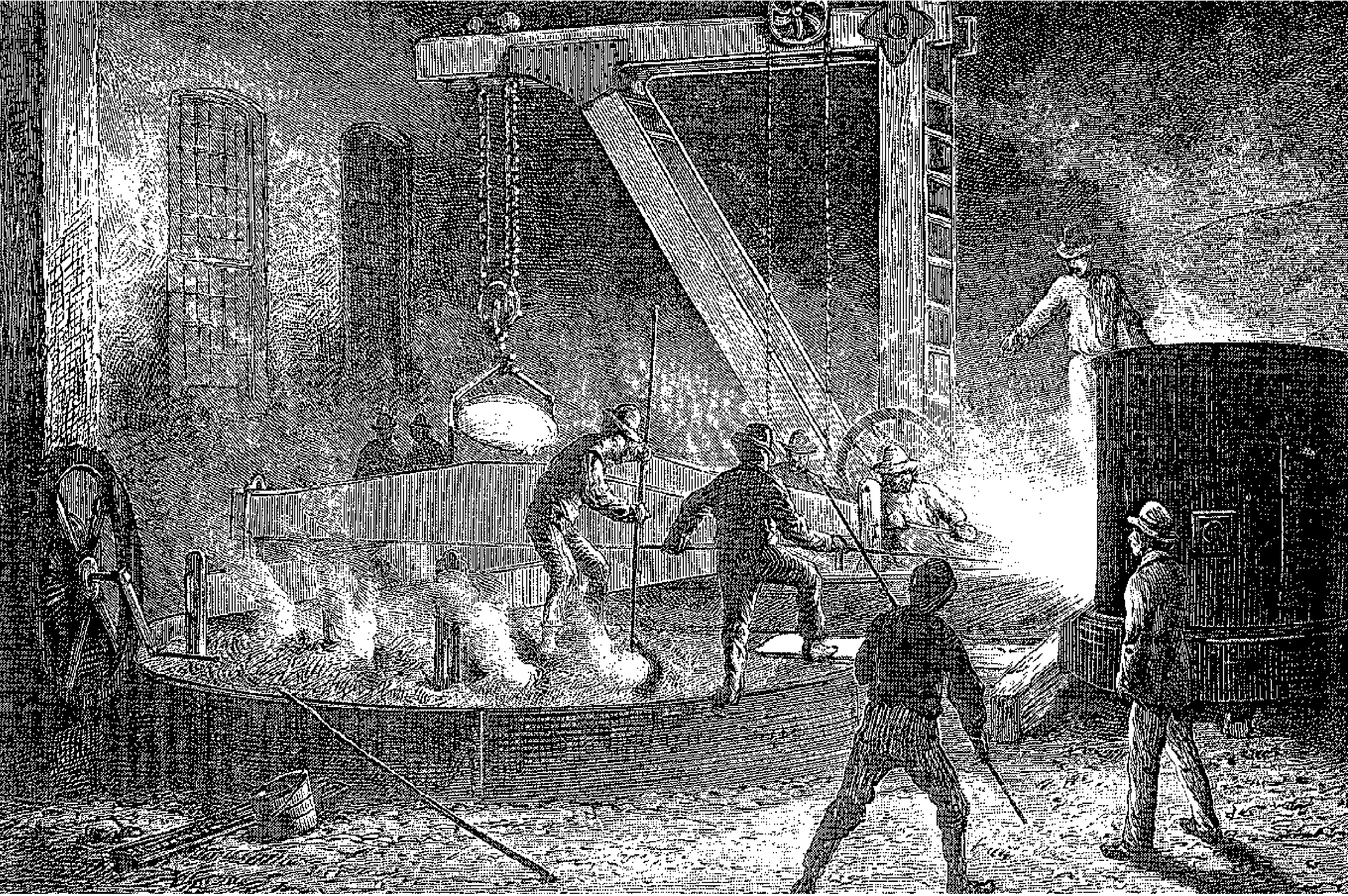
Granite & Gravity

“A material whose very existence is a defiance to the ‘gnawing tooth of time’; hence, when I place a certain amount of dead weight, in the shape of granite, on the anchor plates, I know it will remain there beyond all contingencies.”

WAR – Chief Engineer, 1876

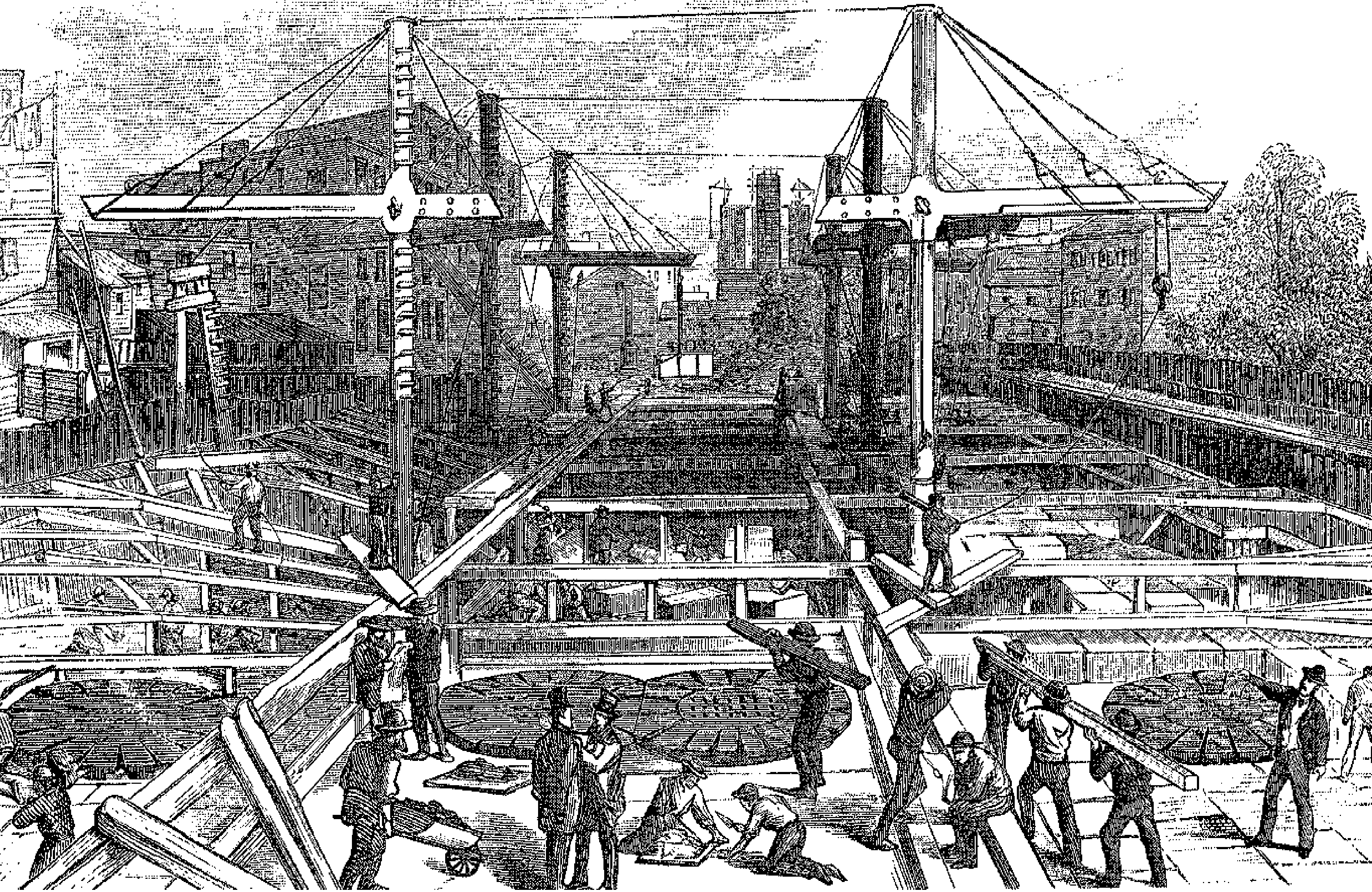
RE: Without reinforced concrete to encase the eye-bar anchor chain (the method used on modern suspension bridges), WAR made use of the only material available that was strong, heavy and durable enough to do the job: *Granite*.

The base plates were cast with two parallel rows of nine oblong apertures into which eighteen iron eye-bars were placed. This made for two identical vertical (upright) rows of nine bars each. Each base plate weighs 23-tons (46K pounds) and only with great difficulty were they maneuvered into place at the bottom of the anchorage/s.



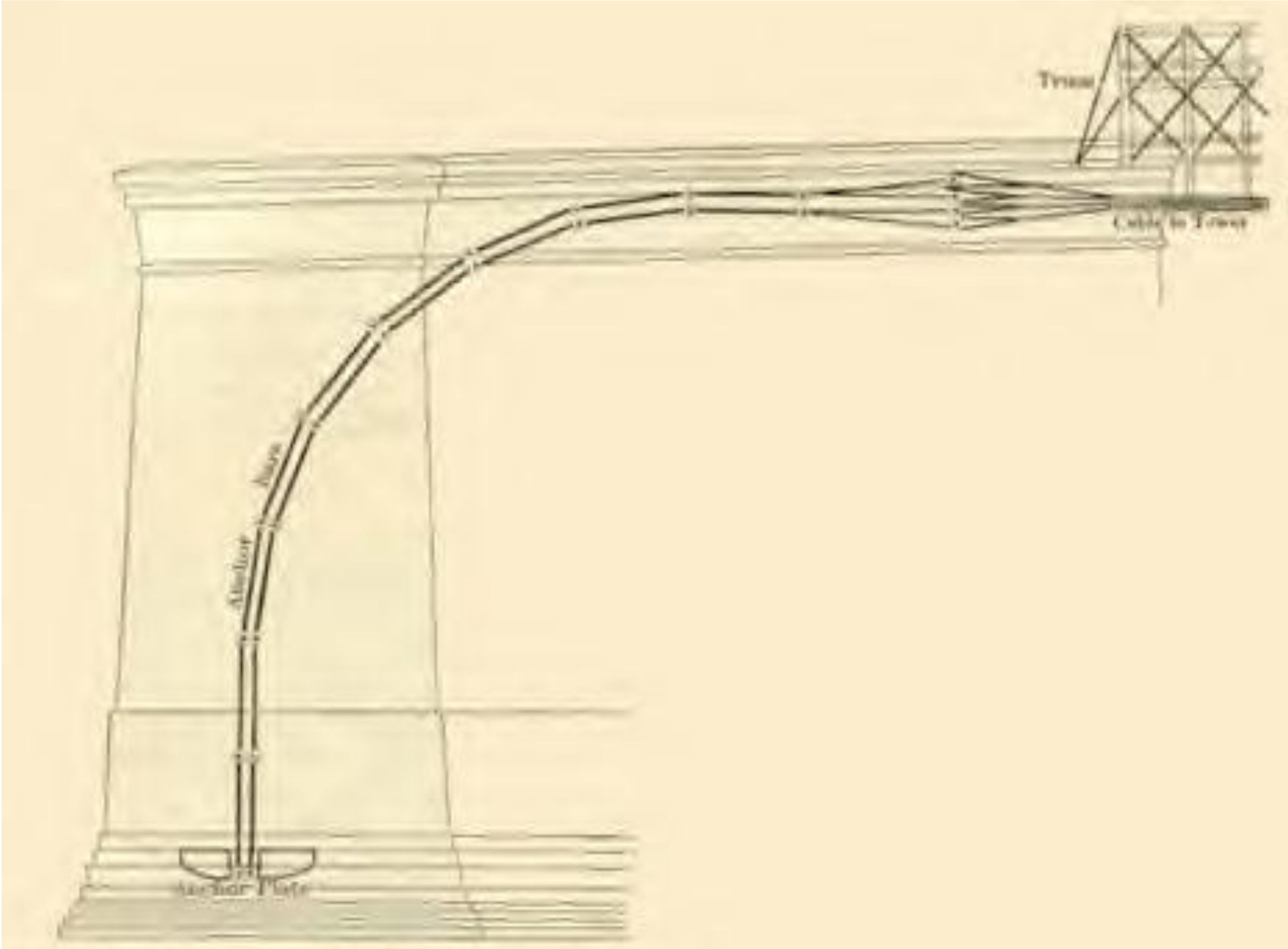
Forging the anchor-chain base plates

There were four base plates per anchorage (one for each of the four cables). They were oval in shape and measured sixteen-feet by seventeen-feet, six-inches by two-feet, six-inches thick. Below the underside of the base plate – through the nine eyes of each row, steel pins were inserted and drawn against the plate forming the first (double-tiered) link with the eye-bar chain.



Anchor-Chain Base Plates in position

The use of a double eye-bar anchor chain was a first in suspension bridge design/construction and one of WAR's many innovations. The first three "links" in the eye-bar chain (closest to the base plate/s) were seven-inches wide by three-inches thick with five to six-inch diameter round holes (for pins) at their ends. The fourth through sixth eye-bar links were eight-inches wide by three-inches thick and from the seventh link to the top of the chain (in line with the pull of the cable) the eye-bar links were nine-inches wide by three-inches thick.



Longitudinal cross-section through anchorage

Showing anchor chain base plate/s and double row of arc-shaped eye-bar chain/s secured to end/s of cable/s

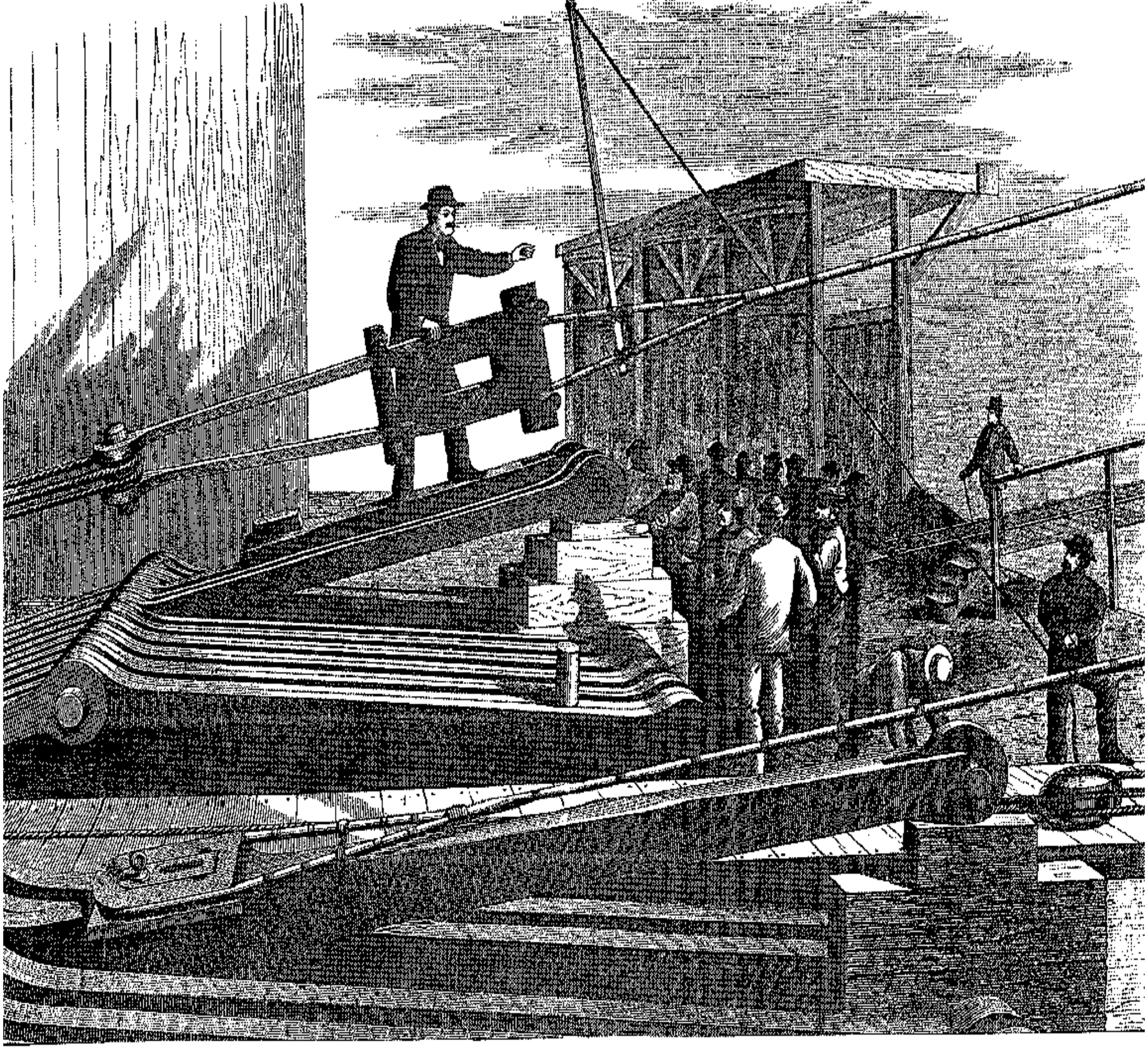
The length of the typical eye-bar varied but averaged twelve-feet, six-inches. For the last link (connecting to the cable/s strand/s), the width of the eye-bars was halved and the number of bars doubled to thirty-eight in four tiers (there are nineteen strands in each cable). All components of the anchor chain were painted with red-lead paint for corrosion protection. WAR spent several months carefully working out the engineering and details of this all-important part of the bridge.

Eye-bars atop Brooklyn anchorage awaiting their place in the anchor chain. Each eye-bar had an “eye” at each end through which a pin secured it to another eye-bar or, at the junction with a cable strand, the strand’s “shoe” (around which the wire strand was spun). Each eye-bar was flat and smooth and forged as a single piece.

In 1867, *Krupp* (of Germany) forged an all-steel prototype of an eye-bar but they couldn’t assure its quality so wrought iron was used and even then, it was no easy task to cast such large pieces. Several mills produced the wrought-iron eye-bars of excellent quality.

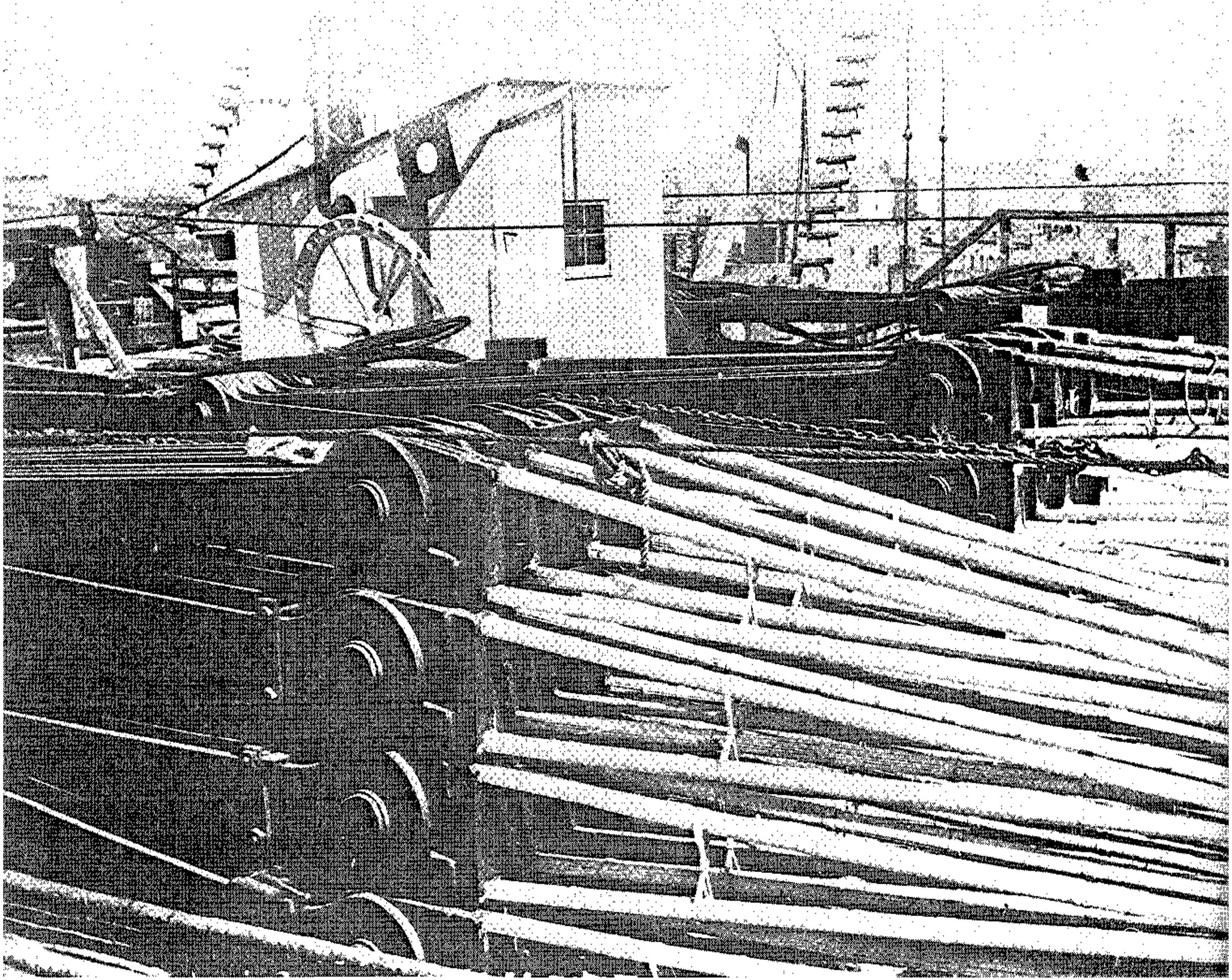
Eye-Bar Chain
(connecting to cable strands)

The cable strands were spun with their shoe/s in a horizontal position and higher/forward of their eventual position in the anchorage (this helped keep tension in the wire and reduced kinking). A block and tackle was used to invert the shoe to a vertical position and place it between two adjoining eye-bars at the end of the eye-bar chain. A pin was then inserted joining the cable strand to the eye-bar chain for eternity.

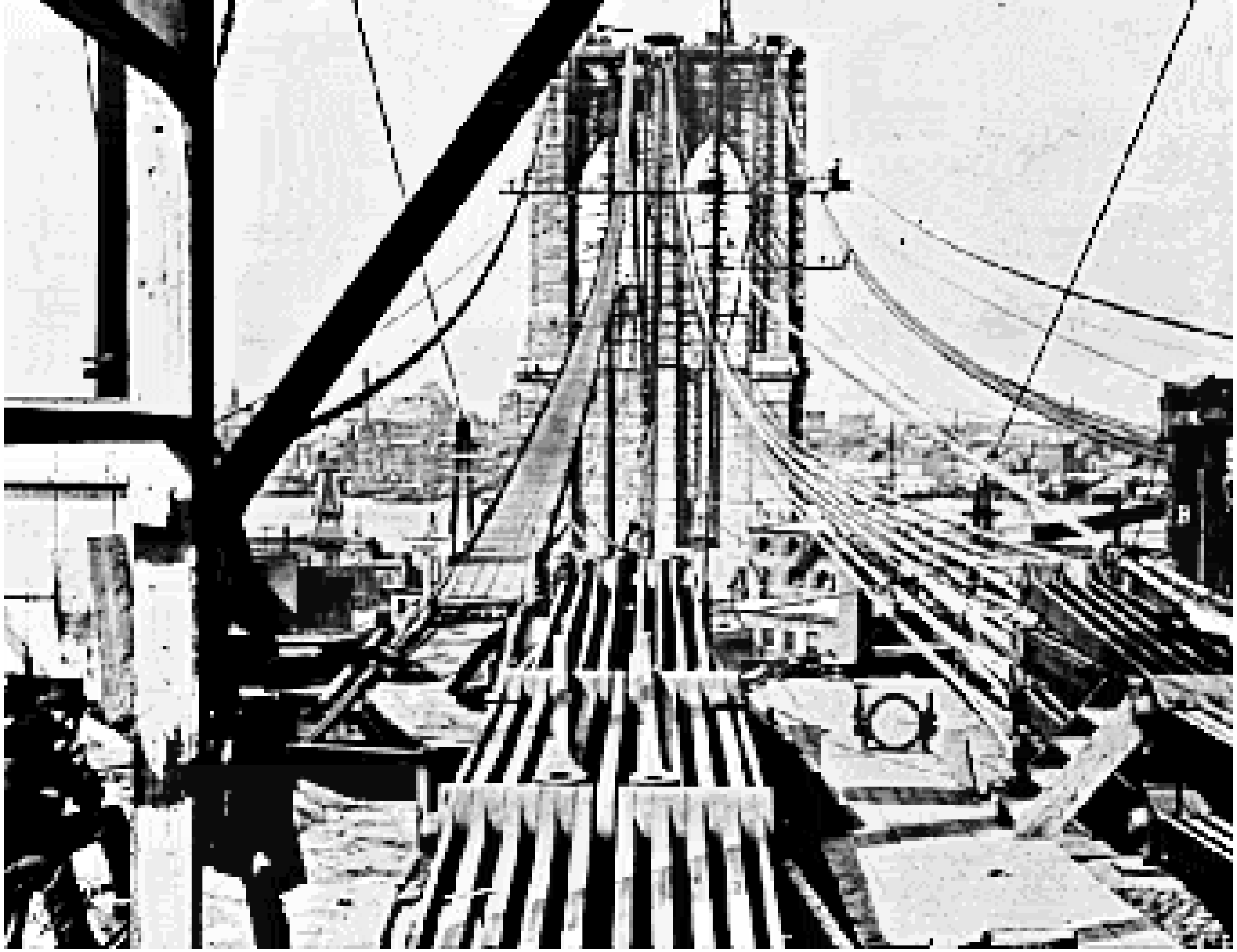


Cable Strand/Shoe being maneuvered into place

The cable strands were joined together (beyond the anchorage/s face) to form a hexagonal configuration (composed of nineteen strands) and then compressed to form the familiar round configuration of each wire cable. Each strand exerts a seventy-ton pull (strain) on the anchorage. By tying each individual strand to an eye-bar, the load is distributed more evenly (like the roots of a tree).



Cable strand/s & shoe/s secured to the end/s of eye-bar chain/s.



Atop the Brooklyn Anchorage

At left, anchor bar chain awaiting connection to wire strands. At right, anchor bar chain completely connected to cable strands. There are two “outer” cables and two “inner” cables – this photograph shows the latter.

Part 15

Footbridge

The Daring Voyager

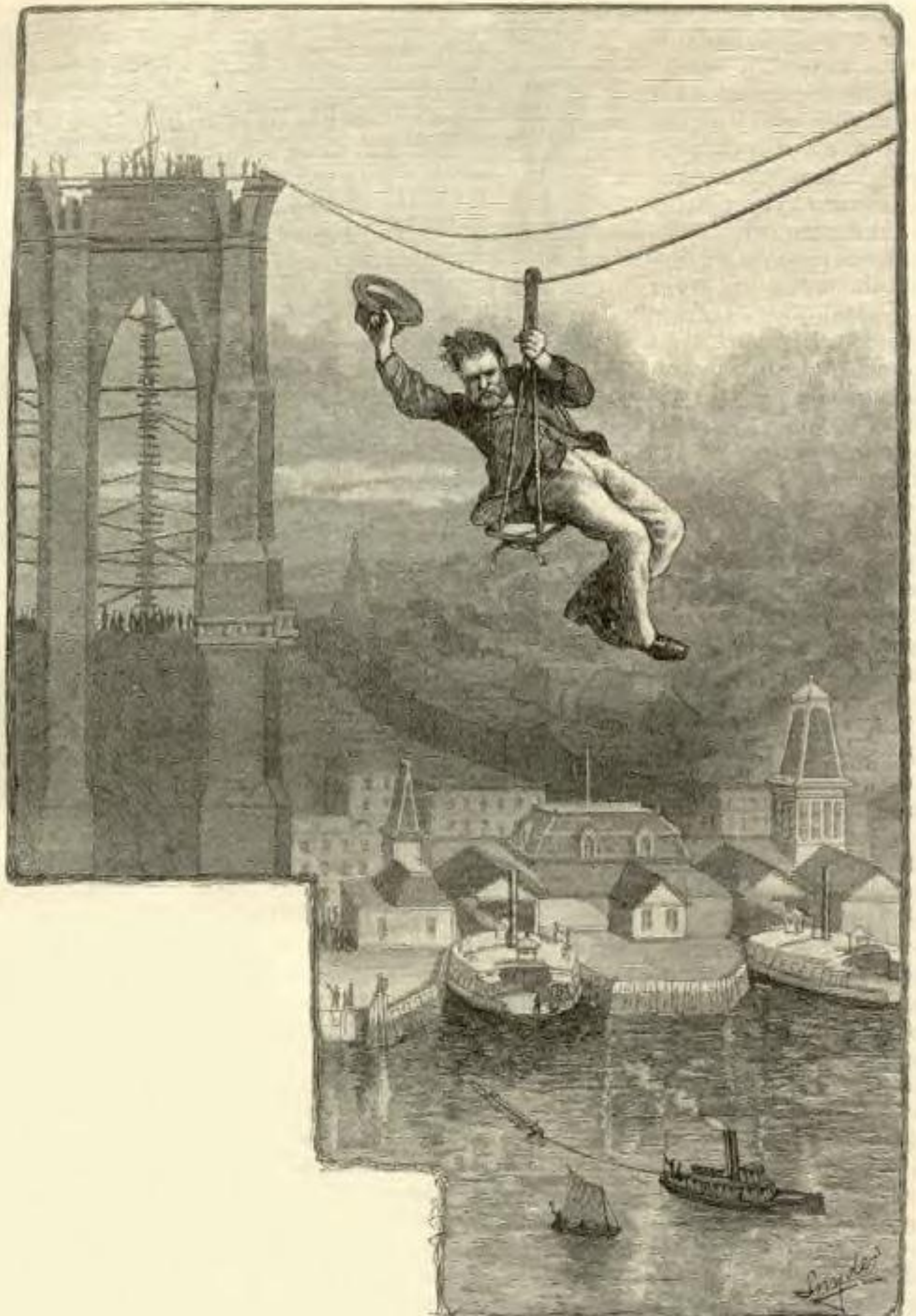
Master Mechanic *E. Frank Farrington* was the only member of the engineering staff with any experience (*Cincinatti-Covington*) with aerial spinning of wire cables. George McNulty, who had been in charge of the Brooklyn Anchorage, was assigned the task of working out the logistics of the cable making process. Though young, he was very capable. Farrington, who was 60yo at the time, had been a sailor and was very familiar with the methods, materials, techniques etc. of cable spinning from his previous experience. Like most sailors in those days, he was not afraid of heights so it was commonplace for sailors to be recruited for the hazardous work of cable making (considered the most dangerous part of making a suspension bridge).

"Our previous bridges, always came near enough together so that many of the old and experienced hands were to be found to initiate the new ones, but they are entirely wanting for this work."

Washington Roebling, 1876 – comment upon the commencement of cable spinning operations and lack - save for E.F. Farrington - of experienced men

"He is a man of great resource when unforeseen troubles arise, and he has the necessary coolness and perseverance and does not easily get frightened in time of danger…"

Washington Roebling, 1876 – excerpt from letter to Henry Murphy regarding E.F. Farrington – Master Mechanic



The first step in cable spinning requires suspending a footbridge to give workmen access. Farrington made a scale model of the footbridge and, to demonstrate to his nervous crew the safety of the wire rope which would support the footbridge, on August 25, 1876 he traveled across the river sitting on a Boatswain. A large crowd gathered and enthusiastically cheered the “Daring Voyager” on. Thus, Farrington became the first person to cross the East River without a boat. Afterwards, he rowed himself back to Brooklyn.

"Despite the shouting and confusion that went on beneath him, he sat quiet with his hands folded, save when he waved them in response and showed every sign of perfect self-possession."

Observer to E.F. Farrington's trip across the river on a boatswain – Friday, August 25, 1876

"The ride gave me a magnificent view, and such pleasing sensations as probably I shall never experience again…"

E.F. Farrington – Master Mechanic

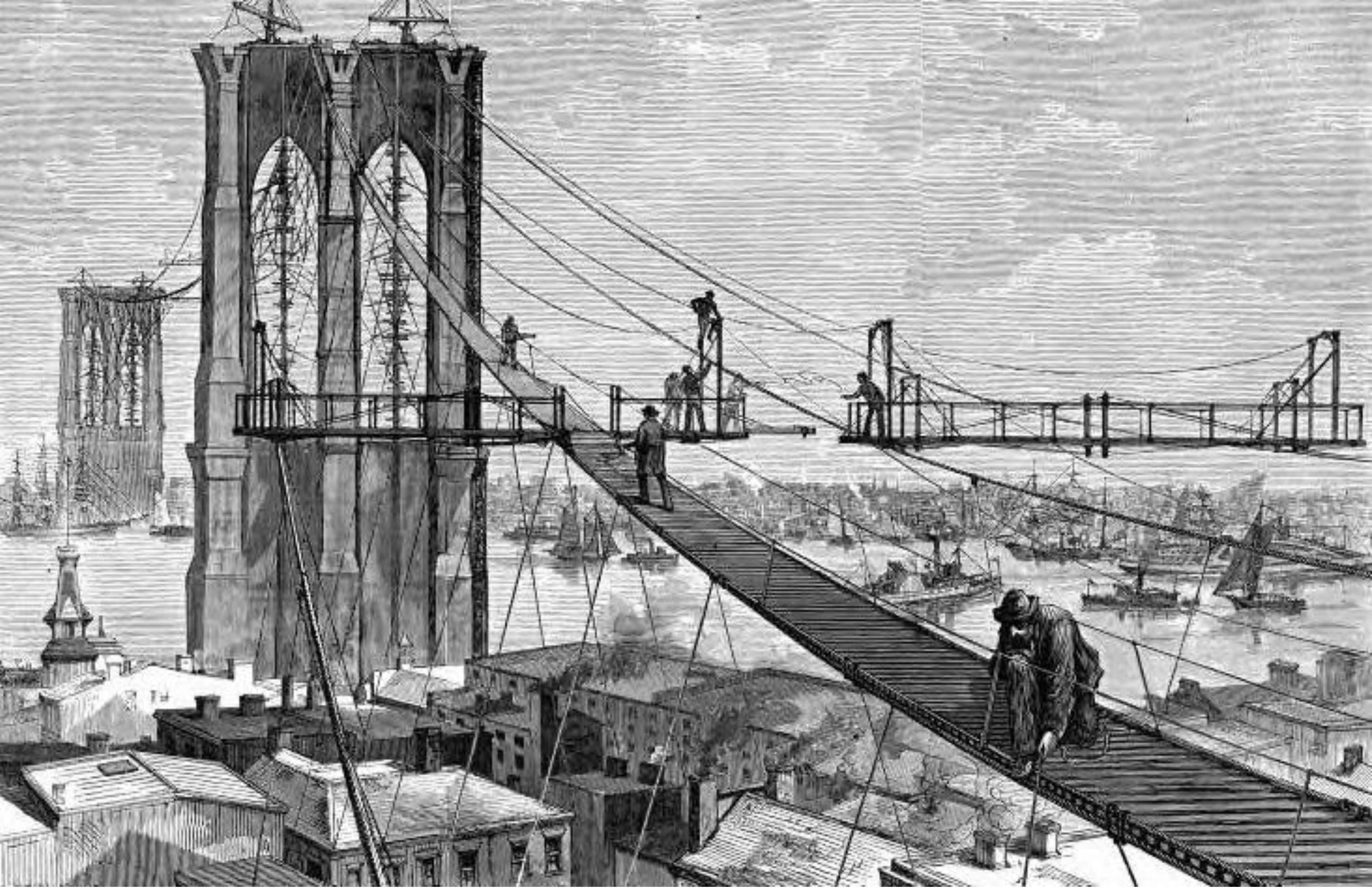
RE: his August 25, 1876 trip across the east river in a boatswain

Commemorative Medal

During the cable spinning operation, Farrington had an argument with superintendent C.C. Martin and walked off the job, never to be seen or heard from again. Nobody knows for certain what the argument was about and/or what ever became of E.F. Farrington.

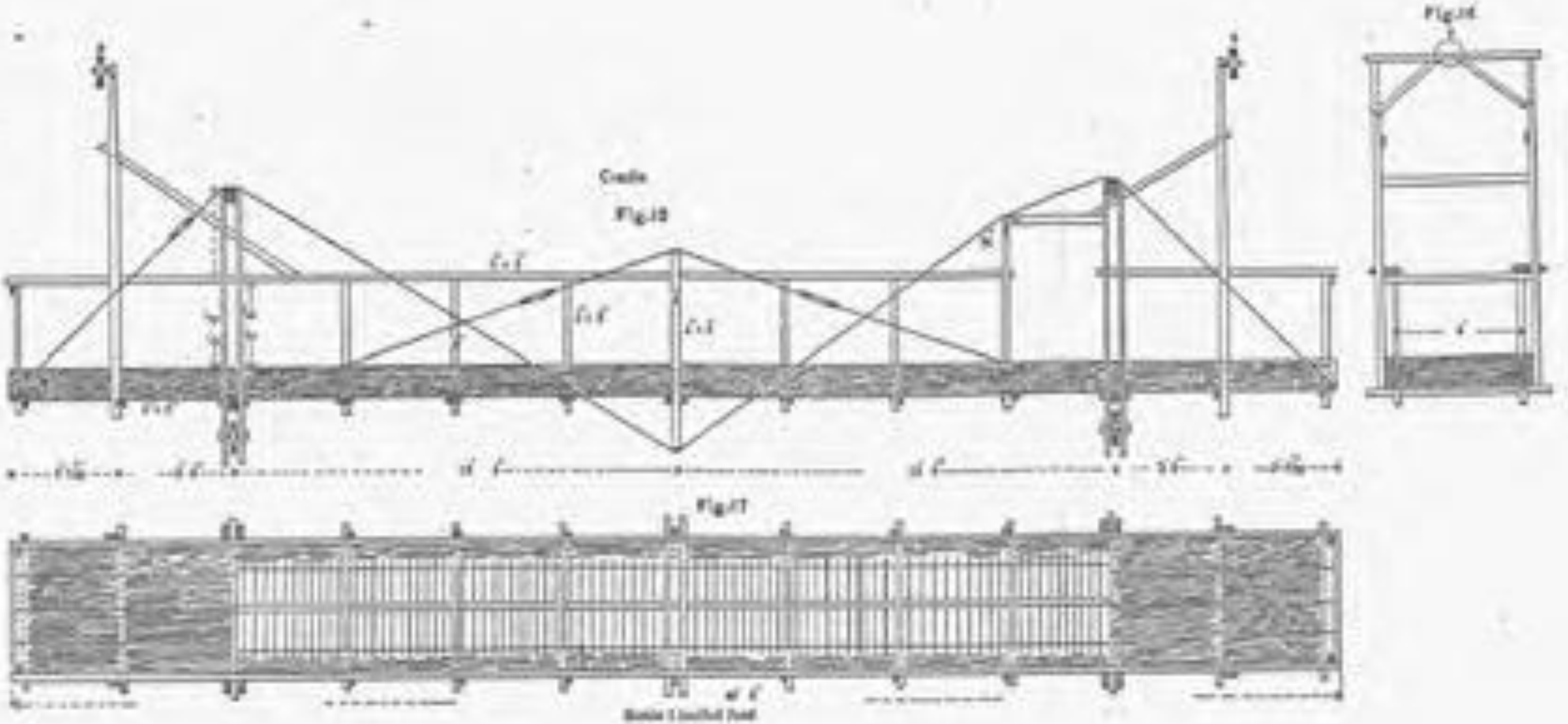
"Much admiration was expressed at the skill and daring of the workmen"

NY newspaper, 1876 – comment on observing the hazardous construction of the footbridge



Footbridge and Cradle
(side/land-span)

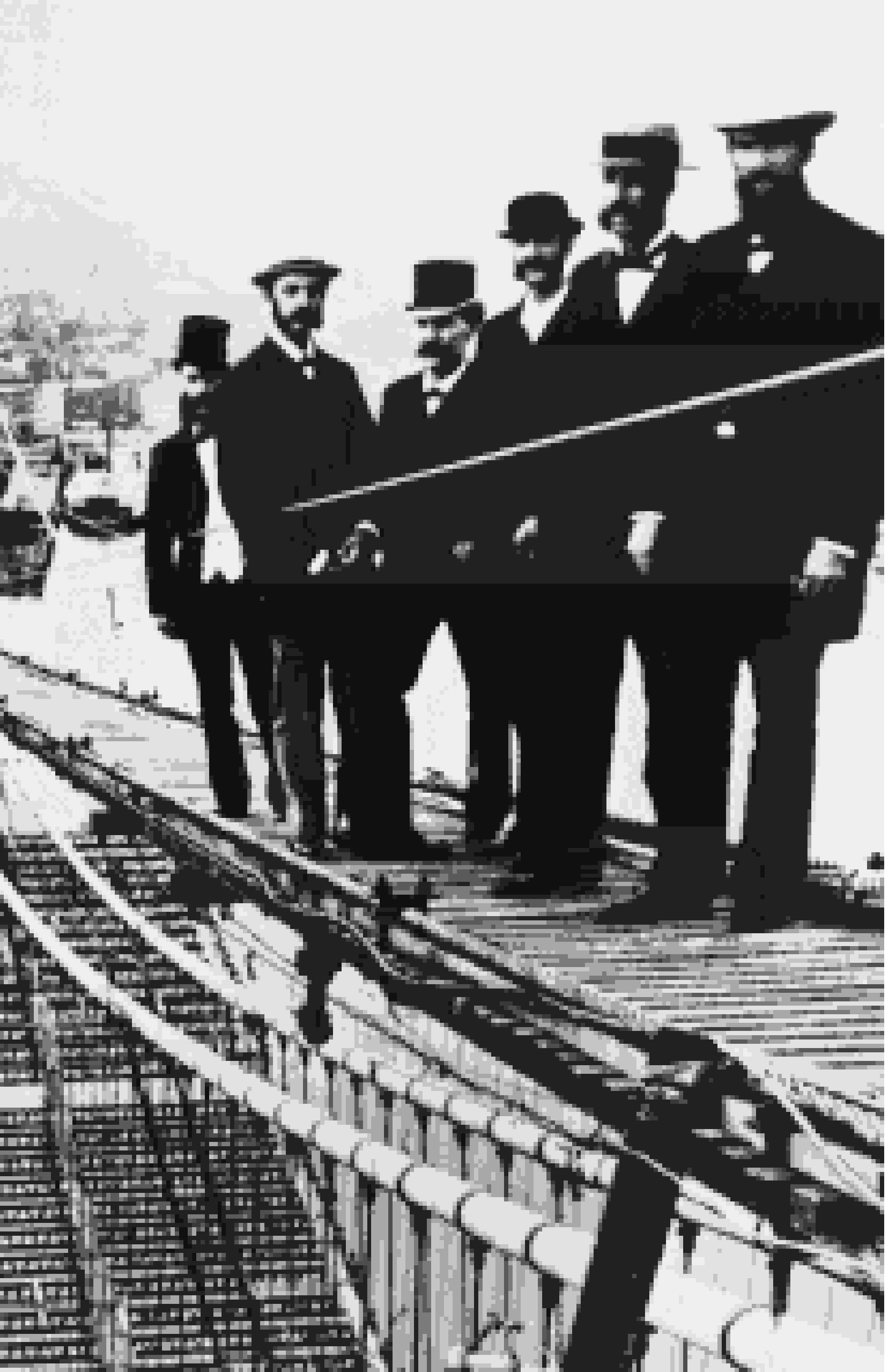
Access to the footbridge was from atop the Brooklyn Anchorage. It was four-feet wide with wire-rope handrails (at hip level) and open wooden slats (to allow the wind to pass through). Guy wires and storm cables made the footbridge reasonably stable. The footbridge itself did not provide access to the cables. Rather, it provided access to the "cradles" whose purpose was to allow intermittent access (land and/or river span/s) to the cable/s for precise adjustment and to form the individual wires into strands.



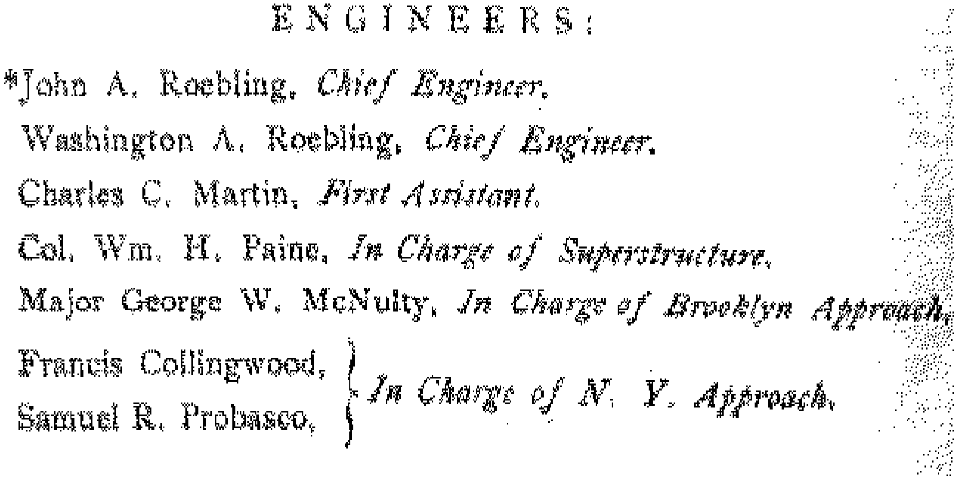
Cradle Plan, Elevation & Section

The cradles were 100-foot long, narrow platforms with wooden handrails hung perpendicular to the main cables. There were a total of five cradles; one each (at mid-span) for the land/side span/s and three (at the quarter points) for the river/main span.

Main/River-span footbridge and access cradles
(cradles at quarter points)



Engineering staff (on the footbridge)



ENGINEERS:

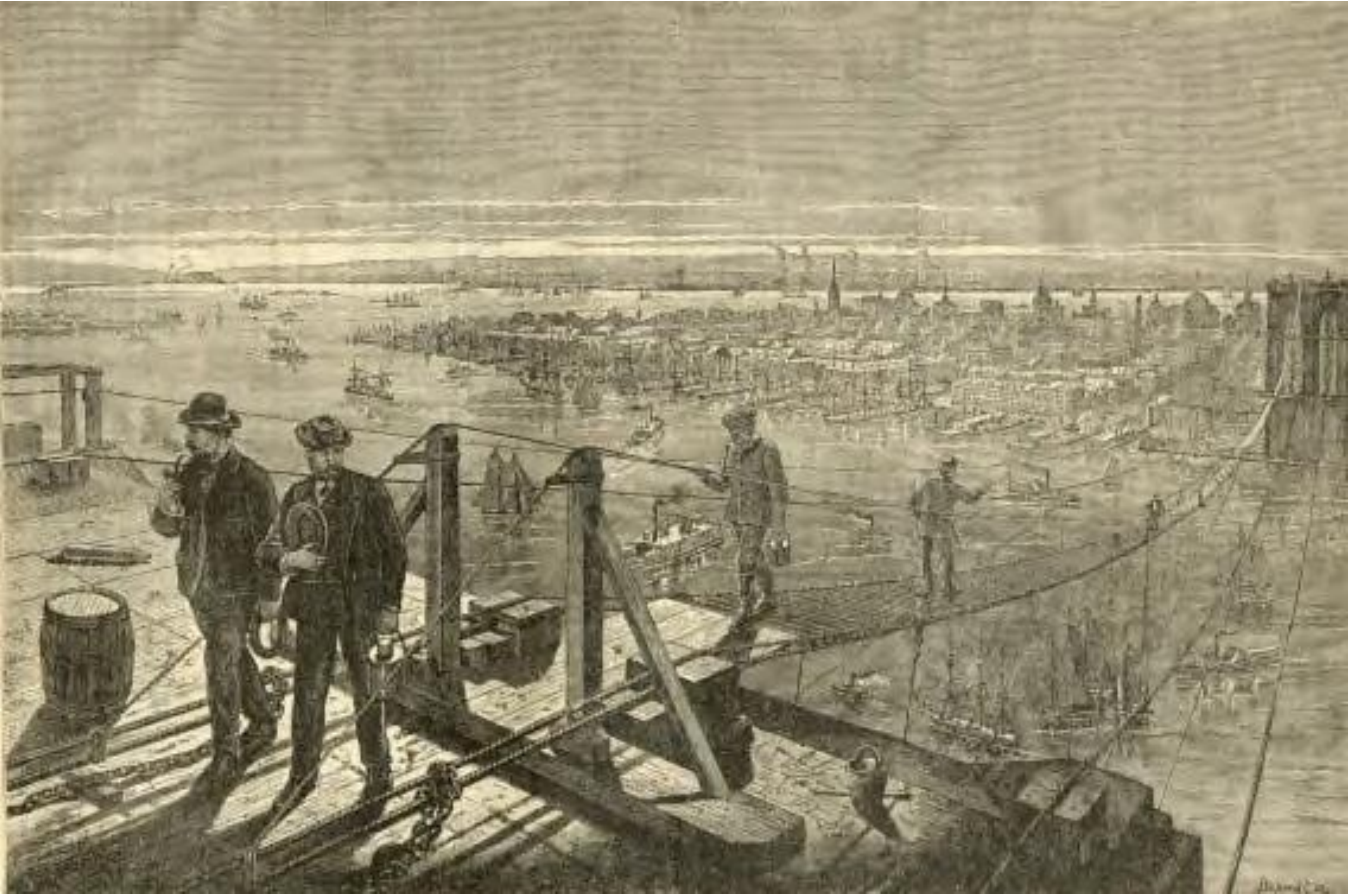
*John A. Roebling, *Chief Engineer.*
Washington A. Roebling, *Chief Engineer.*
Charles C. Martin, *First Assistant.*
Col. Wm. H. Paine, *In Charge of Superstructure.*
Major George W. McNulty, *In Charge of Brooklyn Approach.*
Francis Collingwood, Samuel R. Probasco, } *In Charge of N. Y. Approach.*

Modern Footbridge

The idea is the same; provide temporary access to the cable/s, but in a modern bridge the footbridge itself provides complete, direct access – no cradles are used (which provide limited access). It is temporarily suspended (by heavy wire rope) a few feet below and following the same catenary curve of the main cable/s. Chain-link fencing is typically used as the flooring material since it is strong, lightweight and allows the wind to pass through readily.

"The undulating of the bridge caused by the wind, which was blowing a gale, the gradually increasing distance between the apparently frail support and the ground, the houses beneath bristling all over with chimneys, looking small enough to impale a falling man, the necessity of holding securely to the handrail, to prevent being blown off, produced sensations in the reporter's head – and stomach – never experienced before. In vain he glanced furtively into his companions face to detect any signs of flinching on his part. Stolidly the master mechanic kept on, and the reporter fancied once that he caught a backward glance of enjoyment at his discomposure."

Reporter's experience on the footbridge, 1877



Atop the Brooklyn tower via the footbridge

At first, there was no charge and anyone could venture out onto the footbridge, and venture they did. After excessive publicity in the newspapers of various exploits and occurrences, it was decided visitors must apply for a pass to go onto the footbridge. One fellow tried to ride his horse across, unsuccessfully. After an English sailor had an epileptic fit on the footbridge (he had to be tied down to keep from falling), the footbridge was closed to the public.

"I started to go once, and while I looked upward or ahead I was all right; but I chanced to look down, and…and I determined that I couldn't afford to lose the President of the Company just then, and so I went back."

Henry Cruse Murphy – President, Board of Trustees, 1877

RE: His response when asked by a reporter if he had crossed the river via the footbridge

"I remember Mother sitting at home, saying ten rosaries all the time they were gone! But my father was determined to take the boy across the bridge so he could say he crossed it before it was built…"

Al Smith's sister – recalling her brother Al's journey with his father – a security guard at the bridge, across the footbridge

Beauty on the Bridge

"The women are soonest at ease, and you'll see them swinging their parasols carelessly where brave men hold on with both hands"

NY Times, 1877 – quote from workman on pedestrian footbridge traffic

Part 16

Wire Fraud

"Sealed proposals will be received by the Trustees of the New York & Brooklyn Bridge, up to the 1st day of December, 1876, for the manufacture and delivery in Brooklyn, NY of 3,400 net tons or 6,800,000 pounds of steel cable wire…"

Washington Roebling

"Resolved, that bids from any firm or Company in which any officer or engineer of the Bridge has an interest will not be received or considered; nor will the successful bidder be allowed to sublet any part of the contract to any such person or Company."

Abram Hewitt's resolution adopted by the Board of Trustees – September 7, 1876

As a respected member (VP) of the Board of Trustees and society, Abram S. Hewitt used his considerable influence to have the Board pass a resolution which he knew would prevent the Roebling Company from bidding on the steel wire contract for the bridge since the Chief Engineer was a major stockholder of the Roebling Works in Trenton, NJ. What he didn't allow to be known to the Board was his financial interest in a south Brooklyn wire manufacturer whom the Brooklyn newspapers promoted as a favorite son. Hewitt stood to make a great deal of money, albeit covertly, if this local manufacturer won the contract. Overtly, Hewitt's own firm of *Cooper & Hewitt* would not be able to bid either, but this was just for show (they were brokers and had no facilities for making cable wire). These facts were not unknown to WAR.

Abram S. Hewitt

"In laying this plan, he well took the calibre of the men in the board, for when a demagogue wants to effect an object he always raises the cup of public virtue – and under cover of smoke he raises, slips in himself. It is on such low and crafty tricks that the honor of a Hewitt rests."

Washington Roebling, 1877 – private notes

"I was publicly and specifically singled out by name by Mr. Hewitt, as if I had spent my whole life in concocting a specification which I alone could fill or as if I were a thief trying to rob the bridge in some underhanded manner and against whom every precaution should be taken. Coming from such a source this is an insult I cannot overlook and I am compelled to resent it by declining to remain in a position where I am at any moment liable to a repetition of such acts on his part…As you seem to be deeply impressed with Mr. Hewitt's action in declining to become a competitor for this wire, I desire to say his magnanimity is all a show, as the firm of Cooper & Hewitt have no facilities whatever for making the steel wire and if you receive a bid from a Mr. Haigh of South Brooklyn, it will be well for you to investigate a little."

Washington Roebling, September, 1876 – response to Henry Murphy's declining of his previous resignation letter

"Please acknowledge receipt of this letter, and oblige me by making the above fact known to the Board of Trustees of the New York and Brooklyn Bridge at their next meeting."

Washington Roebling, October, 1876 – letter to Henry Murphy – RE: Sale of all his stock in JAR&S to allow them to bid for the wire contract

"He had recently, it appears, sold out his interest in the Trenton works, so as not to embarrass his brothers…There is no disguising the fact, however, that the whole subject is complicated by this consideration"

The Brooklyn Eagle **– December 1876**

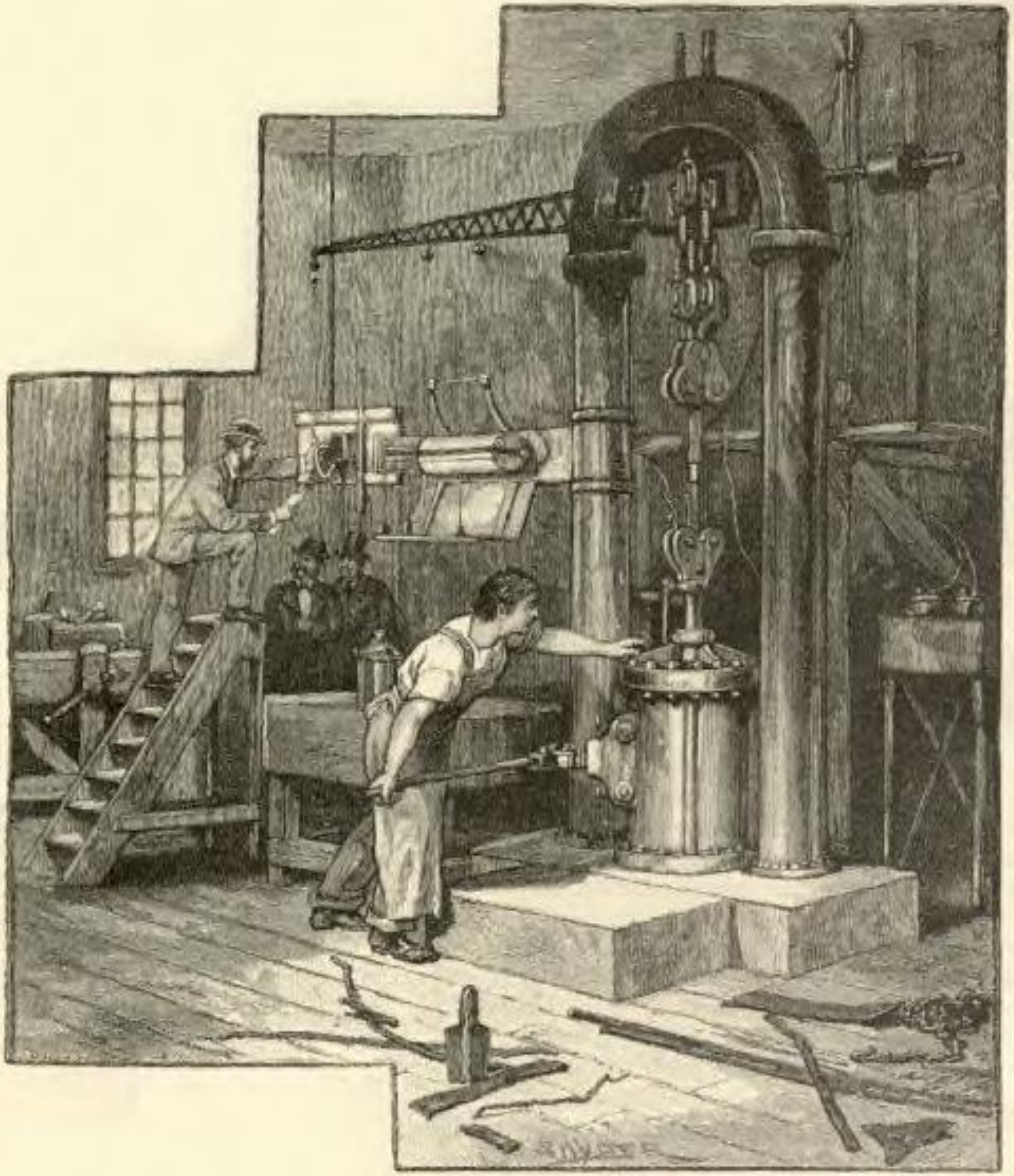
RE: WAR's strategy to mitigate the alleged conflict of interest charge by Abram Hewitt for *John A. Roebling & Sons* (JAR&S) bidding on the cable wire contract for the Brooklyn Bridge – it worked, but Hewitt still had a few tricks up his sleeve

Eminently Wise

The *Bessemer* process for making steel wire was a new, efficient and safe method that WAR called for in his specification and Abram Hewitt first approved of as "emminently wise." The older, less efficient thus more costly wire manufacturing method was known as *Crucible* steel (cast in ingot molds). All bidders put in a base-bid price for Bessemer steel wire and an alternate for Crucible steel wire. When JAR&S was the low bidder for the Bessemer steel wire and *J. Lloyd Haigh* of South Brooklyn the low bidder on the Crucible steel, Hewitt changed his mind on the safety of Bessemer steel and convinced the board and the public that it was unsafe.

"…I confess that I have grave doubts that I would not venture to record my vote in favor of Bessemer steel upon the tests now provided for in the specifications, and I am convinced that the apparent economy involved in the use of wire made from this material should not weigh against the risk involved in its use, unless it can be more carefully guarded than it now appears to be…"

Abram Hewitt, VP Board of Trustees – January 11, 1877 – speech to B of T whereby he flip-floped his position on the use of Bessemer steel and WAR's specifications



TESTING STEEL.

***Albert Hill*, an engineer of dubious reputation, motivation and origin, questioned Bessemer steel wire's safety in the press. The trick worked and J. Lloyd Haigh, a sociopath, won the wire contract for the steel cables of the Brooklyn Bridge. Though J. Lloyd Haigh submitted other manufacturer's crucible steel as samples for approval, he would send *Bessemer* steel wire to the bridge instead.**

"These specifications were intended for the guidance of practical wiremakers, and are written in plain language, easily understood by practical men, and are not incumbered by the formula employed, or the details of the calculations necessarily used in their construction."

Col. Thomas Paine – Engineering Staff, December 23, 1876 – defense of WAR's wire specifications in private meeting of Executive Committee against Albert Hill's publicized chrages against the wire specifications

"The assurance of the correct performance of these tests must remain a matter of confidence and trust. The building of the whole bridge is a matter of trust."

Washington Roebling, January 11, 1876 – annual report to Board of Trustees emphasizing his point that the wire tests should not be taken as a flawless certainty

"If one man's samples were too good he would be sure to reduce his standards, provided he got the contract, and another man, whose wire fell short of the standard, would have to make his wire come up to the mark before any could be accepted…Of all known materials, wire possesses a shape most susceptible of being tested in every direction. If necessary, a whole mile of it could be tested for its elasticity, throughout every foot of its length, without injuring it in the slightest degree. It is not like a huge casting, which may be full of hidden flaws, or like a big gun which bursts at the first discharge."

Washington Roebling, 1871 – RE: wire testing

"They regard that vote, although wanting of a majority, still as decisive against the use of Bessemer steel; for in so important a matter as the main cables, it would, in their opinion, be unwise to adopt a material which is distrusted by any considerable portion of the trustees. The question of cost is an important one, but it is subordinate to that of safety, and the difference of expense between the two is comparatively small to permit such difference to prevent unanimity and entire confidence."

Henry Murphy, January, 1876 – excerpt from letter to B of T explaining the Executive Committee's vote taken (12 to 1) in private meeting (1/11/76) whereby wire contract was awarded to J.L. Haigh for crucible steel rather than JAR&S for Bessemer steel

"most satisfactory…a matter for congratulation…It is, we suppose, admitted on all hands that the cables which are to sustain the bridge structure are the most important features of this great undertaking. These failing, all fails."

***The Brooklyn Eagle*, January, 1877 – RE: award for wire contract to J.L. Haigh of South Brooklyn**

"We shall try to forget as soon as possible that they were ever brought to discuss so absurd a proposition as the use of Bessemer steel."

***The Union*, January, 1877 – RE: award of wire contract**

It was observed that the pile of rejected wire supplied by J. Lloyd Haigh was growing smaller rather than larger, as should have been occurring. This raised the suspicion of foul play to the engineering staff. Haigh was handsome, charming and courting the daughter of a prominent Brooklyn family, until the girl's father discovered Haigh had a wife and children whom he had abandoned.

"It is as brittle as glass…The first question arises is how much of this same brittle wire has been going into the cable without our knowledge and secondly what steps must be taken to prevent its reoccurrence. Is it due to a wrong system of inspection or what is the reason in your opinion…This is what Mr. Kinsella is pleased to call the best. In reality it is worthless…and the most dangerous material that could be employed. How much of this poor wire has been going into the cables I do not know. Can I be held responsible for that? It is scarcely right that the engineers should have to be acting as detectives. I see but one way of preventing such wire being run out and that is to double the number of inspectors at the contractor's works."

Washington Roebling, November, 1877 – excerpt from letter to Henry Murphy regarding snapped wire provided by J.Lloyd Haigh

"From the known reputation of this man, I deemed it necessary from the first to test every ring of wire made by him…A watch was therefore set on the morning of the 5th of July, and the trick was discovered. The wagonload of wire as it left the inspector's room, with his certificate, in place of being driven off to the bridge, was driven to another building where it was rapidly unloaded and replaced with a load of rejected wire, which then went to the bridge with the same certificate of inspection…"

WAR, July 9, 1878

RE: Excerpts from a letter to Henry Murphy

"…The distressing point of this affair, is that all the rejected wire which has come to the bridge has been worked into the cables, and cannot be removed. We know this has been going on for two months, and the probability is that it extends as far back as January…An engineer who has not been educated as a spy or detective is no match for a rascal…in case of a want of strength shall in the future be found in the cables I wish the responsibility to rest where it belongs, with the Board of Trustees."

WAR, July 9, 1878

RE: Excerpts from a letter to Henry Murphy. After the switching trick was discovered, an armed guard on horseback escorted all wagonloads of wire from the inspection room to the bridge.

"I have waited with much anxiety for the report of Colonel Paine…in regard to the wire on hand and not used, which he has been engaged in retesting, since the suspicions arose in regard to the action of Mr. Haigh, and to the possible extent to which any rejected wire has been foisted upon us in the cables…It is manifestly proper, before any definite course be taken by us, that we should know the nature and extent of the injury, and that so far as the work itself is concerned, we should have your distinct recommendation in the premises."

Henry C. Murphy, July 25,1878 – response to WAR's 7/9/78 letter - RE: wire fraud

"The responsibility for any weakness that may be found in the cables, rests with the old Board of Trustees, because they awarded so important a contract as the cable wire to a man who had no standing, commercially or otherwise, and the same responsibility must be assumed by the present board, if they fail at once to put an end to Mr. Haigh's contract…"

WAR – July 1878

RE: Response to Henry Murphy's 07/25/78 letter

"…to continue the contract with Mr. Haigh for the wire required to complete the large cables, on such conditions and terms as he deems proper under the circumstances."

Board of Trustees directive to Henry Murphy, August 7, 1878

J. Lloyd Haigh was required to provide one hundred and fifty additional wires to each cable - at his own expense, and allowed to complete his contract. Nothing of the wire fraud was known/publicized until after the bridge was completed. Haigh would in later years be sent to prison for writing bad checks. Quietly and without competitive bidding, the contract for the steel wire rope for the suspender cables was awarded to JAR&S.

"All I am anxious about, is lest the trustees may entertain a poor opinion of me…I am sorry for that. Do you know that is what I was afraid of? Indeed, it was the only thing I was afraid of."

J. Lloyd Haigh, August 5, 1878 – testimony to the Executive Committee – RE: wire fraud

"Mr. Haigh, the contractor for furnishing the steel wire for the cables, applied to be allowed to substitute the personal obligation of Messrs. Cooper & Hewitt in place of the percentage retained under his contract, amounting now to $29,277.00, in order to save himself interest upon it."

Meeting of Executive Committee, January 8, 1878 – formal request from J.L. Haigh – exposed to all his relationship with Abram Hewitt

Part 17

Catenary Curve

"Before winter shall drive the workmen from their positions, we shall see the first strands of the great cable stretching aloft, spanning the river."

***The Brooklyn Eagle*, Fall, 1876**

"I have carried out your instructions to the letter, and from my perfect familiarity with your plans, and my own experience, I shall expect the cables of this bridge to equal, if they do not excel, the best that were ever made."

E.F. Farrington, 1876

In mid-July 1876, Colonel Paine reported to WAR that all saddle plates (four per tower) weighing 13-tons each (26K pounds) were in place atop both the Brooklyn and NY towers. The saddle plates served as a base for the saddles over which the cable strands would run (the saddle/s rested on rollers atop the saddle plates allowing for movement of the cable/s). With the saddles in place, the first wire was run across on August 14th 1876 thus marking the half-way point of the bridge’s construction.

25

Blank No. 1.

THE WESTERN UNION TELEGRAPH COMPANY.

The rules of this Company require that all messages received for transmission, shall be written on the message blanks of the Company, under and subject to the conditions printed thereon, which conditions have been agreed to by the sender of the following message.

1 Pw

WILLIAM ORTON, Pres't, A. R. BREWER, Sec'y, New York.

Dated New York 14 1876

Received at 12.45 August

To Col W. A. Roebling

West State St.

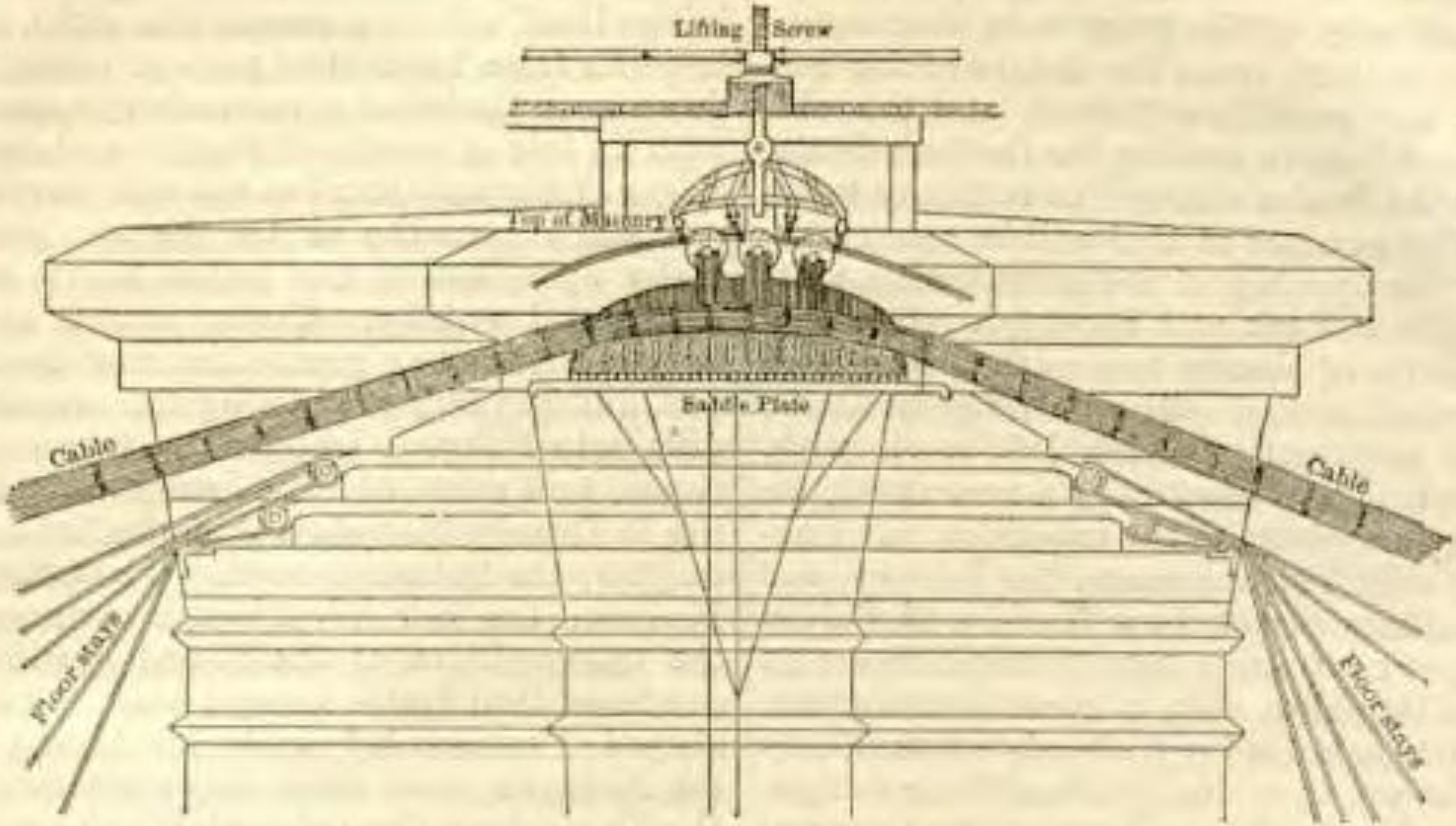
The first wire rope reached its position at Eleven and one half oclock. Was raised in Six minutes.

W H P.

18 Paid

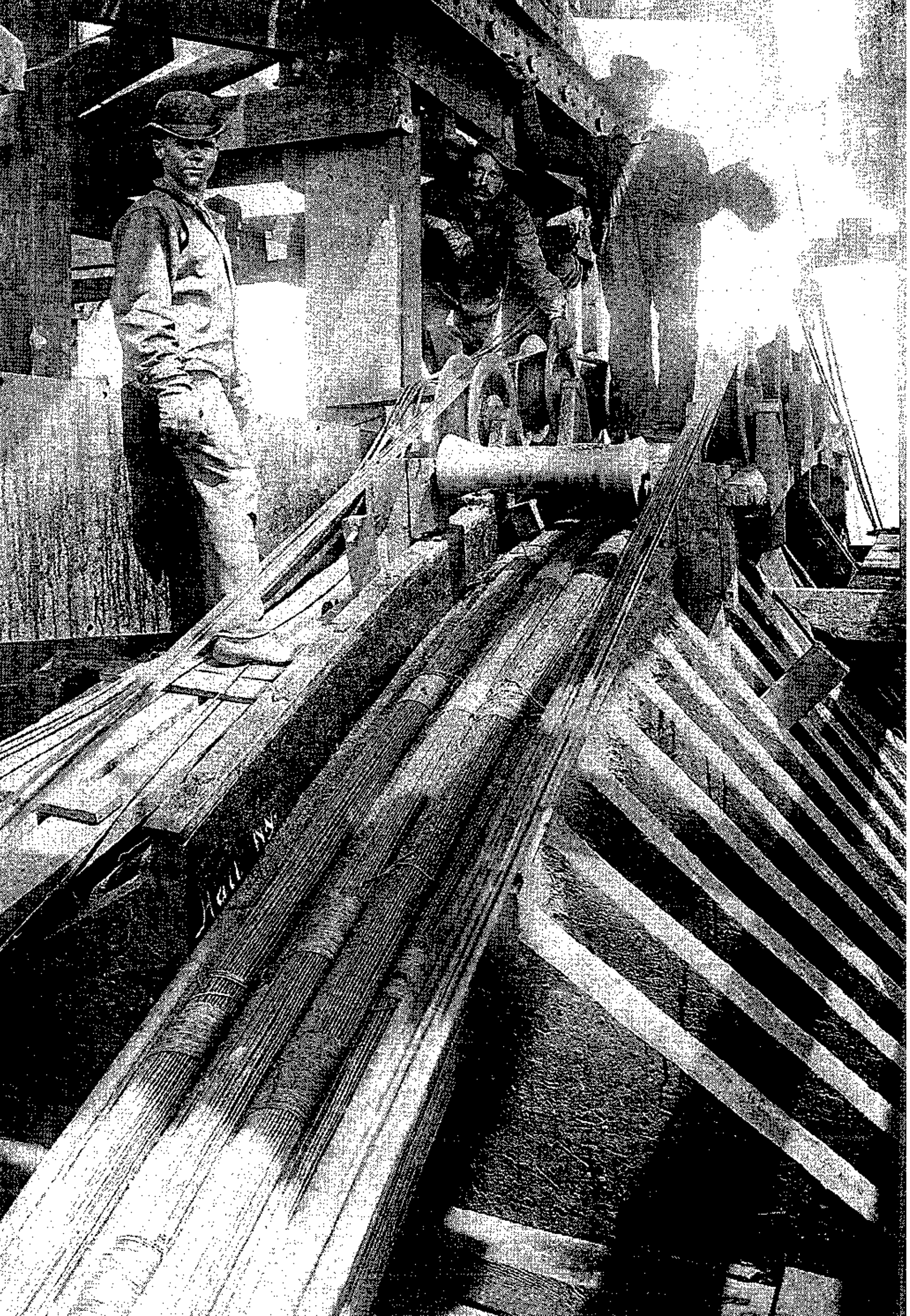
Telegraph from Colonel Paine to WAR (in Trenton, NJ)

(dated August 14, 1876)



SECTION OF TOWER, SHOWING SADDLE-PLATE AND LOWERING OF STRAND INTO POSITION.

Tower section showing cable-strand lifting/setting apparatus



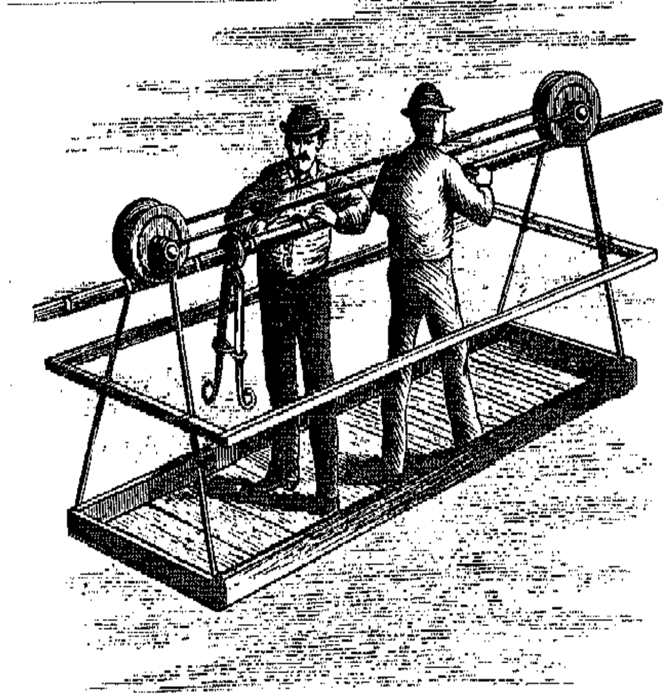
Cable Strands set in saddle

At left (near workman's feet) a strand is being formed from wire "spinning". Once complete, it will be lifted (via the lifting screw apparatus) and take its place with the completed strands already in the saddle.

The tensile load of the cable/s is transformed into a compressive load that is transmitted through the saddle, into the masonry tower to the caisson and into the earth where the load is absorbed. Each saddle is four-feet high and elliptical in shape. A groove at the top of the saddle allows the nineteen cable strands to pass over the saddle. The strands cannot be compressed and bound (into a circular cross-section) in the saddle, they remain nineteen individual strands in a hexagonal configuration.

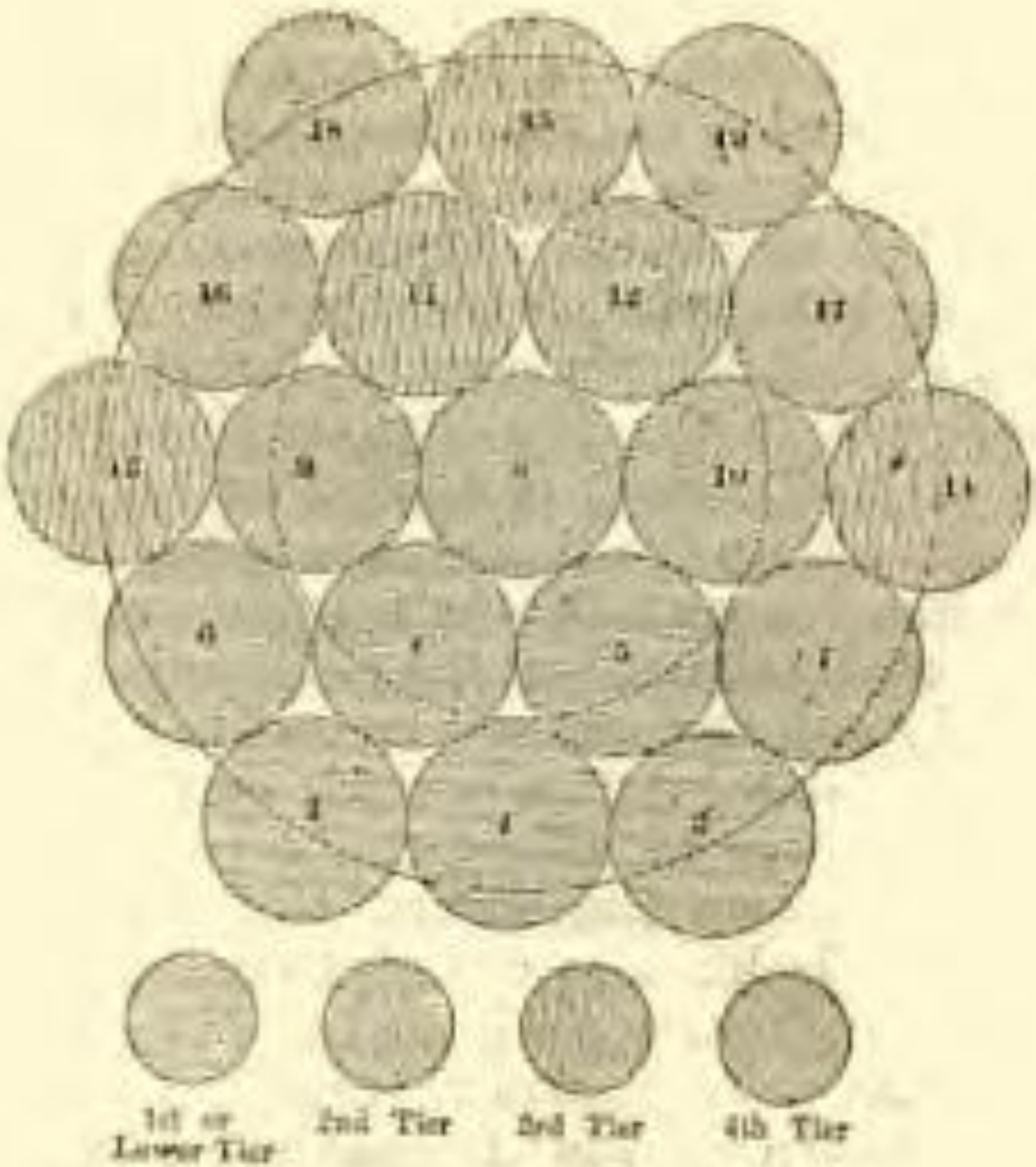
"Each must hang in its own peculiar length and curve to a mathematical nicety, for if left but half an inch too long or too short for its true position, it will be too slack or too taut for its fellows, and it will be impossible to bind them solidly in one mass and make them pull equally together."

Magazine article, 1878 – RE: "Regulating" the wire strands to form cables



Once a strand was complete, a pair of workmen in a 6-foot by 10-foot traveling "buggie" (supported by the strand on trolley wheels) used clamps to compress the strand's wire into a cylindrical (round) form and, at about 15-inches on-center, placed soft wire bindings (a.k.a. "seizings") around the strand to bind the wires together. With the individual strand complete, it could be lowered into the saddle from its elevated position. On July 2, 1877, the first two strands for the downstream cables were completed. By the summer of 1877, the work was going smoothly and ahead of schedule.

Each cable strand was “spun” individually and bound together with seizing. At mid-span, the strand/s were hung at a height 60-feet higher than their actual position as part of the cable. This served two purposes; first, it kept the wires well above the top masts of passing ships and second, it nearly doubled the tension it would have in the cable (at a lower elevation). This assisted greatly in “straightening out” the wire by removing kinks.

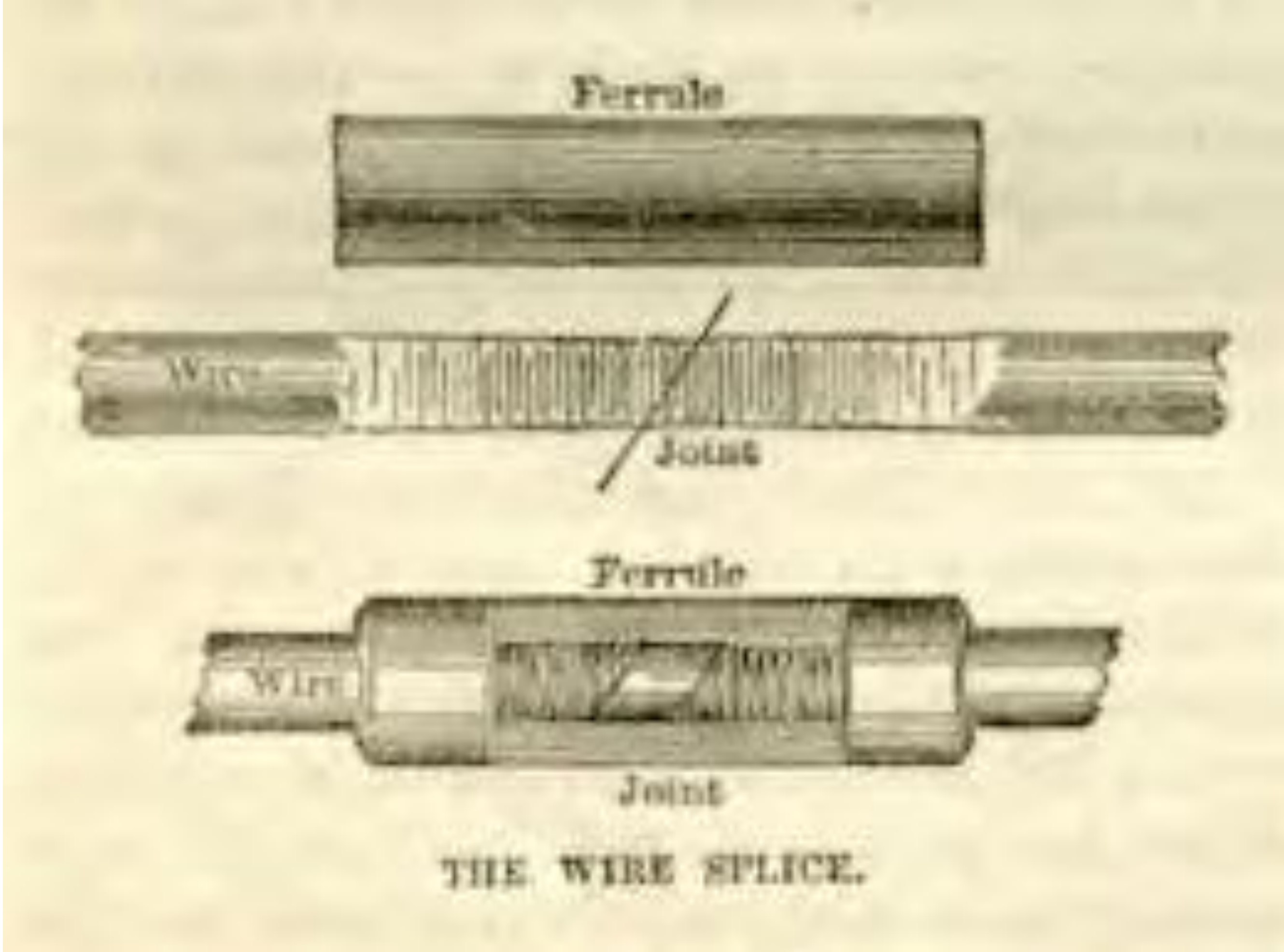


SECTION OF CABLE, SHOWING STRANDS.

Hexagonal configuration of the cable strands.

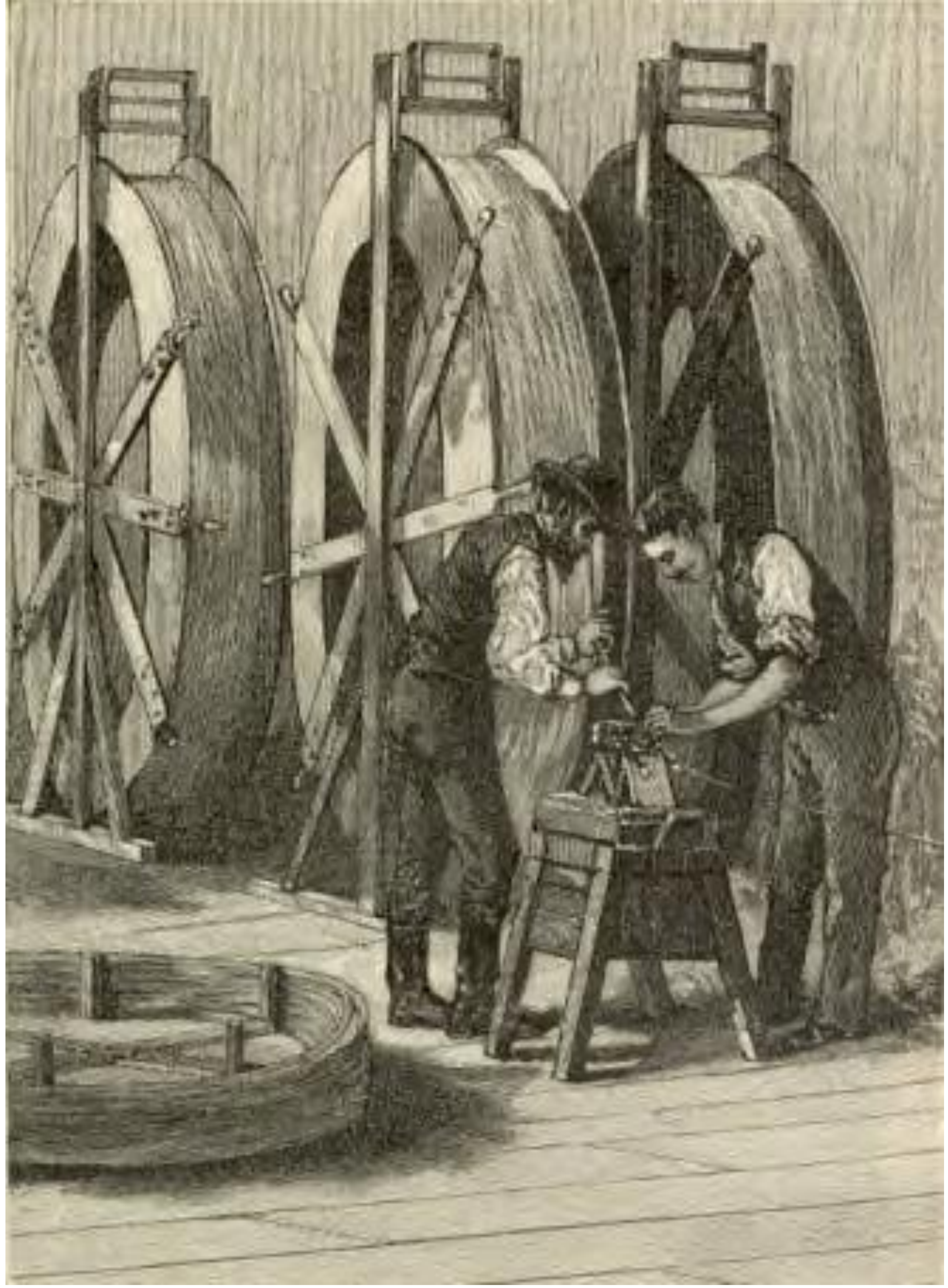
The wire that forms the individual strands and the strands that form the main cable/s are in parallel, they are not twisted to form a "wire rope" as are the suspender cables, that would be impossible given the diameter of the cable and the distances involved.

At the factory, the wire was spun onto a wooden coil that was only a few hundred feet in length thus, many splices were required. The end/beginning of the wires (off the coil/s) would need to be joined on-site once a coil of wire had "played out." It was critical that the joint where wires connected be as strong or stronger than the wire itself. To this end, WAR devised a *Ferrule* – a hollow sleeve into which the wire end/s of two separate wire coils were inserted and joined. Under tension, it was found that the pencil-thick wire would pull apart inside the Ferrule. To solve this problem, WAR had the wire ends cut at a 45-degree angle so when they met inside the Ferrule it would form a "lock-joint" that would not pull apart under tension. WAR spent two years perfecting this splice.



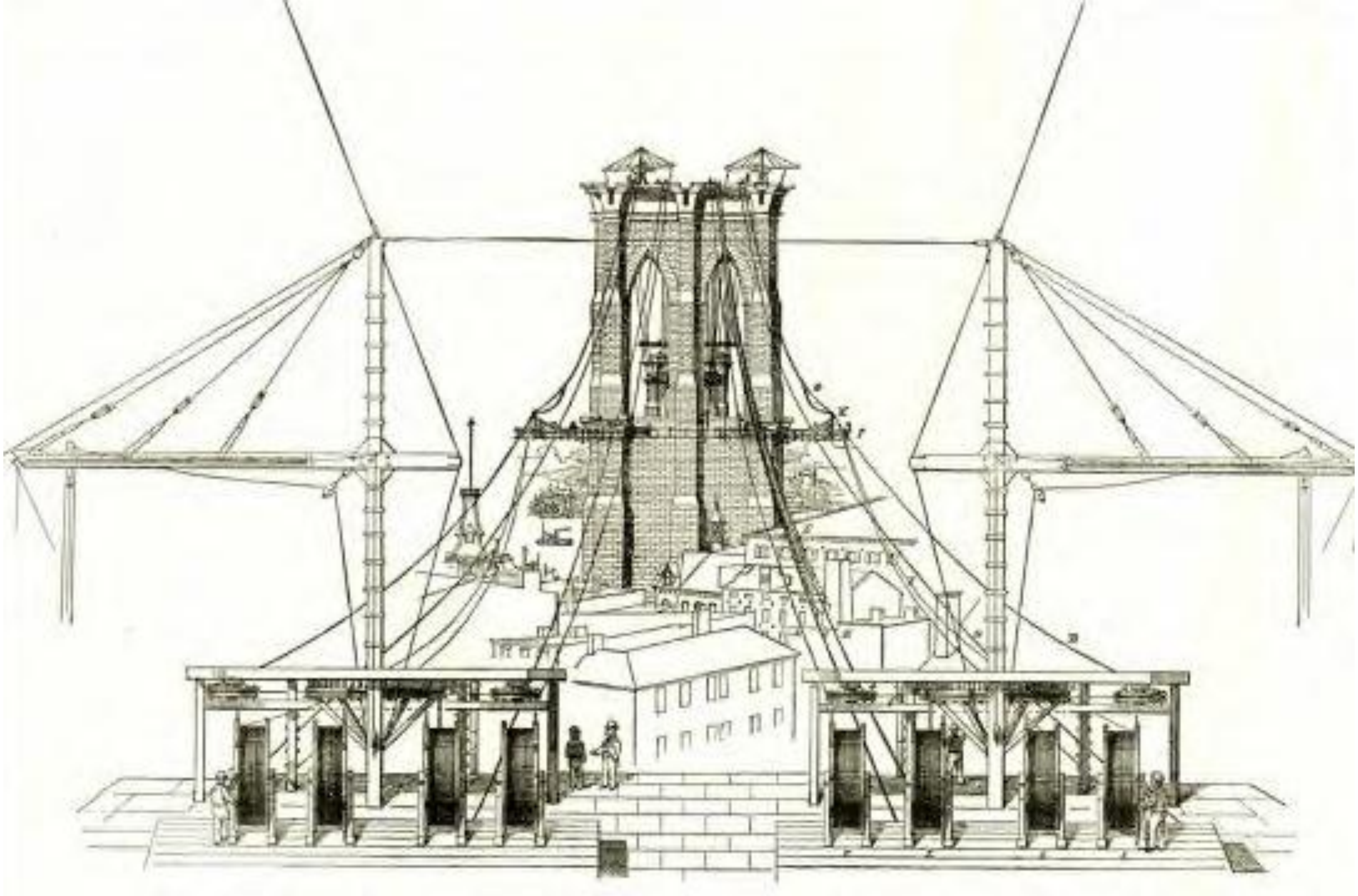
The Ferrule (wire splice)

One wire-end was given a right-hand thread and the other a left-hand thread (with corresponding threading inside the Ferrule). Placed in a vice-like apparatus, the Ferrule was turned with a wrench until the ends of the wire met inside the sleeve.[416]



Splicing the wire (in Ferrule) off the wooden coils

A coil of wire was first dried and then hoisted to the top of the anchorage where it was wound onto the small, horizontal wheel/s first and then onto the large upright drums which could hold fifty-two coils (nearly ten miles of spliced wire). This process was known as "Drumming Up" and the phrase was added to the English language (i.e. "*drumming up* some business"). From the drum/s, the wire would be played-out via the *Traveler* (a.k.a. *Carrier*) *Wheel* to form a cable strand. On June 11th 1877, spinning of the two downstream cables began. It was anticipated that four drums (about forty miles of wire) would be used every working day.



Atop the Brooklyn Anchorage

Wooden drums mounted upright (in timber frames). Behind these drums, smaller reels were placed horizontally in the floor.

***The Traveller* (or *Carrier*) – a six-spoked wheel, carried the wire from the drum atop the Brooklyn anchorage (temporarily secured to a cable-strand's shoe), over the two towers and around a corresponding cable-strand shoe on the NY anchorage. Once enough wire had been "spun" to form a strand, the end of the wire was spliced to the wire end (on the Brooklyn cable strand's shoe) thus forming a continuous loop of wire. The shoe/s would then be placed between two eye-bars protruding from the end of the anchor eye-bar chain/s in their respective anchorage. It took about ten minutes for the wheel to make the trip between anchorages. Men were stationed atop the towers and in the cradles to ensure that the wire maintained proper position, tension and sag.**

The Traveler Wheel

In this photograph, at left, can be seen the six-spoked *Traveler Wheel*. To it was secured a cow's bell whose clang reminded workmen stationed on the towers and/or cradles of it's approach. Even today, a cow's bell is used on the traveler wheel when spinning the cable of a modern suspension bridge.

"It is refreshing to see how the work is pushed forward, and yet the thoroughness with which everything is done, in these days of slighted work and ill-performed operations…"

***The Brooklyn Eagle*, 1876**

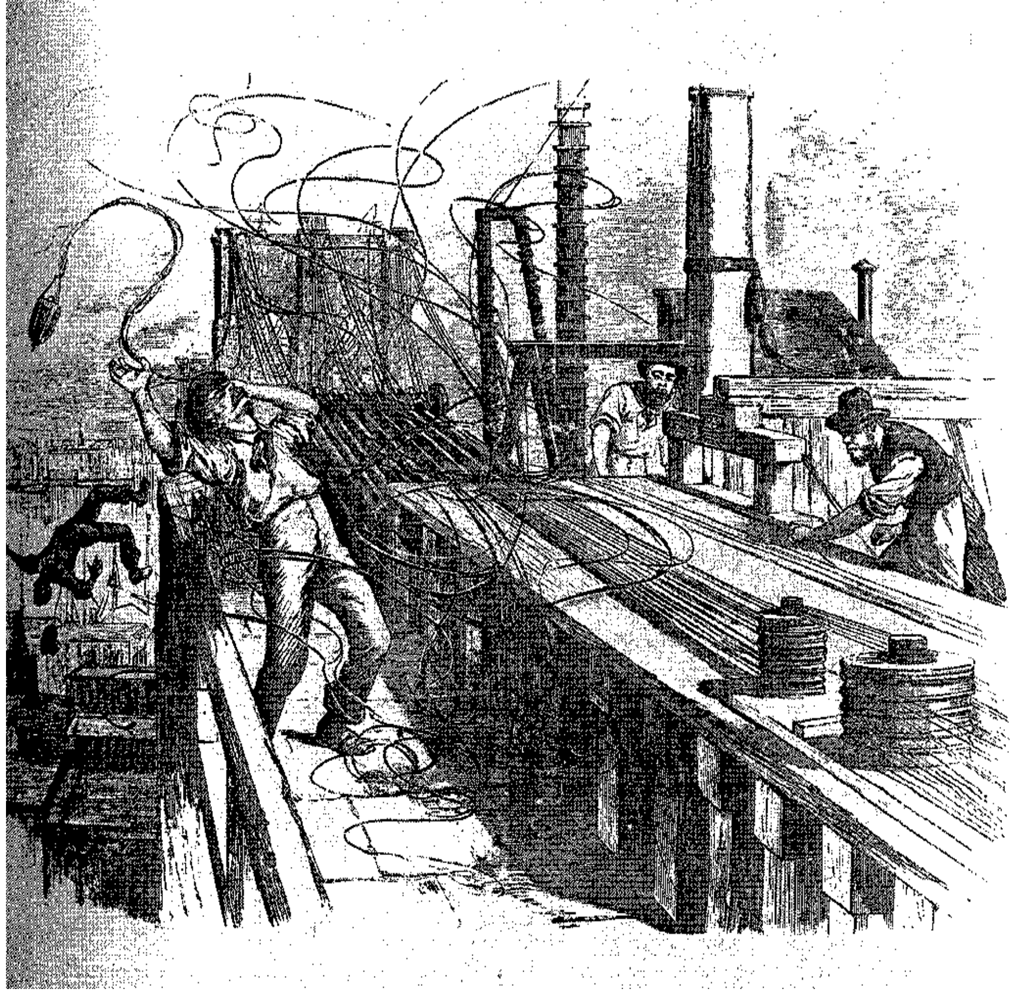
RE: Cable-spinning operations

"The network of wires across the East River is rapidly beginning to look something like a bridge."

***New York Herald*, August, 1877**

"No sir, no man can be a bridge-builder who must educate his nerves. It must be a constitutional gift. He cannot when 200 feet in the air, use his brain to keep his hand steady. He needs it all to make his delicate and difficult work secure. They must plant their feet by instinct…and be able to look sheer down hundreds of feet without a muscle trembling. It is a rare thing for a man to lose his life in our business for loss of nerve."

E.F. Farrington, Master Mechanic, 1877



Fatal Accident (newspaper depiction)

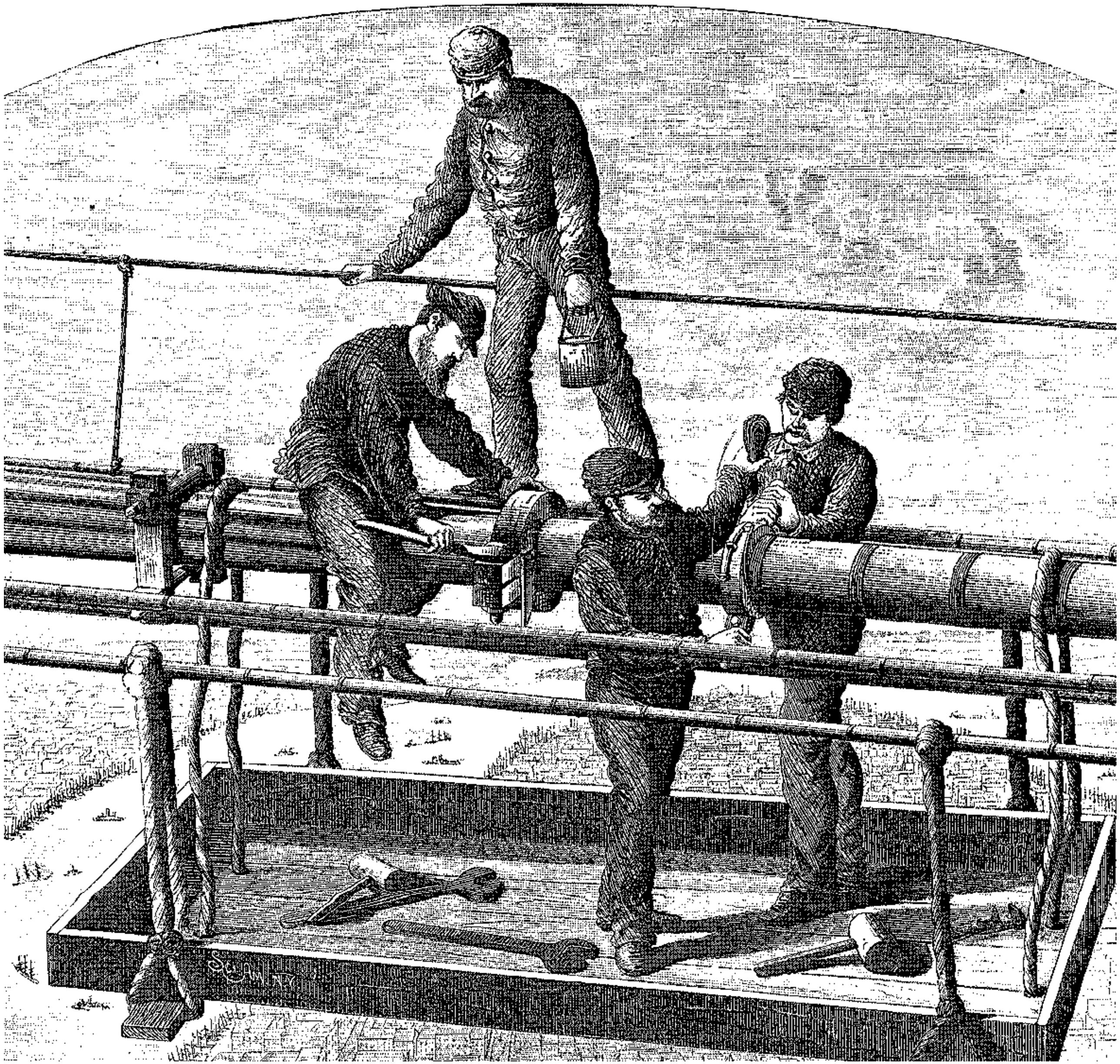
Aerial cable-spinning was/is considered the most hazardous part of building a suspension bridge, it lived up to its reputation with the creation of the Brooklyn Bridge. A total of twenty men, plus JAR, are known to have died building the bridge.

“These operations, though simple in themselves, acquire a special interest from the circumstance that they are carried on at such a gigantic scale and such an enormous elevation above the river”

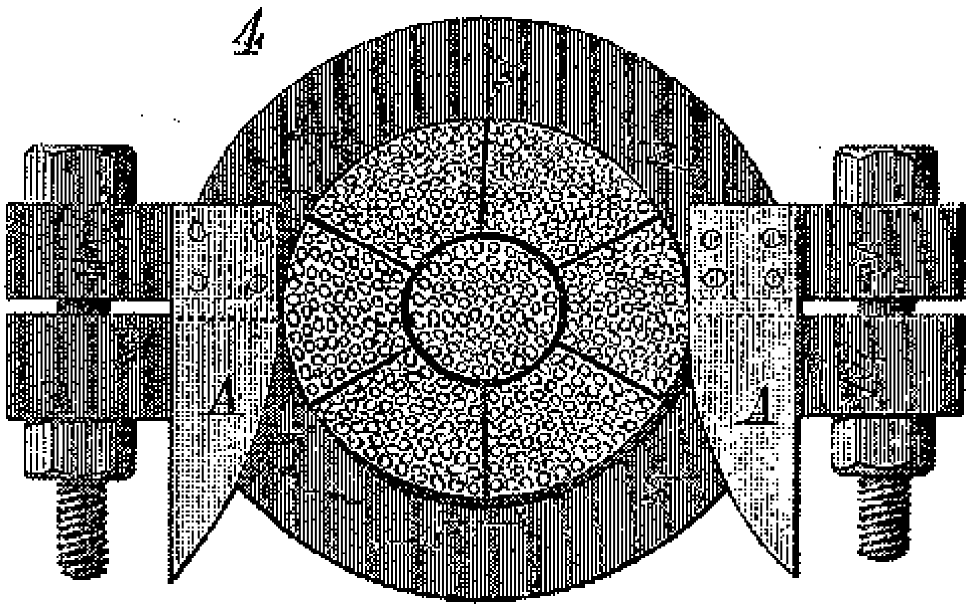
***Scientific American*, 1878**

RE: Cable-wrapping operation

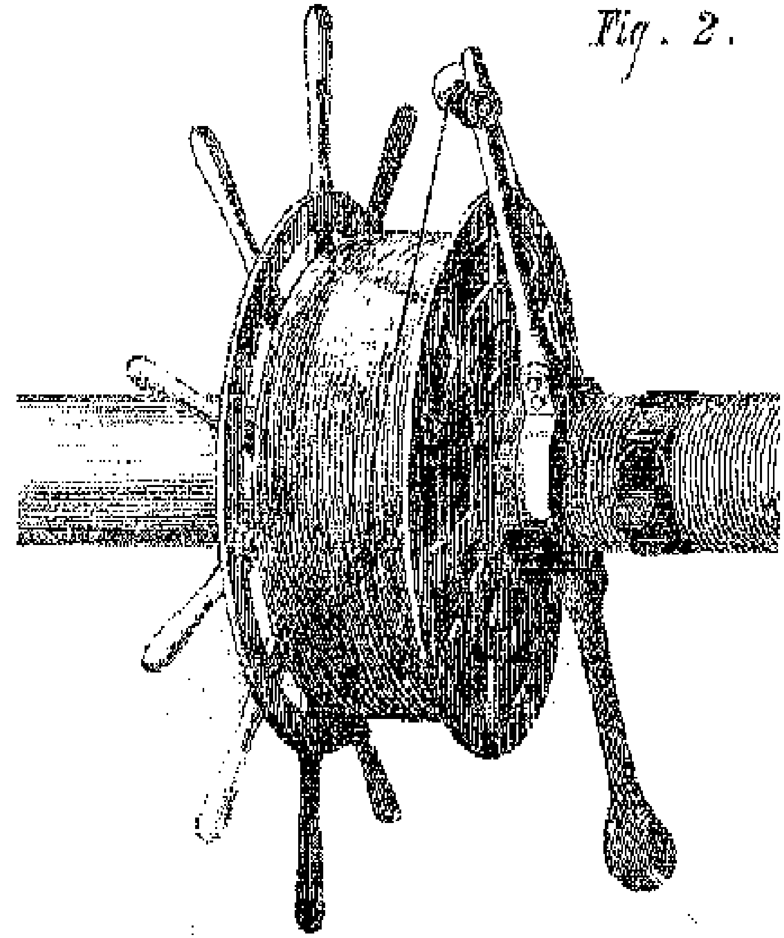
Once all nineteen strands were complete, two pairs of workmen set out on a traveling buggie. The first pair used a manual jack to compress the hexagonal configuration of the strands into a cylindrical (round) cross-section. Following a few feet behind them, the other pair used a ships-wheel like wrapping device (that fit around the diameter of the plus fifteen-inch diameter of the round cable/s) and played out a fine galvanized wire thread binding the strands together permanently and protecting the cable strands from the elements.



Cable compressing/wrapping operations
(off a traveling "buggie")



Manual Jack



Cable Wrapping Apparatus

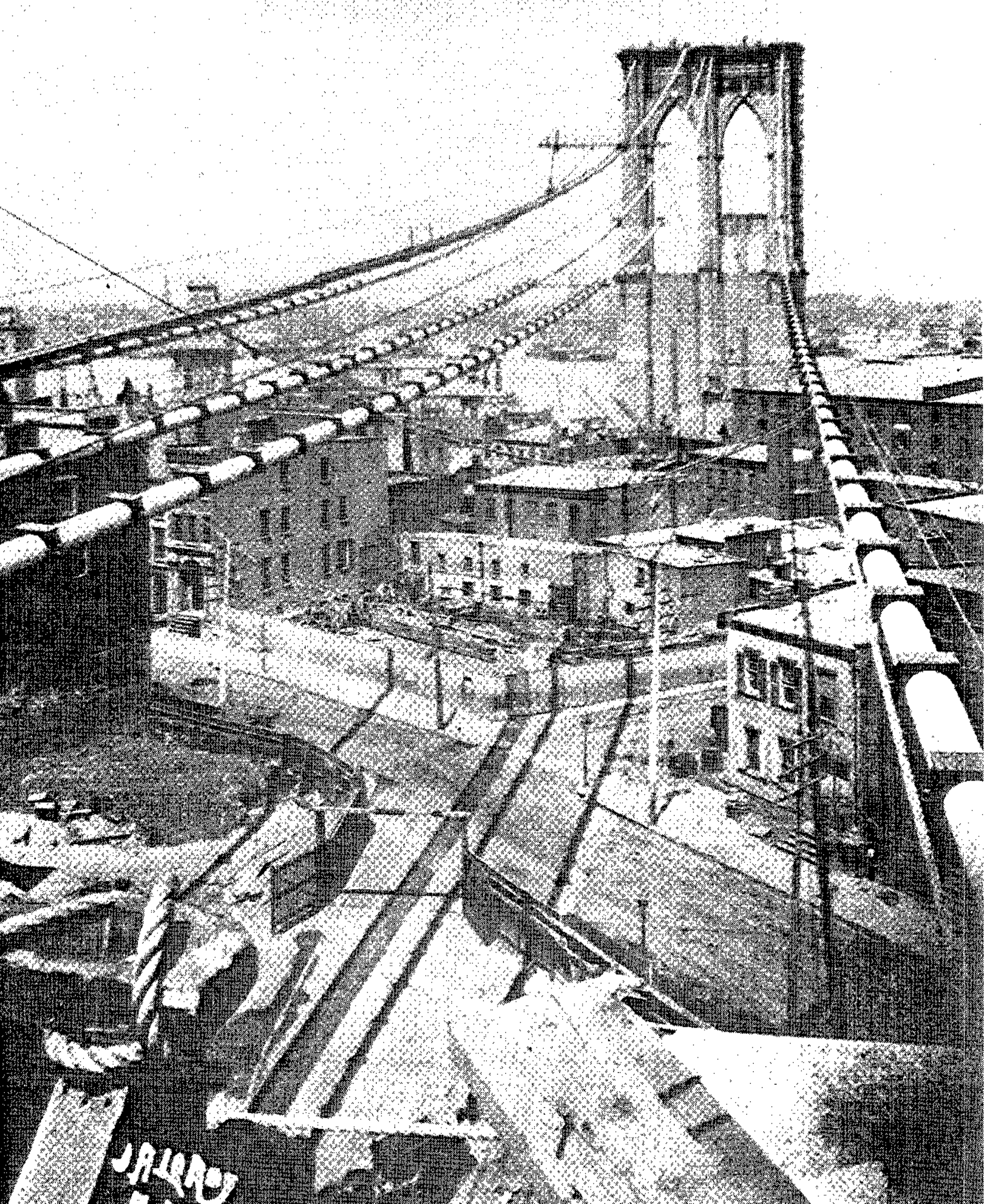
After the binding and painting process was complete, cable bands were installed at precise intervals along each cable and in line with their corresponding cable band/s on the other three cables. From these bands, the wire rope suspenders would support the suspended road and promenade deck/s below.

This Desirable Event

"This desirable event, was marked by no demonstrations, save the sounding of a steam whistle, and the raising of a United States flagon the Brooklyn tower"

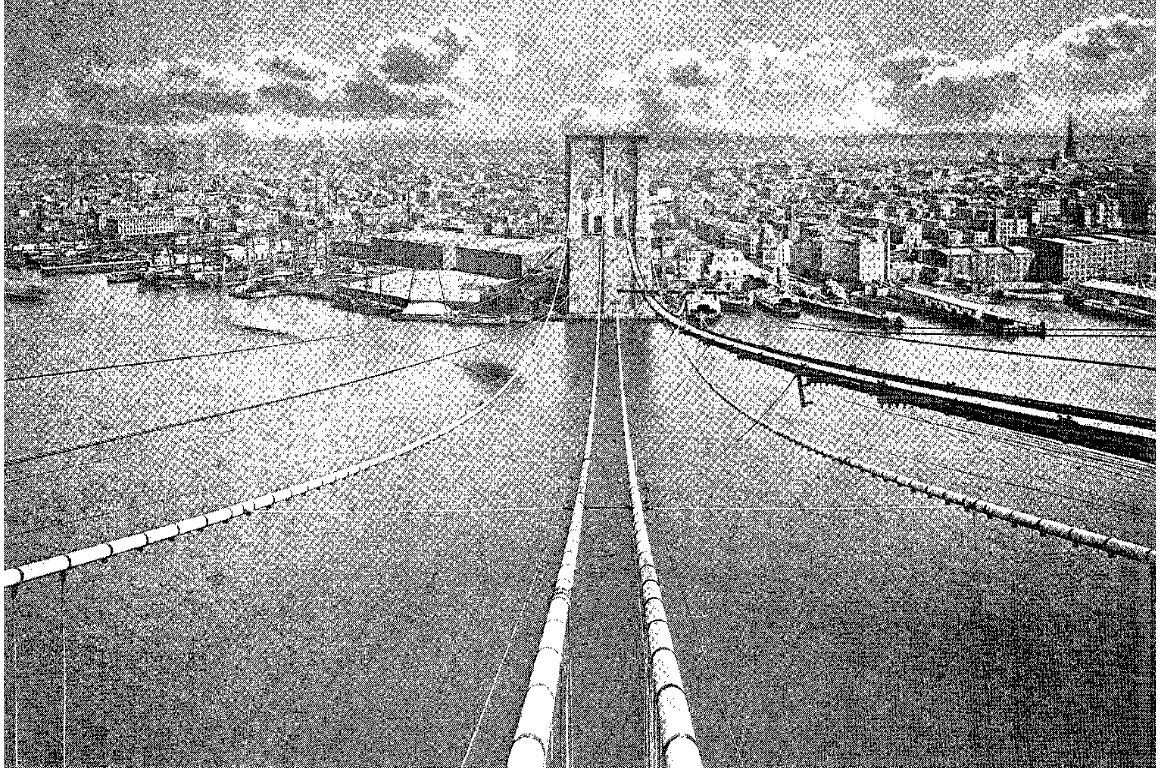
E.F. Farrington – Master Mechanic - October 5, 1878

RE: Comment made on the day the last wire crossed over the river



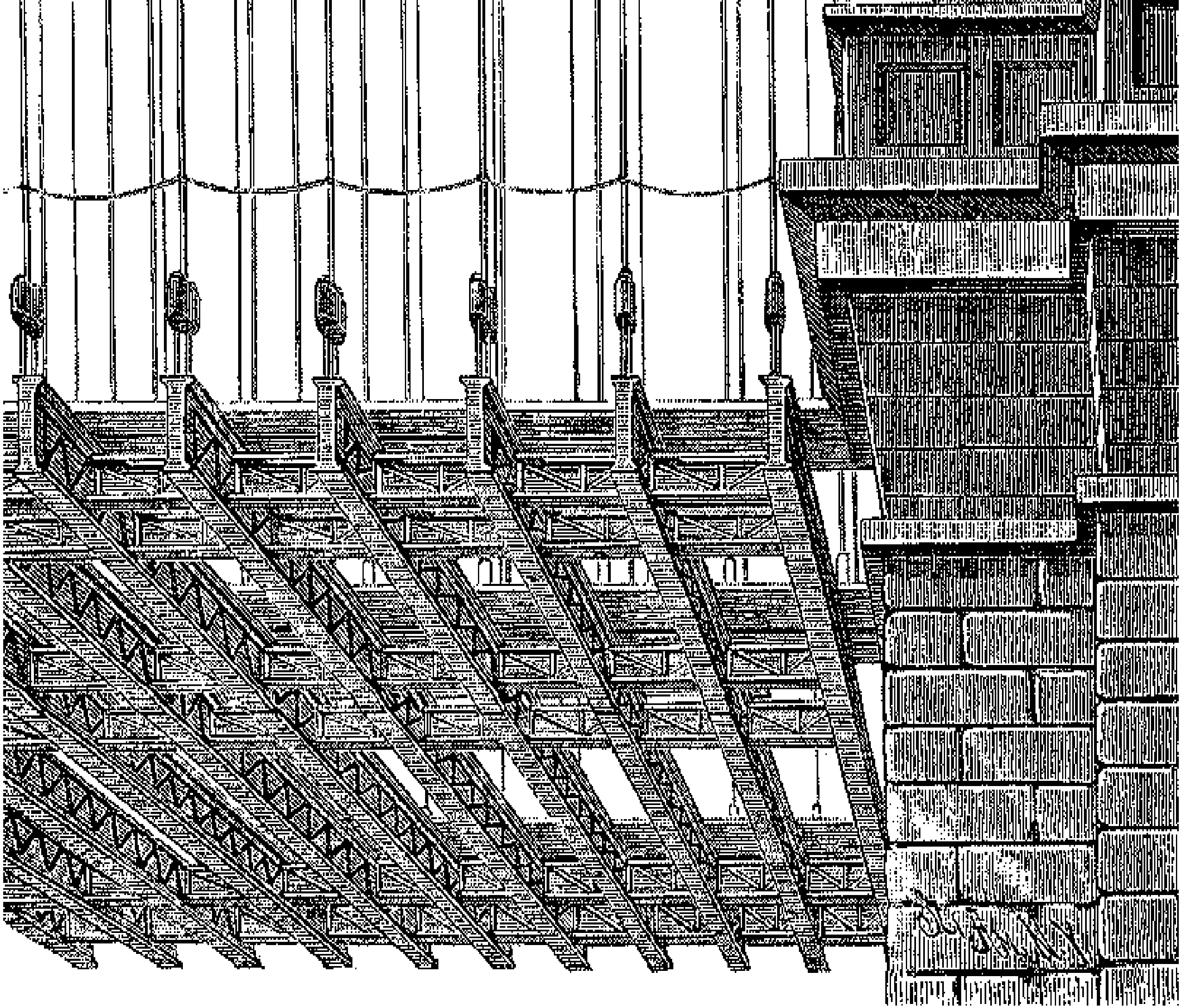
At 4:45pm on October 5, 1878, cable spinning was completed one year and four months after it had begun – eight months sooner than expected. The traveler wheel had made 23K trips across and a one-day record was set when 88-miles of wire was laid-up. Once the four cables were completely wrapped with galvanized thread, they were oiled and painted white.

Wedded



February 1880

Cable wrapping was complete and suspender cables were being installed. Each suspender cable was an individual galvanized wire-rope bolt connected to the cable band. An integral "boss" (at the end of the wire rope) secured the suspender to a deck truss. Planking was laid over the completed deck trusses and the proceeding suspender cable/s were pulled back and the process repeated until the deck was complete.



Deck trusses secured to suspender cables

(near tower)

Newspaper drawing depicting workers installing the suspender cables (1880)

***National Geographic* cover celebrating the 100th anniversary of the opening of the Brooklyn Bridge (1983)**

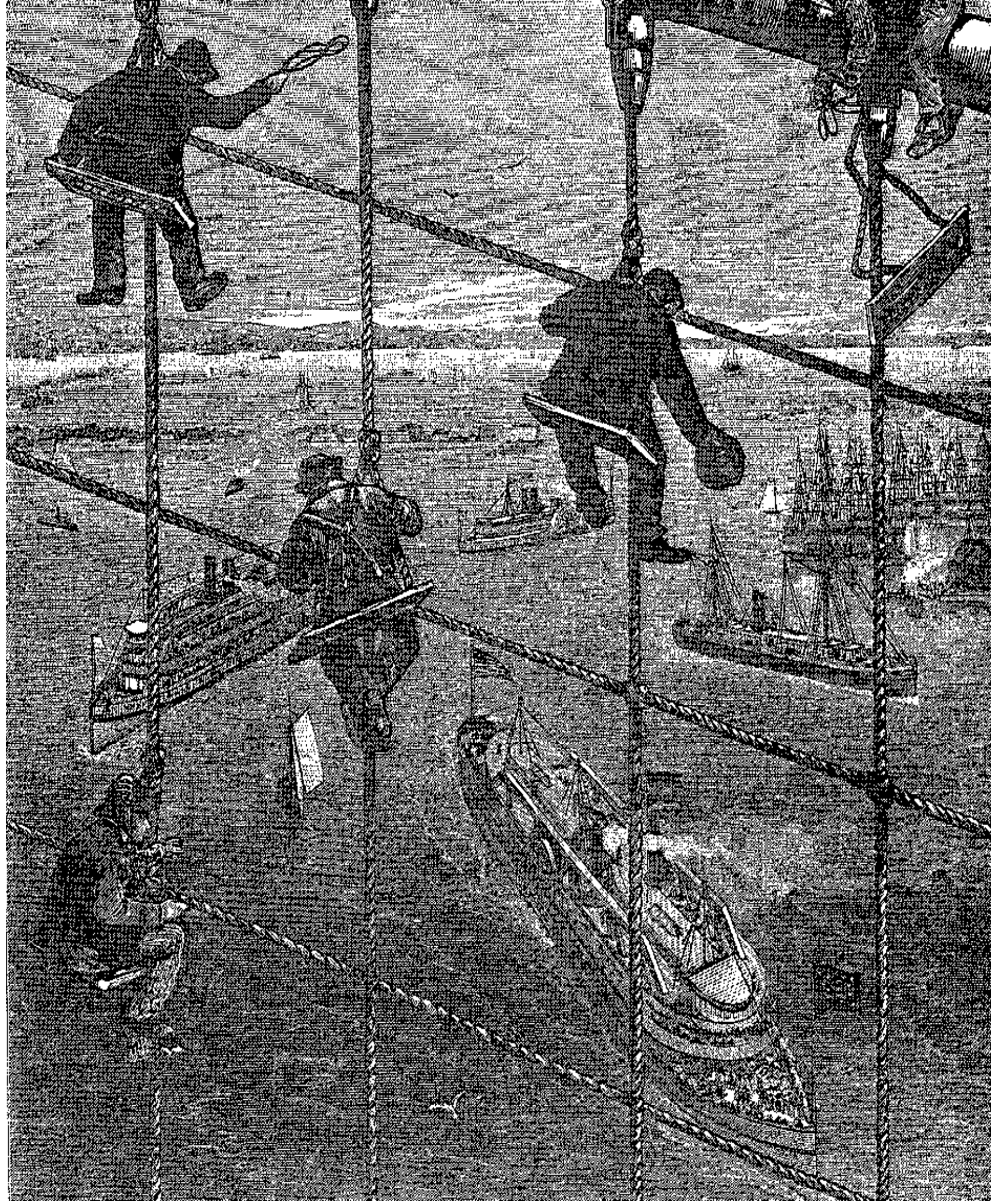
Close-up of typical bolt connection of suspender rope to cable band

In a modern suspension bridge, a pair of suspender cables are "looped over" the cable bands (which have grooves welded at a precise angle depending on the band's position) to maintain a vertical orientation to the bridge deck.

Stays

"Each rigger is provided with a large pail of marlin, or tarred line, with which he lashes the stays and suspenders together until the diamond shaped spaces are perfect in form. This is done so that when the superstructure is lowered by means of the screws at the base of the suspenders the strain will be equally distributed. The marlin lashings are temporary and will shortly be replaced by permanent iron clamps."

***Frank Leslie's Illustrated News*, 1883**



JAR's trademark cable stays
(being tied to the suspender cables)

If all four of the Brooklyn Bridge's main cables were cut in half at mid-span, the Brooklyn Bridge would not drop into the East River, it would sag in the middle (because the cable stays do not extend to mid-span), but it would not fail since the stays help support the bridge deck. However, the cable stays main function is to stabilize the suspender cables in the wind by providing a damping effect (at every point a stay crosses a suspender rope). There is also an aesthetic beauty to the spider's web-like pattern of the stays radiating out from the tower/s as they do. Each stay rests atop the tower (in a special saddle notch) and radiates over both the side/land span/s and main/river span as one unit, transferring its tensile load into a compression load via the tower/s.

Radiating cable stays off Brooklyn Tower (foreground)

Manhattan Bridge (background)

Despite reassurances from public officials, newspapers etc. concerning the bridge’s safety, many people were fearful and reluctant to “risk their life” by crossing the river by bridge. In fact, the ferry service was busier than ever. The single event that changed many people’s minds was the blizzard on March 12th 1888. The fact that the bridge still stood after the storm subsided and that it provided the only way across the river during the storm endeared the bridge to the public-at-large forever.

The Brooklyn Bridge open for business during the *Blizzard of ’88*

"They say the bridge cable slipped, that's just what the designers and constructors intended it to do. If the bridge cable had not slipped, one end of the bridge would have fallen down. There is no need of rebuilding the bridge. It will last for 100 or 200 years."

Washington Roebling, 1922 – comment upon incident whereby a cable slipping incident during rush-hour traffic jam

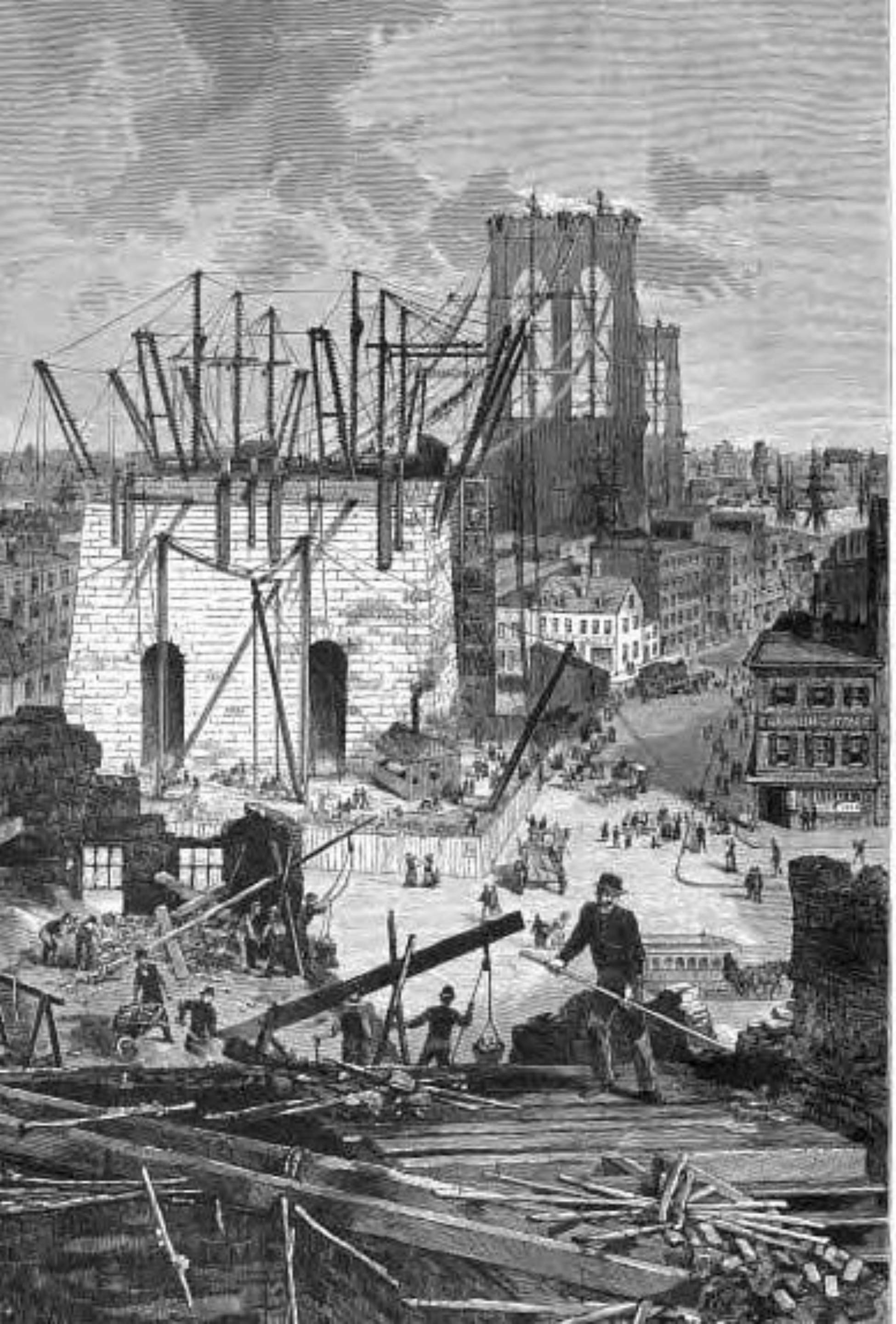
Part 18

Approaches

When JAR submitted his report and budget estimate in 1867, he overlooked the cost to purchase (by eminent domain) and demolish buildings for both the Brooklyn (on prime real estate) and NY approaches. Combined, both approaches are nearly a mile long. The oversight by JAR cost the Bridge Company $3.8 million. Ultimately, the bridge would cost $15 million – 2x JAR's estimate and take 3x as long as he predicted.

View of Brooklyn from atop the Brooklyn Anchorage

(all these buildings would be demolished)



Demolition in Progress

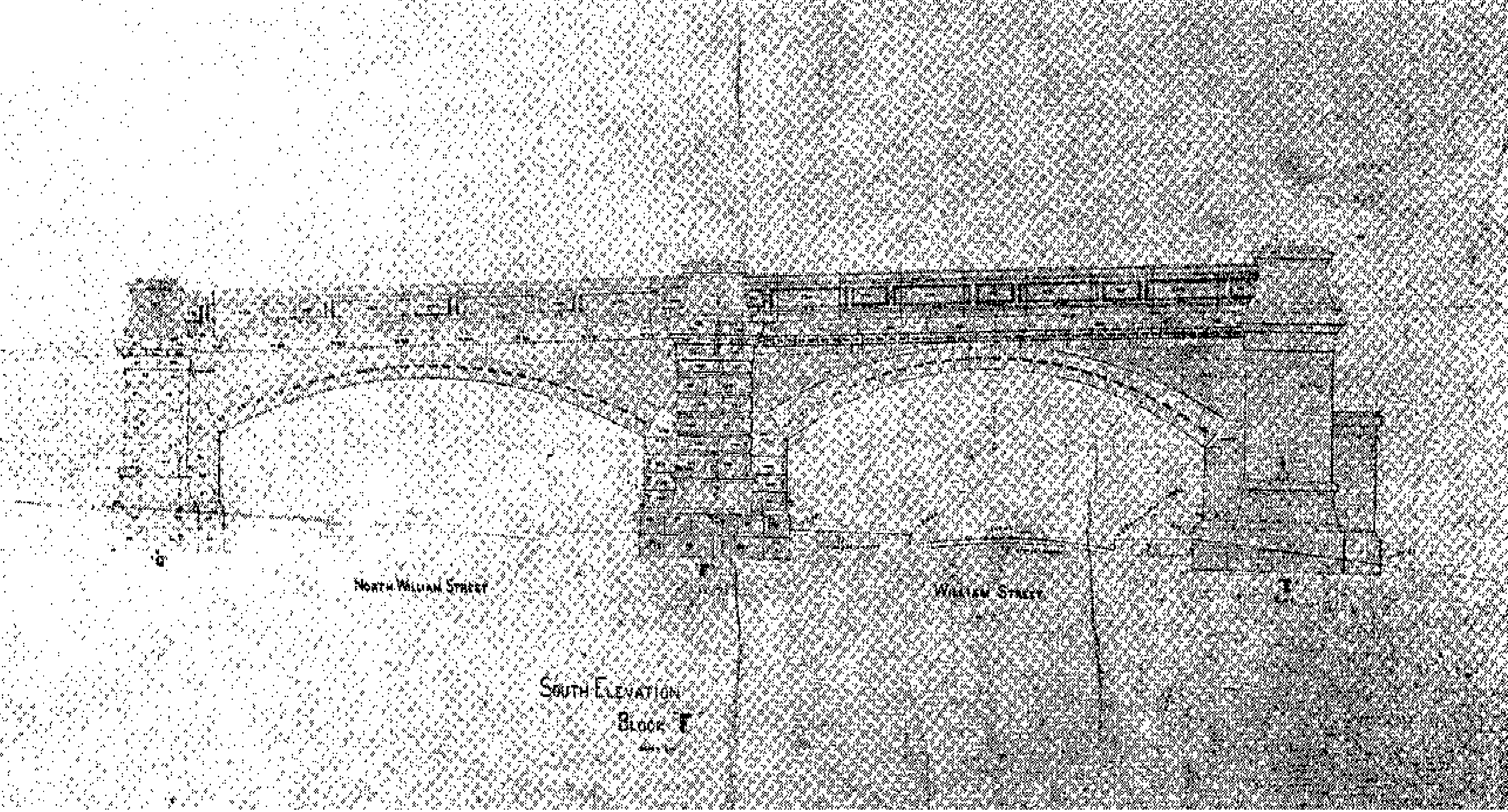
Because both NY and Brooklyn have low-lying shorelines along the East River, they required very long approaches to achieve the 135-foot spring high-tide clearance at mid-span (NY's approach was/is longer)

Removing telegraph lines for the NY Approach

Unlike Brooklyn, the demolition of buildings to make way for the approach was welcomed (the area was a notorious slum)

"The street bridges are uniformly imposing by size and span and especially attractive also by reason of the fact that through them we get what is to be got nowhere else in our rectangular city, glimpses and 'bits' of buildings. The most successful of them all, and the most successful feature architecturally of all the masonry of the bridge, is the simple, massive, and low bridge of two arches which spans North William Street in New York"

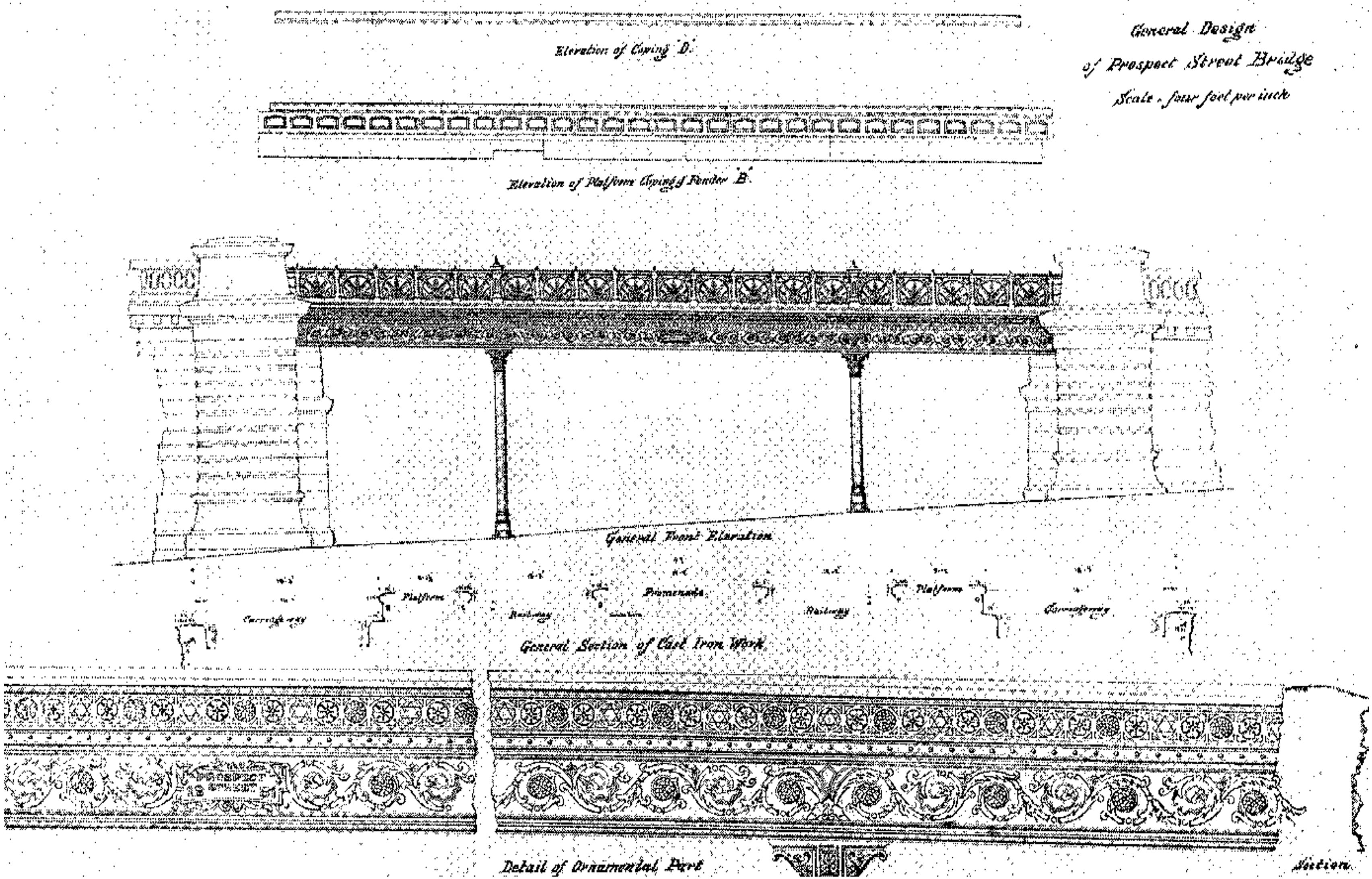
Montgomery Schuyler, *Harper's Weekly*, 1883



North William Street Bridge
(Elevation)

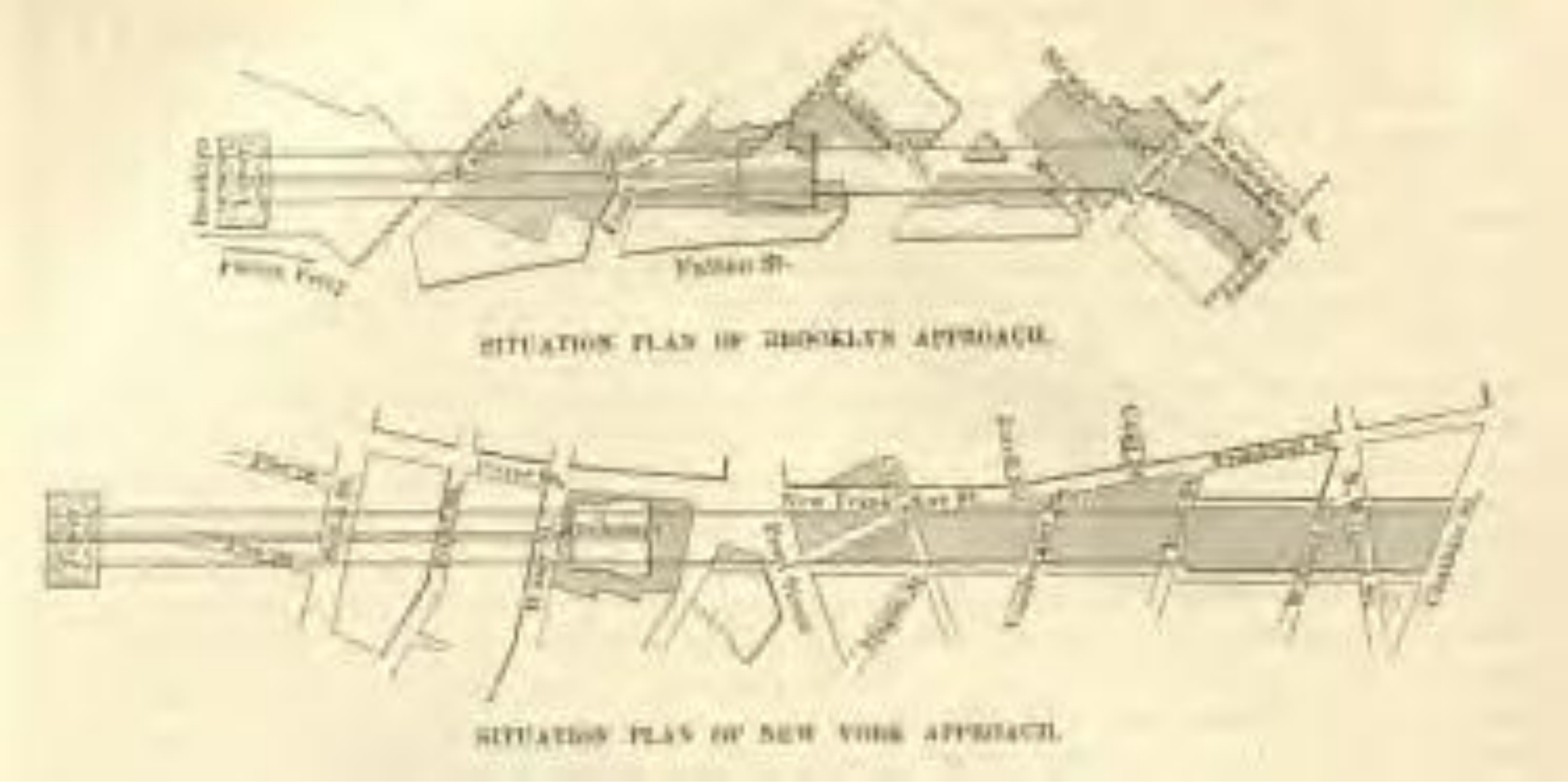
North William Street Bridge
(replacement with steel arch - present day)

Over the years, many of the nine original stone and/or iron girder bridges that spanned streets that intersected the approaches have been altered to accommodate modern traffic conditions. In fact, Joseph Pulitzer's *World* building – once NYC's (and the world's) tallest skyscraper, was torn down in the 1950s to make way for a ramp onto the Bridge. Of all the major elements of the Brooklyn Bridge, the approaches have suffered most due to alteration, demolition and/or obstruction from view.



Iron girder bridge over Prospect Street

Note the beautiful ornamental ironwork adorning this bridge. German architect *Wilhelm Hildenbrand* designed the approaches with great care; the result was impressive.



Plan of Brooklyn (top) and NY (bottom) approach
(note the increased length and multiple intersecting streets for the NY Approach as compared to the Brooklyn Approach)

THE BROOKLYN APPROACH.

Elevation/rendering of the Brooklyn Approach

THE NEW YORK APPROACH—EASTWARD FROM THE CITY HALL.

Elevation/rendering of the New York Approach

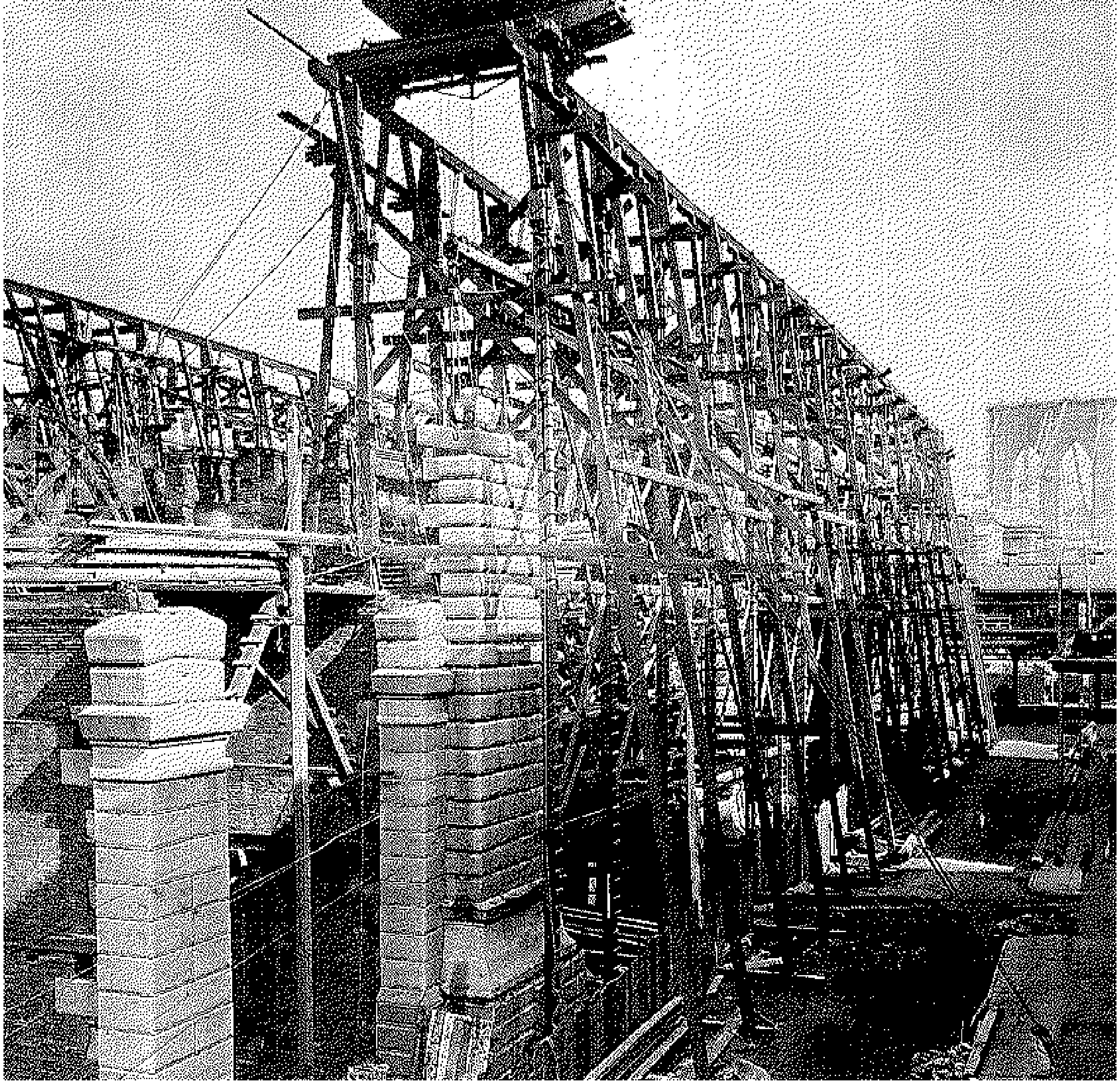
New York Approach

Parking lot adjacent to Brooklyn Bridge Approach

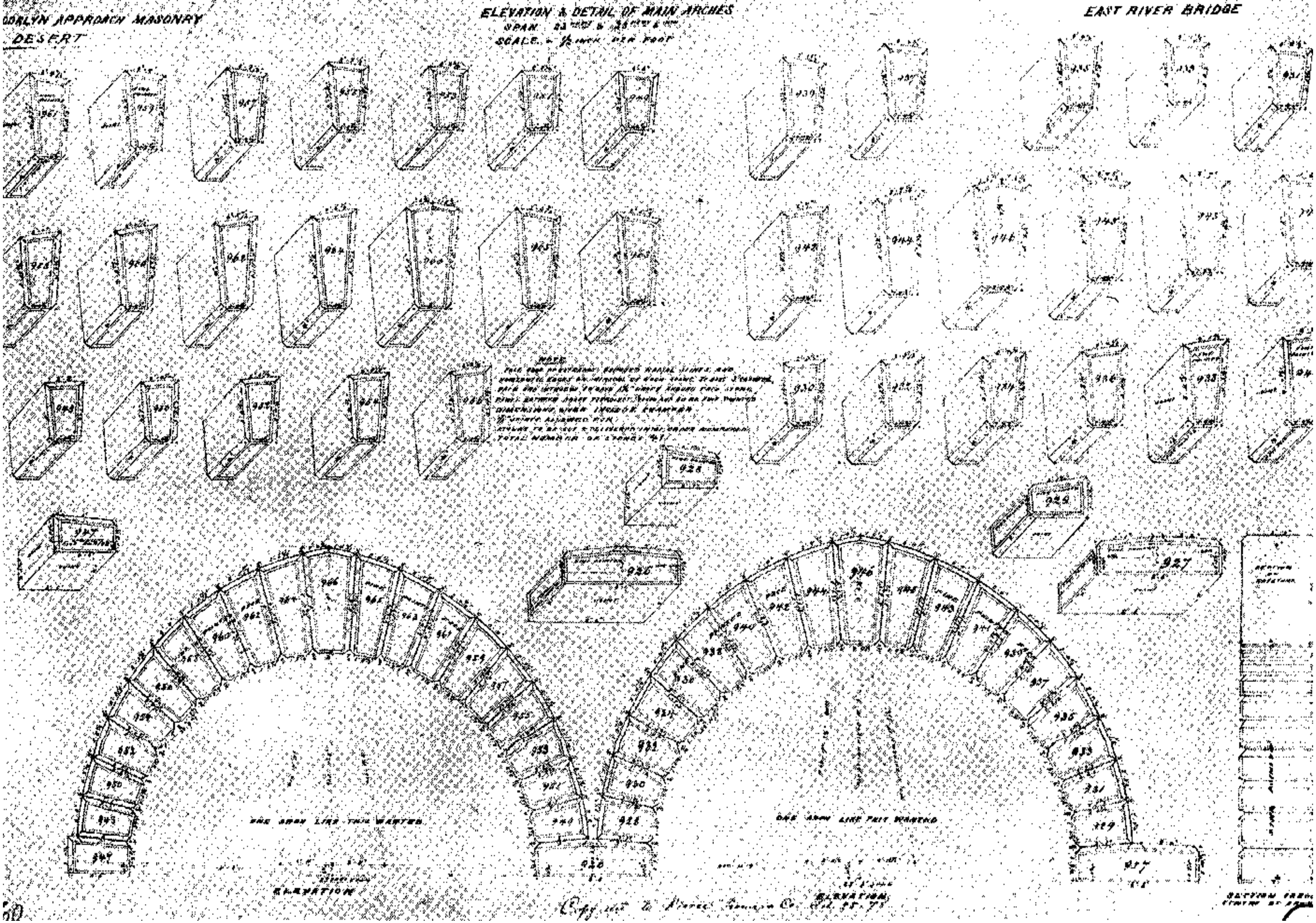
(present day)

"The brick arch fell because it had a right to fall…Every arch, be it round or flat, must fall if its thrust is not met by an adequate lateral support…The real accident was not so much that this arch fell; as that the other one stood…Ambitious natures are apt to be overconfident and to shrink from asking counsel of more experienced persons for fear their infallibility might be impugned…Time and age cures all this."

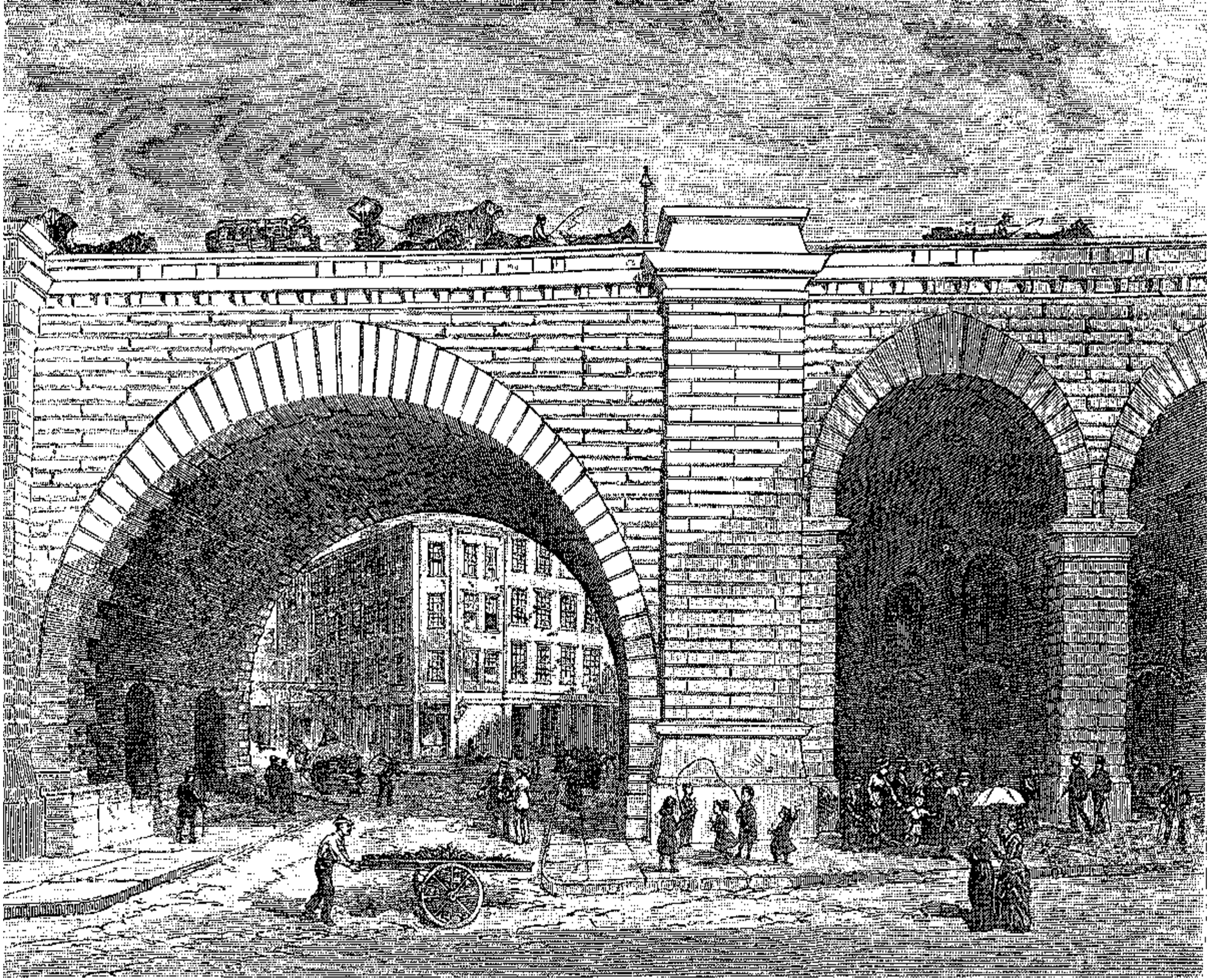
Washington Roebling, December, 1877 – excerpt from letter to Henry Murphy concerning collapse of arch in Brooklyn approach that killed one man – Neil Mullen, a widower with six children – due to premature removal of falsework by McNulty



Masonry for bridge approach
(under construction)



Stone Arch Detail Drawing for Brooklyn Approach
(by Wilhelm Hildenbrand)



Masonry Arches
(Brooklyn Approach)

Modern ramps obscuring approach arch
(present-day)

NY Approach
(present-day)

Part 19

A Great Avenue

1882

Work on the bridge was entering its final stages. The masonry approaches were nearly finished, the deck trusses were nearing completion as was the plank flooring for the roadway and promenade. The superstructure was being painted and the footbridge would be taken down having served its purpose. By early spring 1883, the bridge was "substantially complete."

Installing Deck Trusses

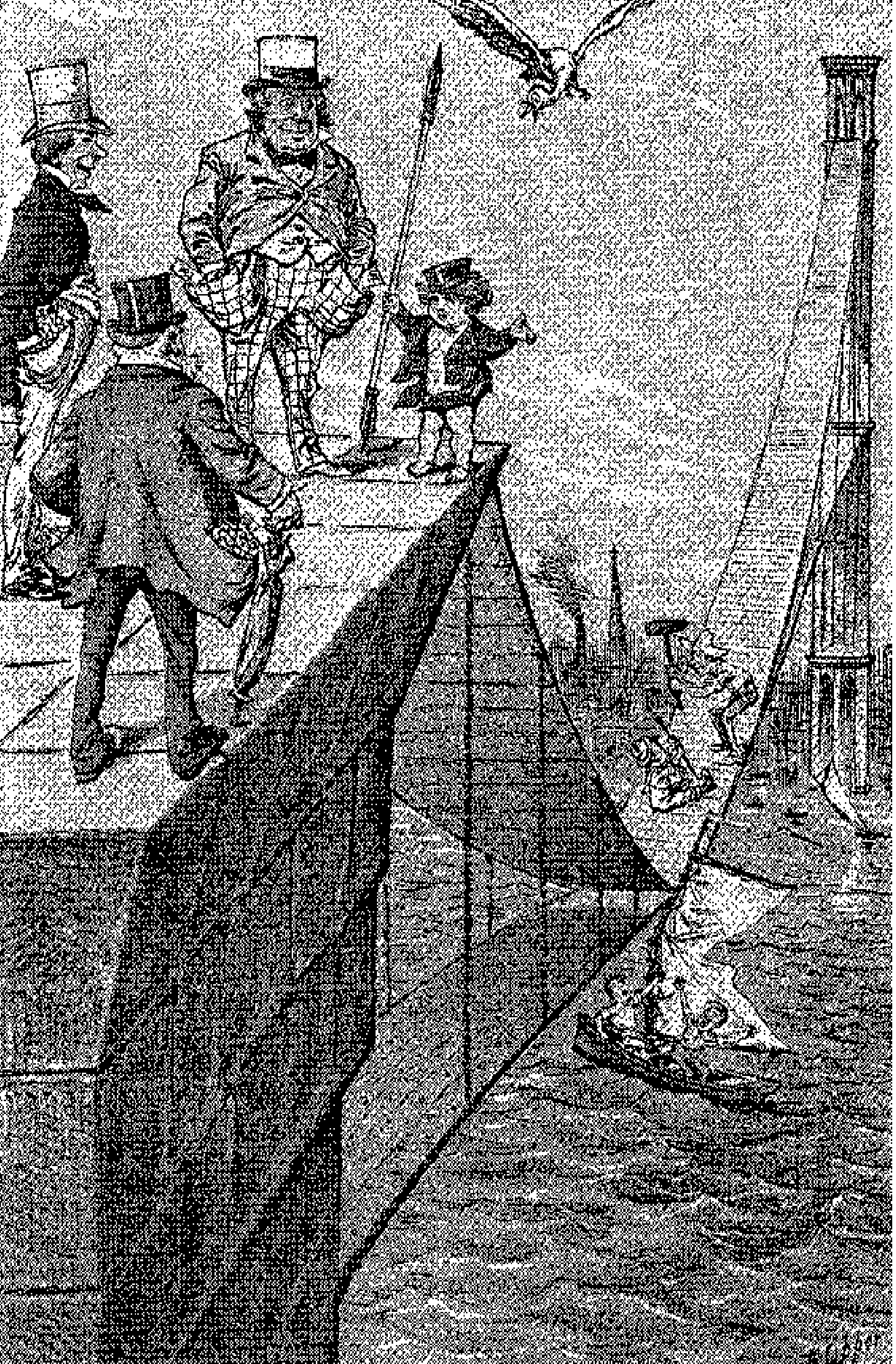
The trusses were installed from the tower/s (and/or anchorage/s) toward the center of the span

A Never Ending Job

"At present all labor seems to be at a stand-still because the commissioners...can not find the means to coerce a company that is trying to dodge its contract to supply the iron for the bridge. No one supposes that the commissioners, individually, would permit business associates to humbug them after this fashion; and it is not to be wondered at if an indignant public at last falls back upon a bad old pun, and asks indignantly if these supine gentlemen are waiting for more 'steel'."

***Puck*,1881 – commenting on the Edge Moor Iron Company's poor performance in delivering the steel for the bridge floor**

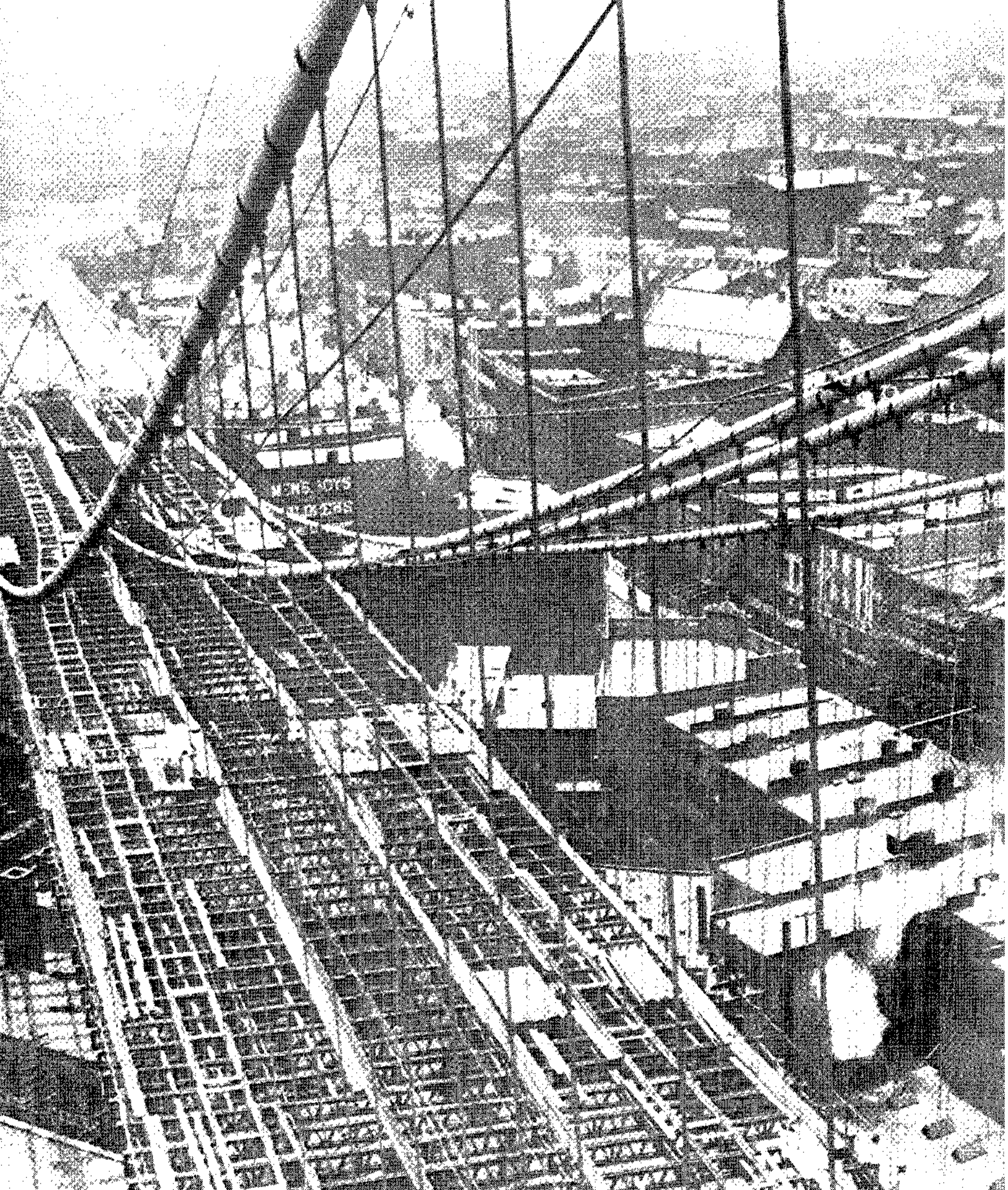
The deck trusses should have been the easiest part of constructing the bridge since it was a very repetitive task. First, there was a controversial change from wrought iron to steel and then additional deck bracing (for train service) that unduly upset some board members. More significant however was the manufacturer (*Edge Moor Iron Company*) of the trusses' inability to supply the deck trusses in quantity and/or on time, to the frustration of all concerned, not least the public-at-large.



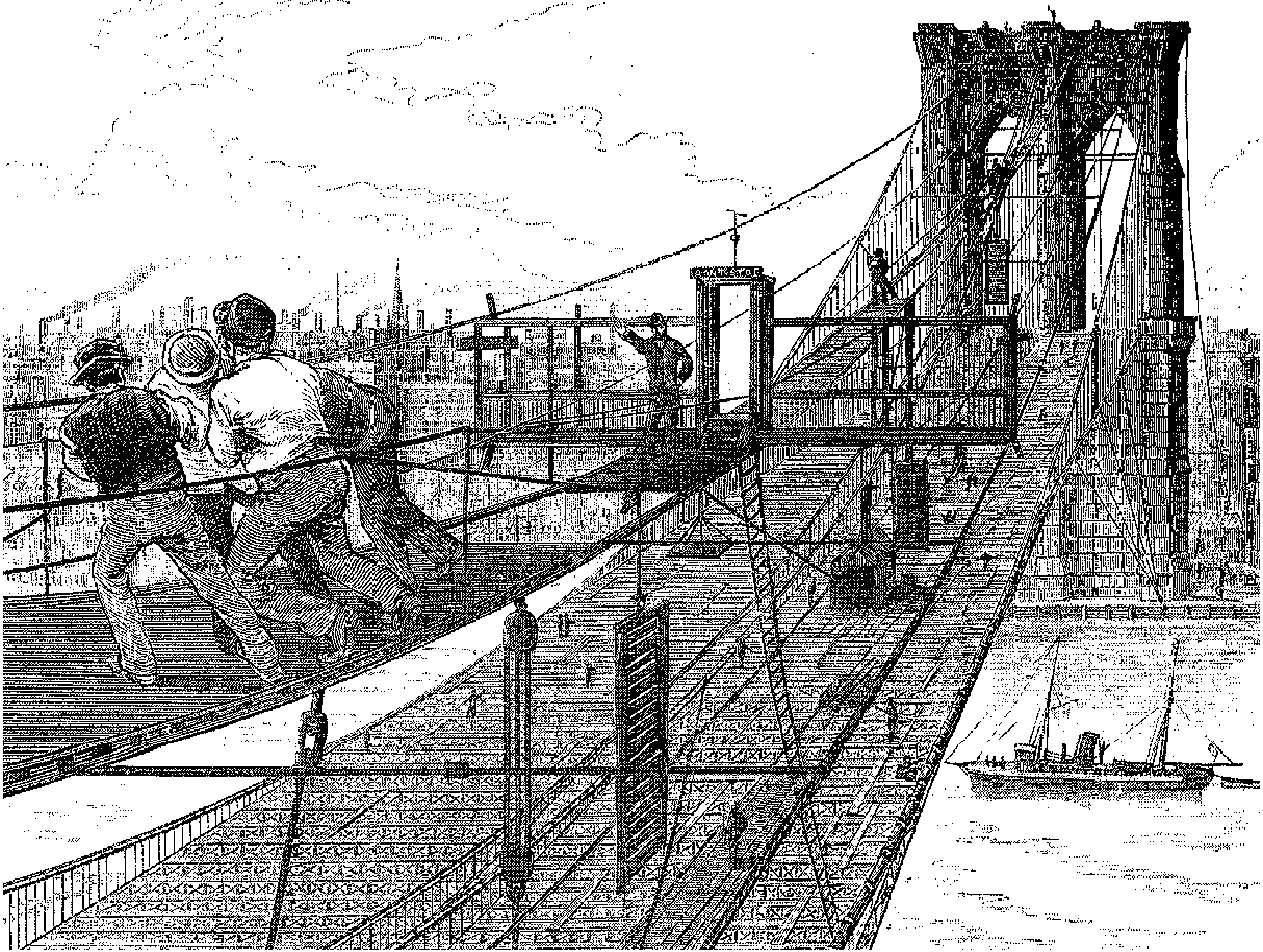
Newspaper Cartoon

Mocking the inability of the Bridge Company to complete the bridge due to a lack of deck trusses.

Deck trusses nearing mid-span



Deck Trusses complete

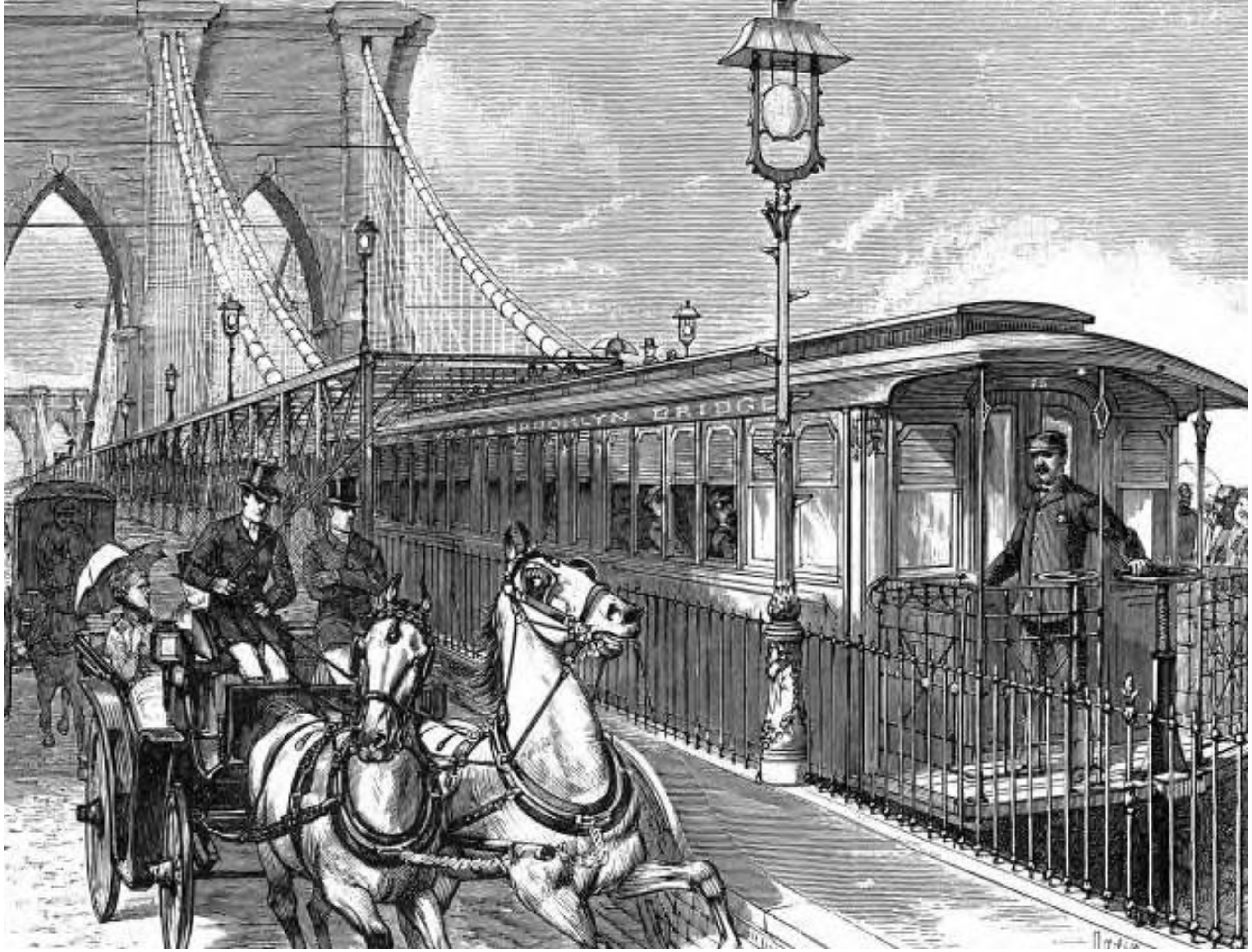


Footbridge removal

With the deck complete, the footbridge and cradles were removed

Build it and They Will Come

Crowds of pedestrians using the elevated promenade to get to work, go home or just to enjoy the view. A toll of $0.01 was the cost to a pedestrian when the bridge first opened.



Spooked Horse

It was fairly common for horses to be "spooked" by the trains that served the terminals at each end. It cost $0.10 for a horse and carriage, $0.05 for a horse and rider, $0.02 for sheep and hogs and $0.05 for cattle to cross the bridge.

A Splendid Suicide

"It is hardly necessary to point out to thoughtful men the splendor of a suicide committed from this virgin height."

***The Brooklyn Eagle*, 1877**

Mourners at Bridge Rail

The bridge attracted many "jumpers" intent on ending their life. Most often, the body would be taken out to sea in the strong six-knot tidal current of the East River. Jumping from a height of +100-feet into the river below has the same amount of force as a car hitting a brick wall at eighty mph (18K PSI). Few survived but, incredibly, some (even those who fell off the bridge accidentally) did.

Robert E. Odlum

On May 19, 1885, Odlum (a swimming instructor from Washington D.C.) wearing swim trunks and a bright red swim shirt, set out to be the first person to jump off the bridge and live to tell about it. He was the first fatality.

Steve Brodie

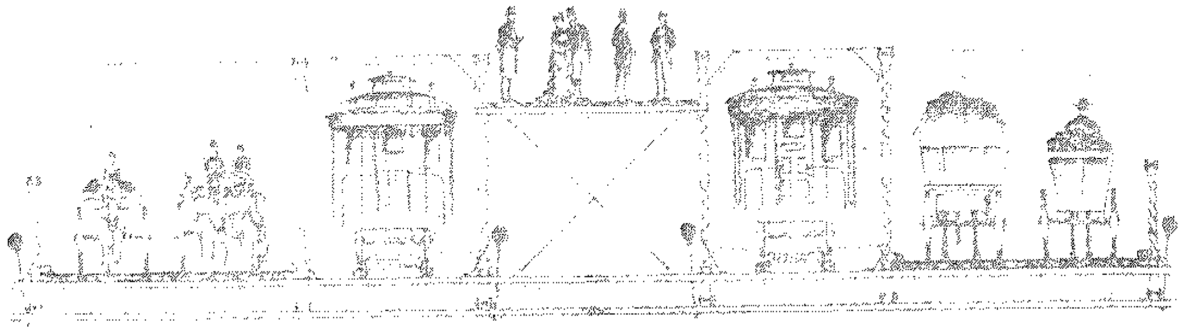
By far, the most famous – and controversial, “jumper” was an unemployed Irishman in his early 20s. To his Bowery buddies he announced he would jump off the bridge and live to tell the story. Many bets were placed for or against his survival. On June 23, 1886, Brodie was picked up in the river by a barge captain and his friends bore witness to his death-defying act. Whether he actually jumped or not is still debated. He was jailed briefly and became a celebrity. He then opened a bar and got rich. In 1894 a play entitled *On the Bowery* opened featuring Brodie’s jump set to music. He did die, eventually, of diabetes in 1903.

Horse and carriage ca. 1915

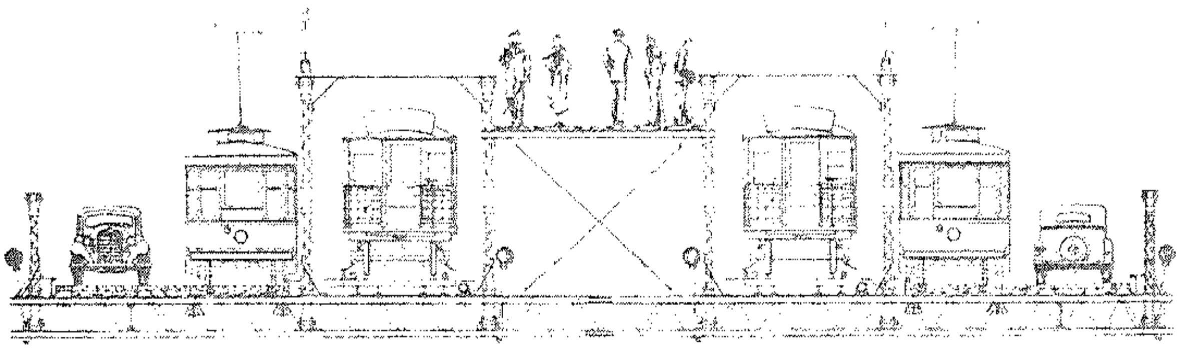
These horse-drawn carriages had the tendency to create ruts in the surface of the bridge deck. With the rise of the automobile and truck in the 1920s, the configuration of the road deck needed to be modified to accommodate increased vehicular traffic.

Dr. David Steinman

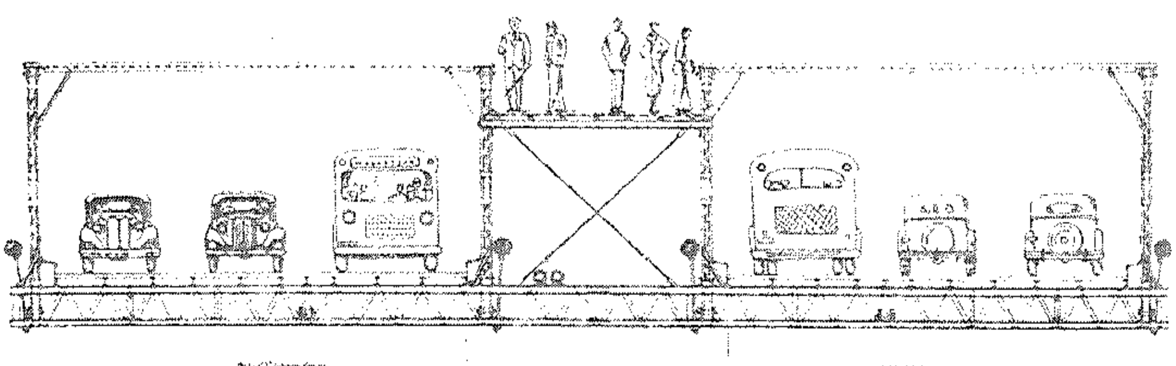
Having grown up on the lower east side, Steinman was in awe of the Roebling's achievement and set out to be a great bridge builder as well (he succeeded). In 1944, his firm was hired to do a comprehensive study of the bridge and to oversee the reconfiguration of the roadway.



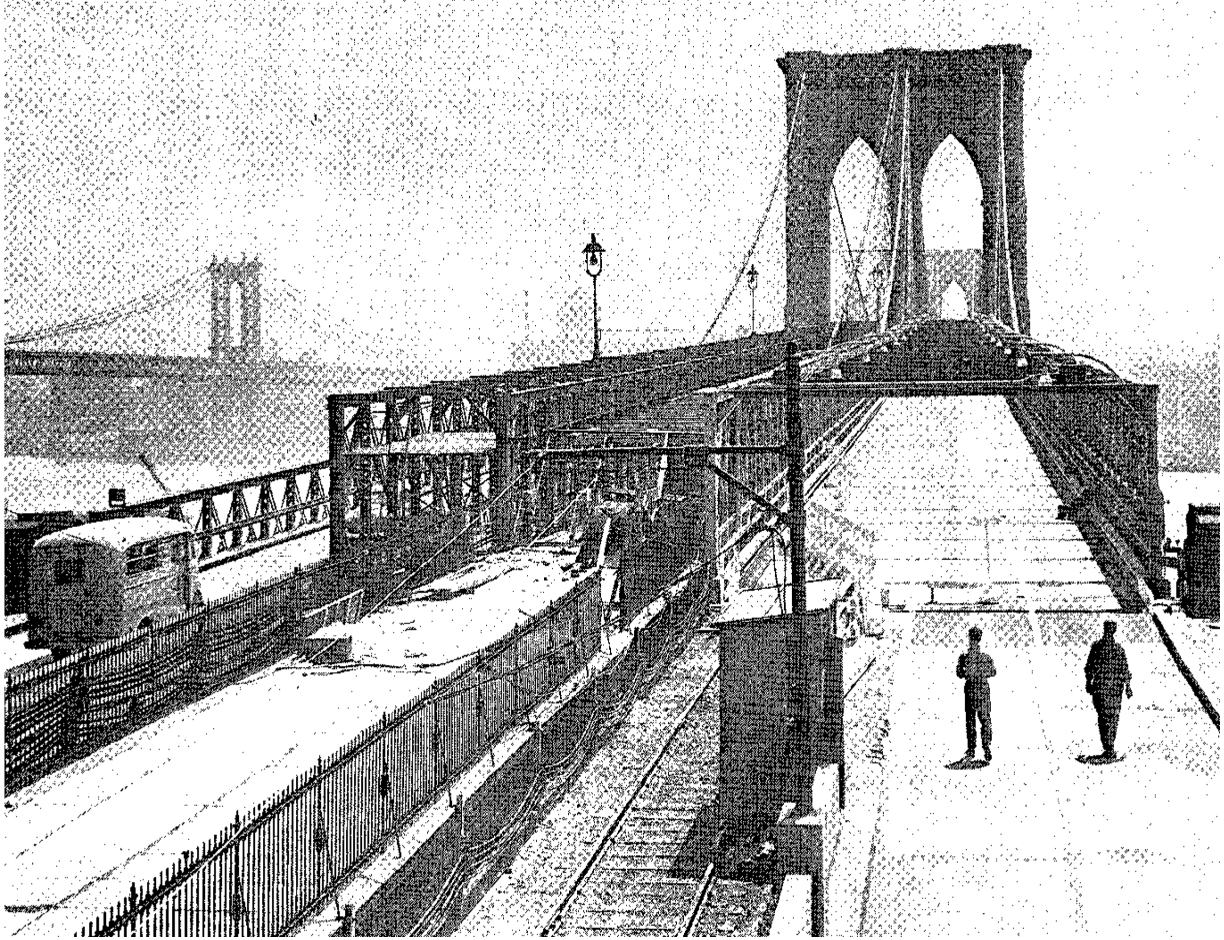
(a) Cross-section in 1883



(b) Cross-section 1898 to 1944



(c) Proposed cross-section



Reconfiguration Underway

The new roadway configuration would remove both train and trolley service from the two inner lanes and provide for three vehicle lanes (in each direction). This configuration remains in place today (with height and weight restrictions). Only the elevated promenade remains, essentially, unchanged.

Reconfiguration complete
(1954)

Present-day

(three vehicle lanes in each direction)


CITY OF NEW YORK
ROBERT F. WAGNER
MAYOR
HULAN E. JACK
PRESIDENT, BOROUGH OF MANHATTAN
JOHN CASHMORE
PRESIDENT, BOROUGH OF BROOKLYN
BROOKLYN BRIDGE RECONSTRUCTION
1954
DESIGN AND CONSTRUCTION SUPERVISED BY THE
DEPARTMENT OF PUBLIC WORKS
FREDERICK H. ZURMUHLEN, P.E., R.A.
COMMISSIONER
J. FRANK JOHNSON, P.E.
DIRECTOR, DIVISION OF BRIDGES
D. B. STEINMAN, P.E.
CONSULTING ENGINEER
KLEVENS CORPORATION, CONTRACTORS

Elevated Promenade

"The elevated promenade will allow people of leisure, and old and young invalids, to promenade over the bridge on fine days, in order to enjoy the beautiful views and the pure air. I need not state that in a crowded commercial city, such a promenade will be of incalculable value. Every stranger who visits the city will at least take one or two walks on this promenade, and the receipts of the Bridge Company from this source alone will be quite large."

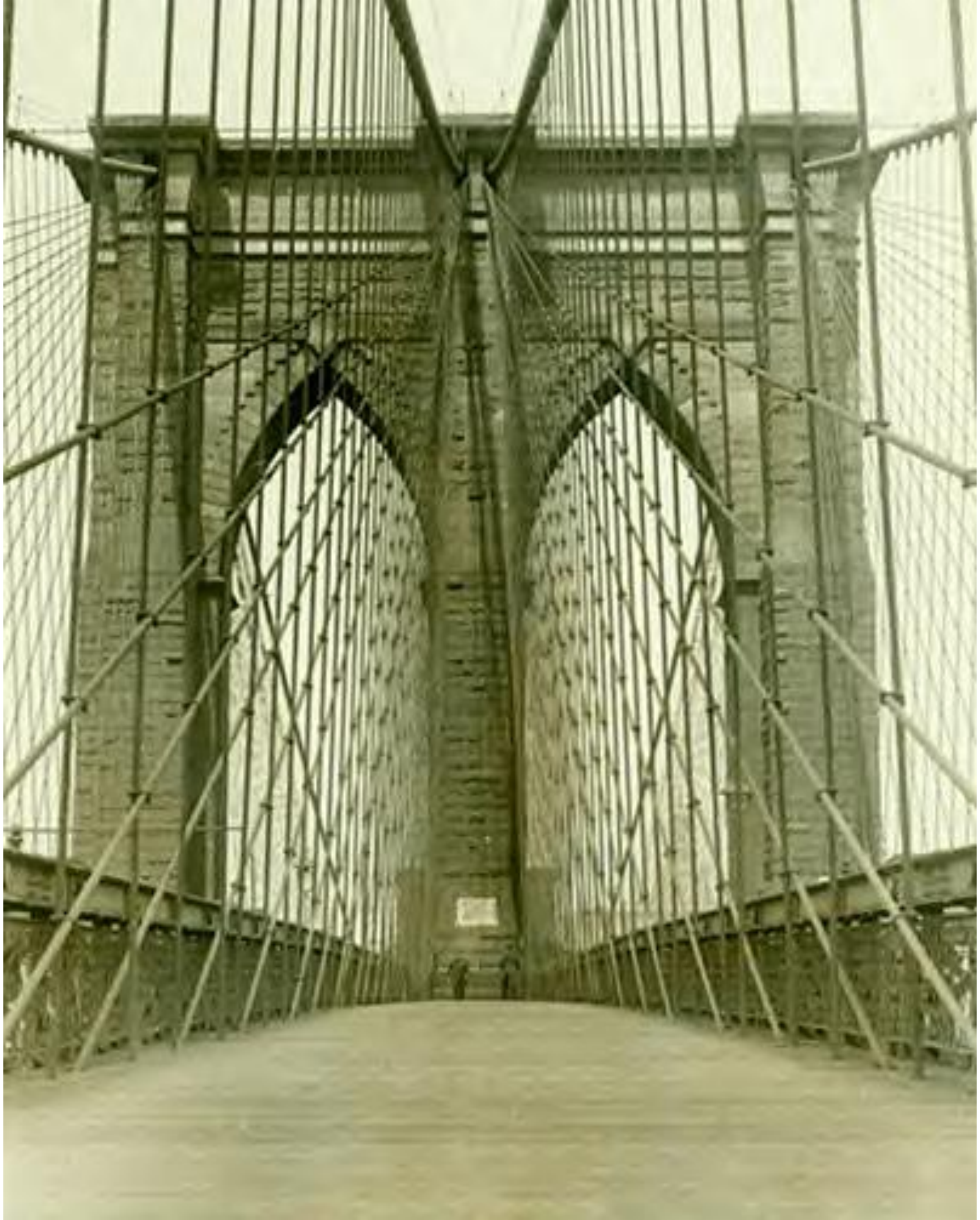
JAR, 1867

RE: excerpt from his report to the Bridge Company

"What a relief it will be from the ill-smelling streets and stuffy shops! What a happy escape from those dreadful cabins on ferryboats! What a grand place to stretch your legs of a bright winter's day after toiling through the streets! To go from shore to shore in one straight and jolly tramp, with the sky for a roof and the breeze for good company."

Anonymous, May, 1883 – RE: Bridge Promenade

Viewing Platform
(at Tower/s)




New York City

Part 20

Two Cities As One


"Two Cities As One"
NEW YORK
& BROOKLYN

The newly united cities of NY (left) and Brooklyn (right)
(birds-eye view)

"When I consented to make this change, it was not so much owing to personal solicitation as to the reflection 'of what benefit had it been to erect this bridge at a vast expense unless we use it for every possible purpose to which the structure will lend itself.'"

Washington Roebling, January 9, 1882 – excerpt of letter to B of T concerning additional bracing to allow locomotives to use the bridge in the future

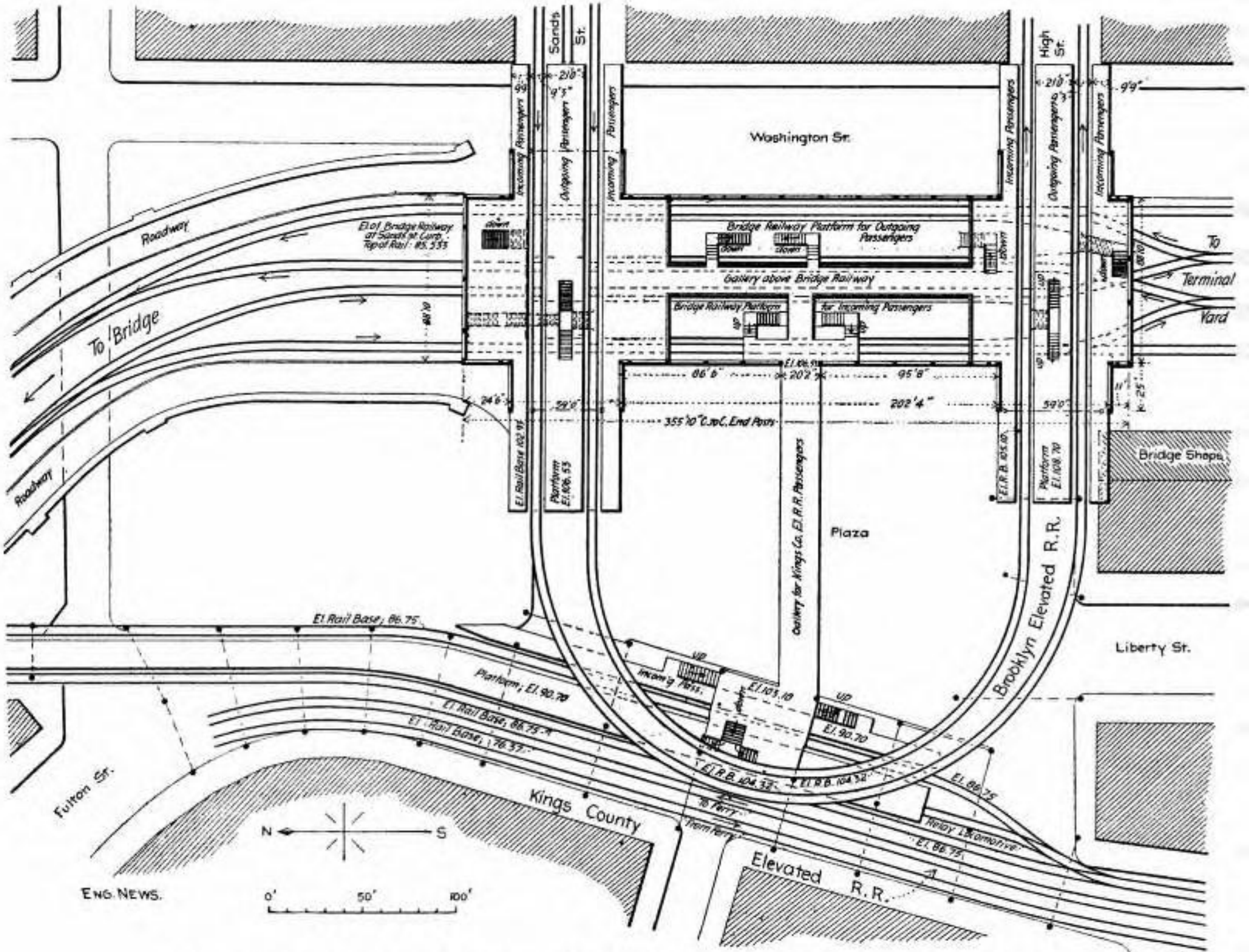


FIG. 9. PLAN OF BRIDGE AND ELEVATED RAILWAY TERMINALS.

(Brooklyn Terminal)

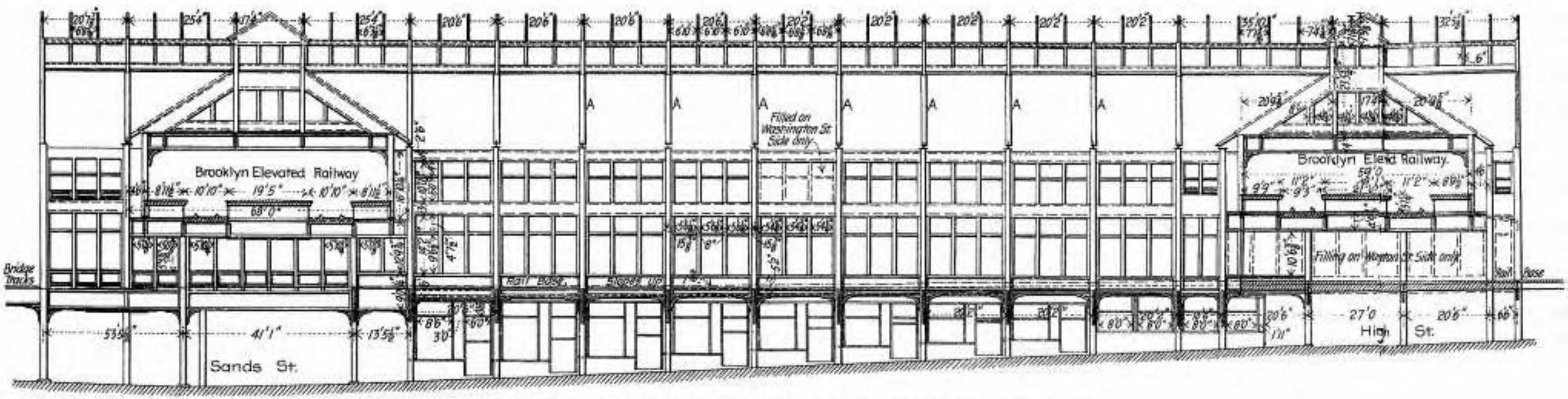


FIG. 1. ELEVATION OF FRAMING OF STATION ON FULTON ST. SIDE.

(Brooklyn Terminal)

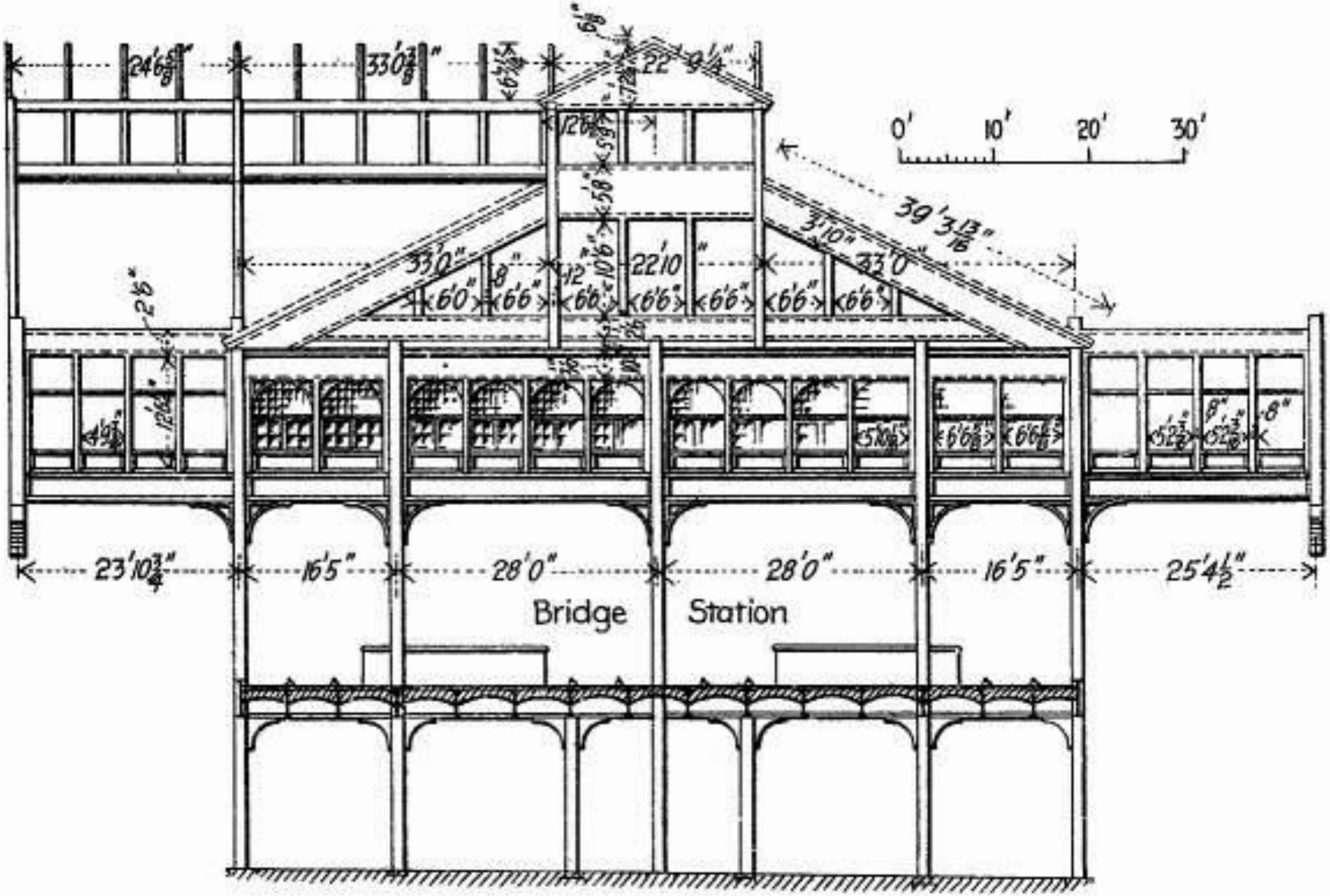
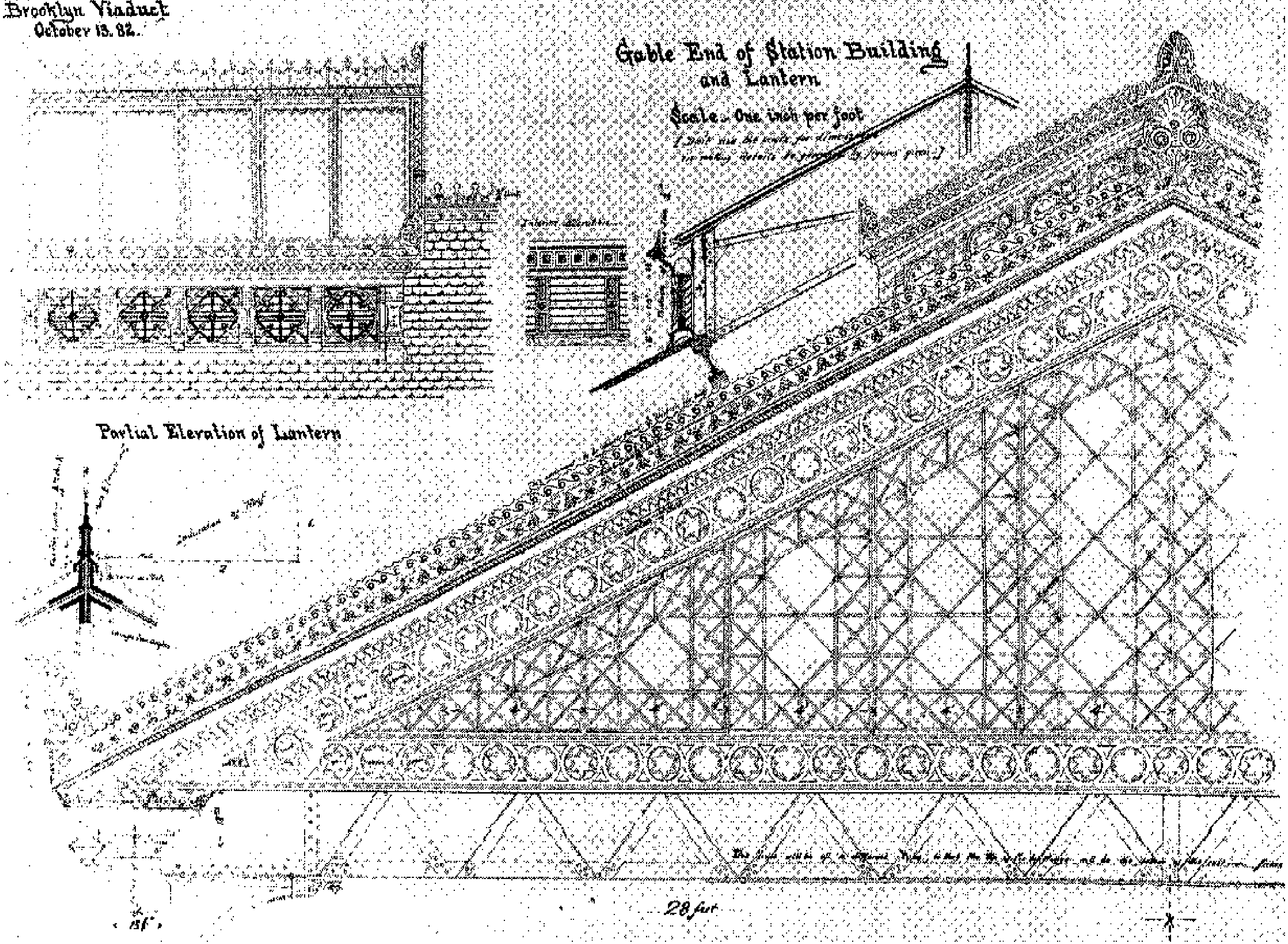


FIG. 2. ELEVATION AND SECTION AT SANDS ST. END OF STATION.

(Brooklyn Terminal)

Brooklyn Terminal

The terminals were very ornate and painted a dark shade of red. Access was similar to the elevated subway lines (via stairs). WAR was intimately involved with the design of the terminals and oversaw every detail (it occupied most of his time).



Detail Drawing
(Brooklyn Terminal)

With the decision taken to include train service on the bridge, in October 1881 WAR ordered 1K-tons of steel to stiffen the deck sufficiently enough to support the weight of heavy trains. Tank engines were used to pull the trains and the tracks were placed as close to the center of the bridge as possible to reduce torsion. WAR also insisted that the trains run on an exact schedule whereby trains left terminals simultaneously and traveled at the same speed to cancel out any distortion to the bridge deck due to torsion.

NY Terminal

The tall building in the background is Joseph Pulitzer's *World* building. Though the bridge's limited train service survived the arrival of the NYC subway system (in 1904), it ended in 1944 with the re-configuration of the road deck. It was fortunate that bracing was installed to support the additional weight of trains, it would have been required to support the live load of modern vehicular traffic that the bridge carries every day.

1898 to 1944

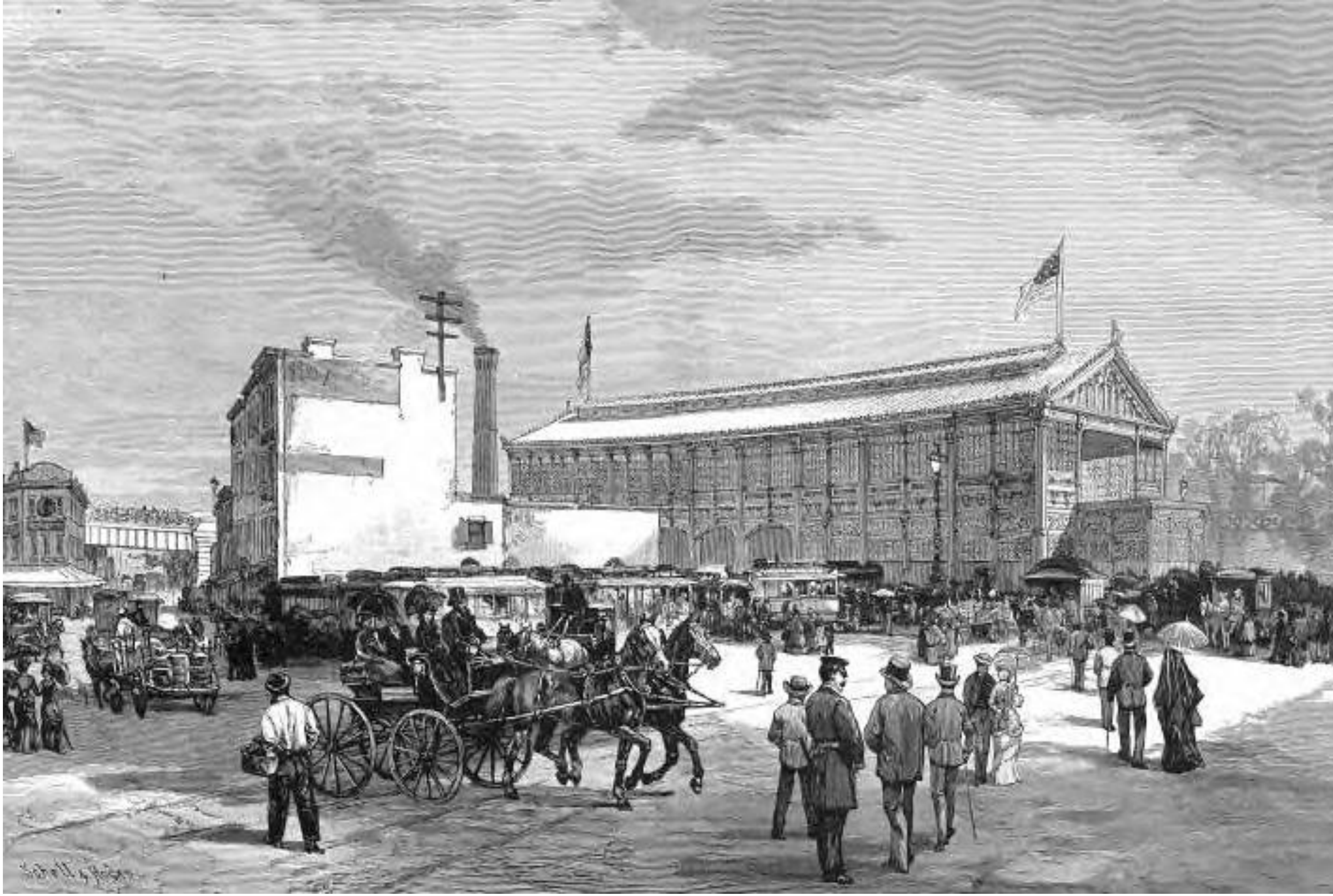
The first reconfiguration of the bridge deck (in 1898) converted the center lane from vehicular traffic to trolley service over the bridge. It limited the vehicle (carriageway) traffic to only the outer lane/s in each direction (problematic when there was a break-down).

Trolley and Train service
(1898-1944)

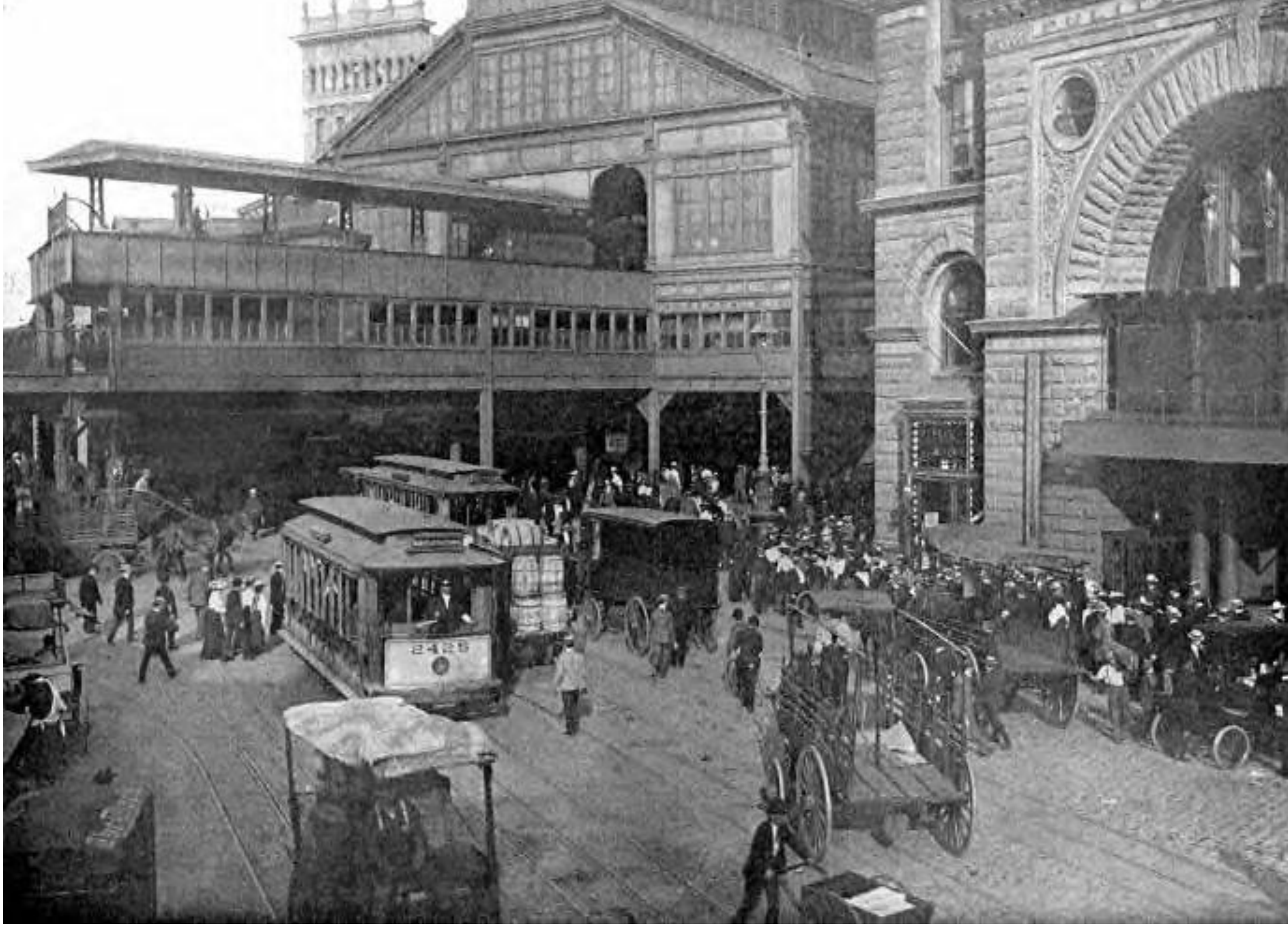
Tank Engine
(approaching terminal)

1883 to 1898

In this early newspaper drawing, the original Brooklyn terminal (at the base of the approach) is shown and the original road and rail deck configuration; two outer lanes (carriageways) for vehicular traffic and train service (inner lane/s - adjoining the elevated promenade) in each direction.



Brooklyn Terminal
(Powerhouse chimney visible)



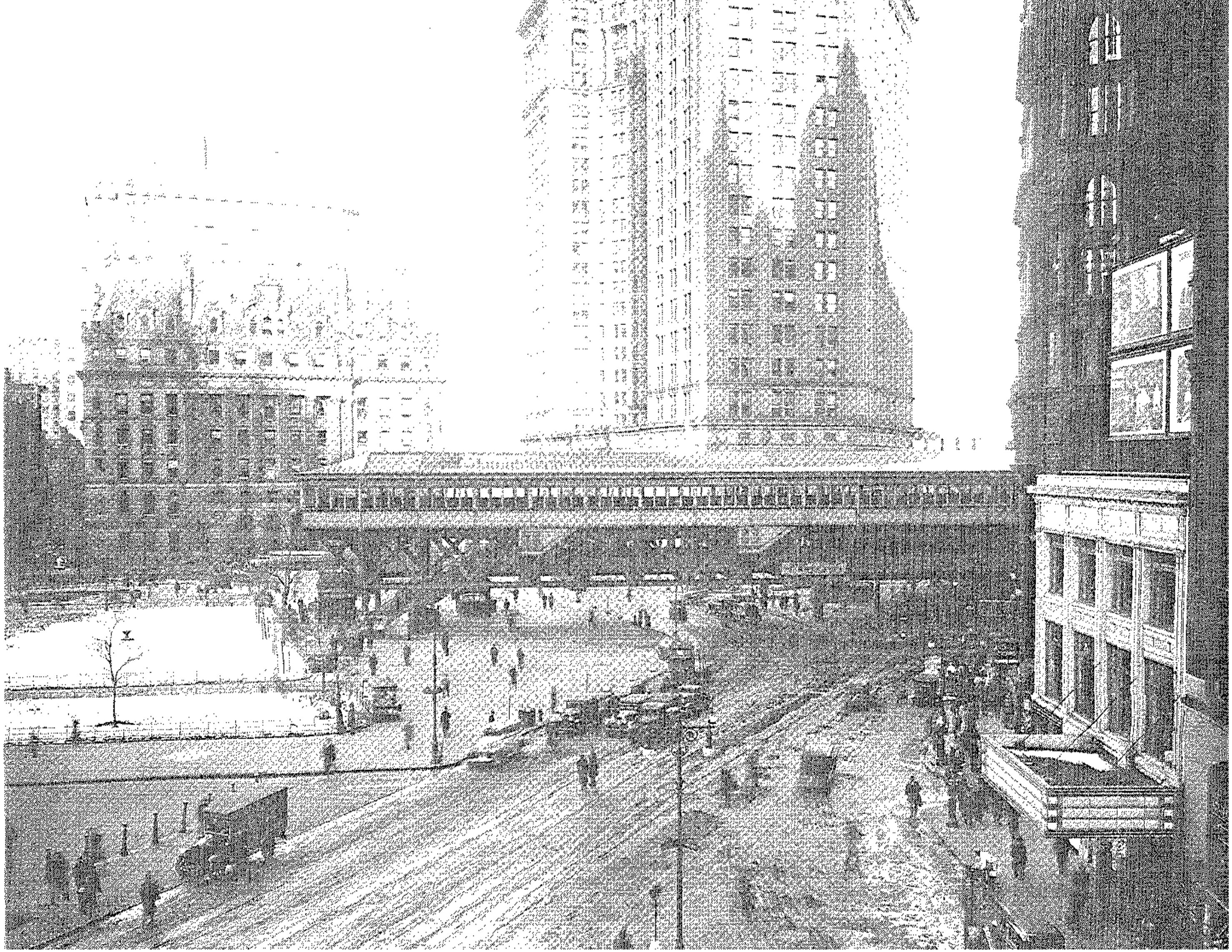
Extension of the NY Terminal over Park Row
(note “PULITZER” in the façade of the adjoining (*World*) building)

Park Row (ca. 1910)

NYC's version of London's *Fleet Street* (at the time). At center is the *Tribune* Tower/Building and Joseph Pulitzer's *World* Building. For a brief time, both claimed the title of world's tallest building. Park Row is situated across from *City Hall Park* (in foreground). In 1954, the World Building was demolished to make way for a ramp onto the Brooklyn Bridge.

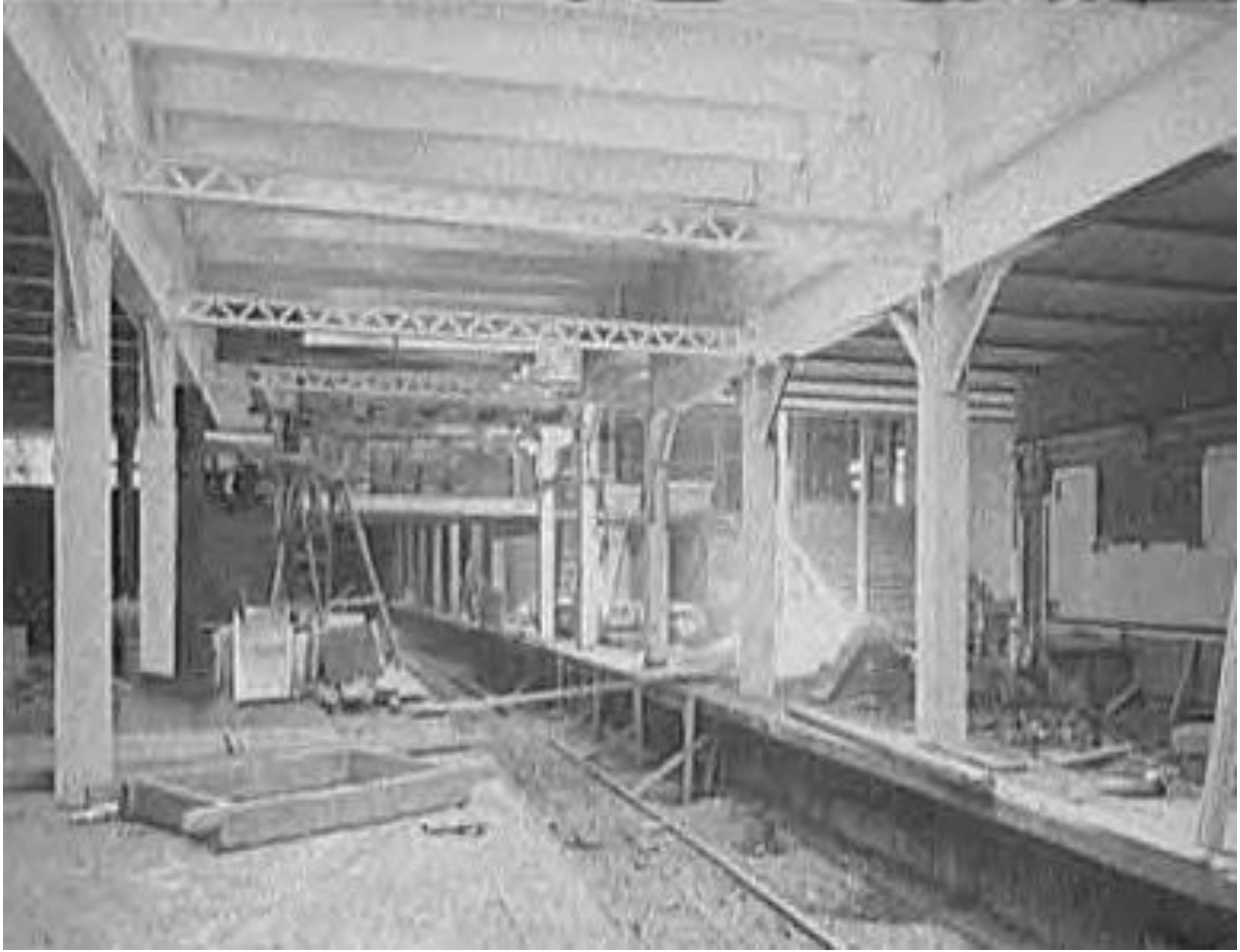
Park Row Extension

NY Terminal (left) and Tribune Tower (right), ca. 1883
(Pulitzer's *World* Building was completed in 1890)



Further extension of the NY Terminal into *City Hall Park*
(the tall building behind the terminal is the *Municipal Building* at One Centre Street (1915)

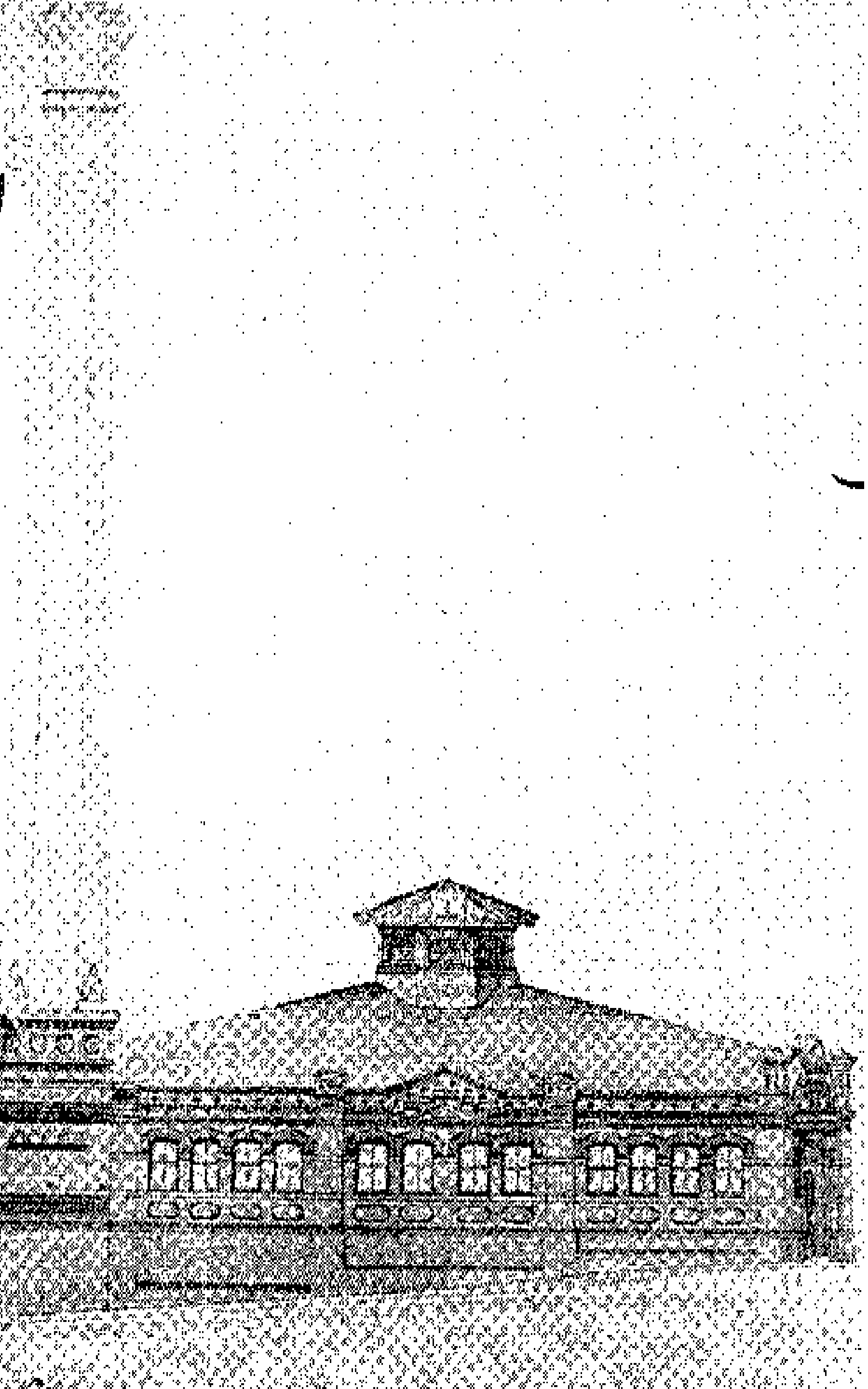
Rush Hour
(NY Terminal)



NYC *Brooklyn Bridge* Subway Station

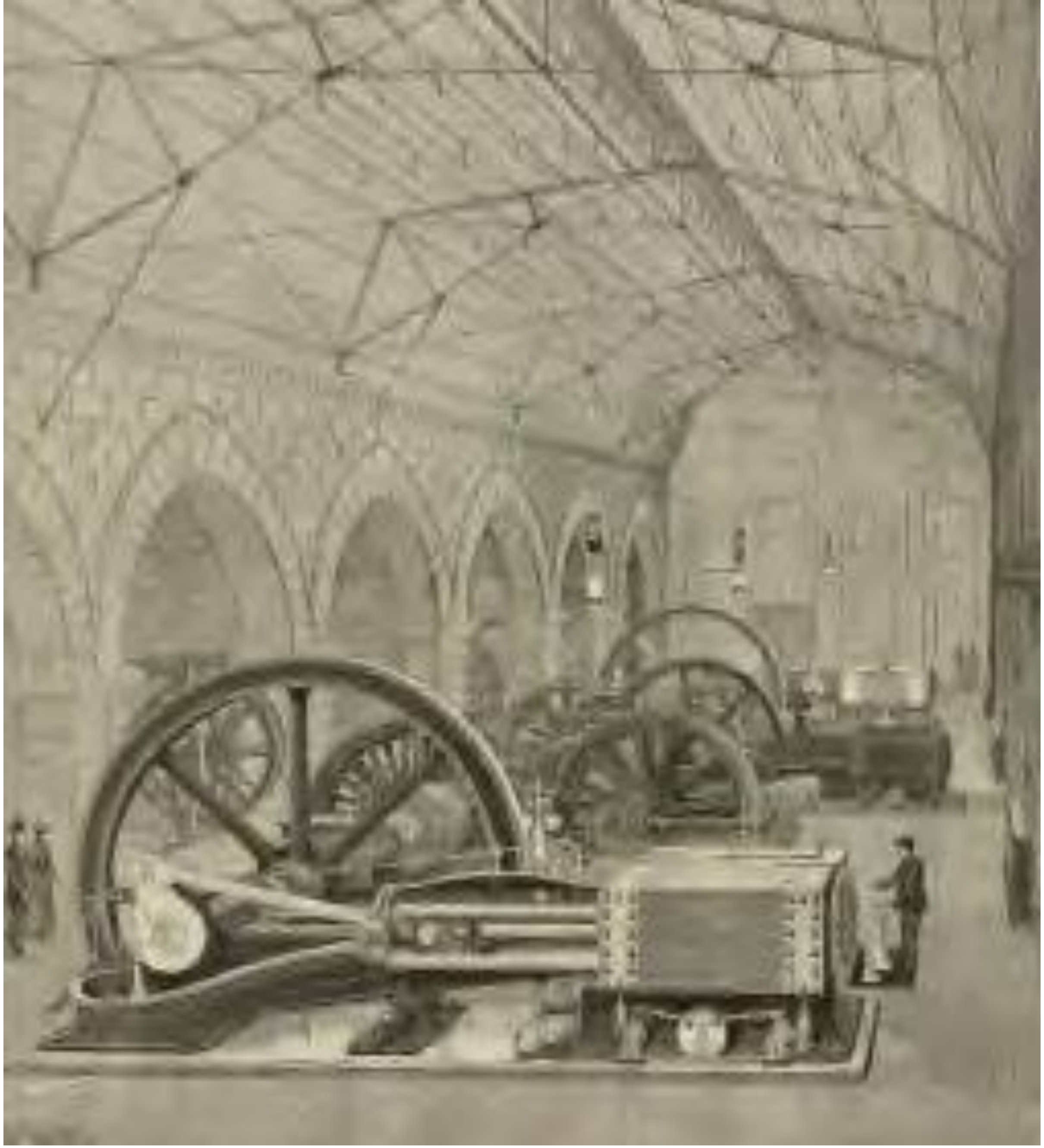
(under construction ca. 1904)

Tile from the Brooklyn Bridge subway station

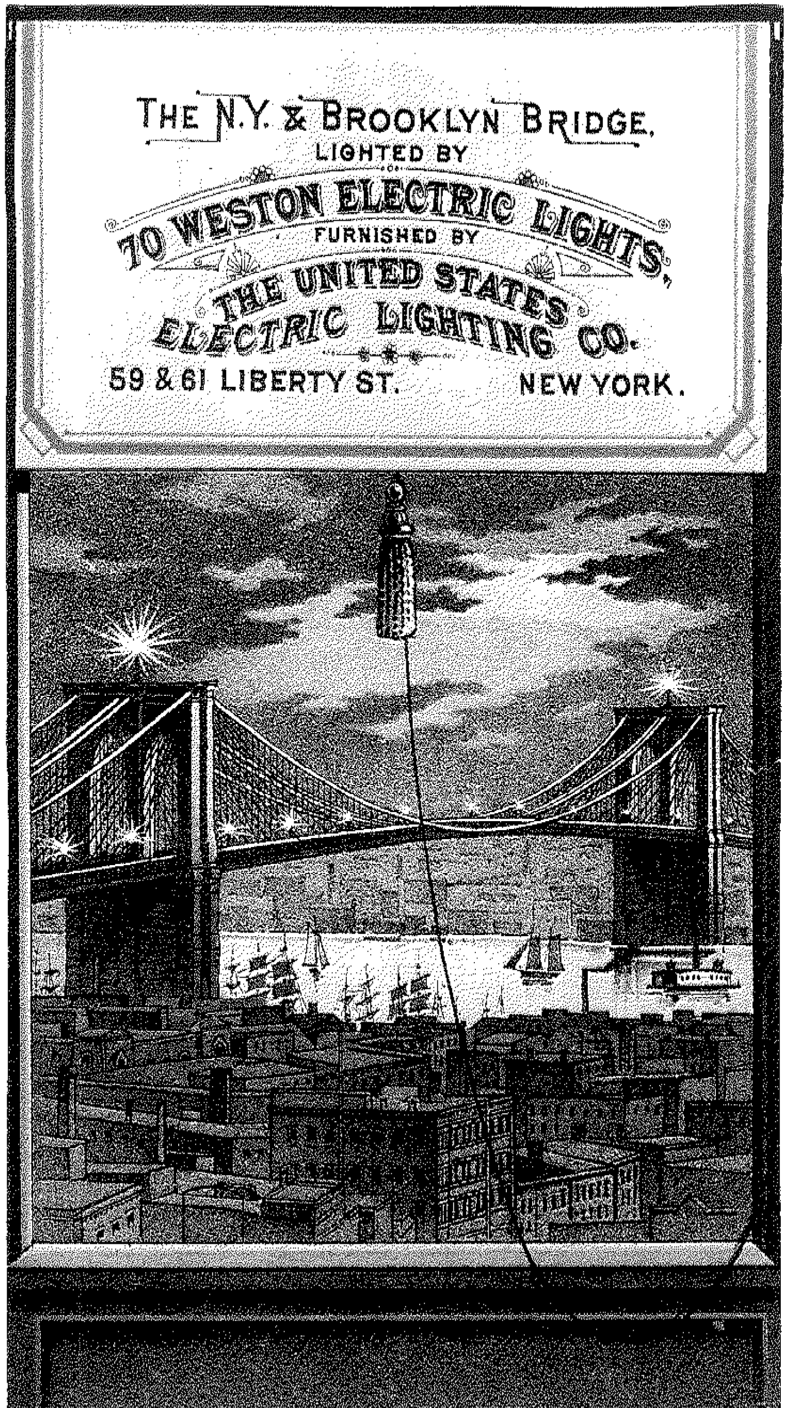


Brooklyn Powerhouse

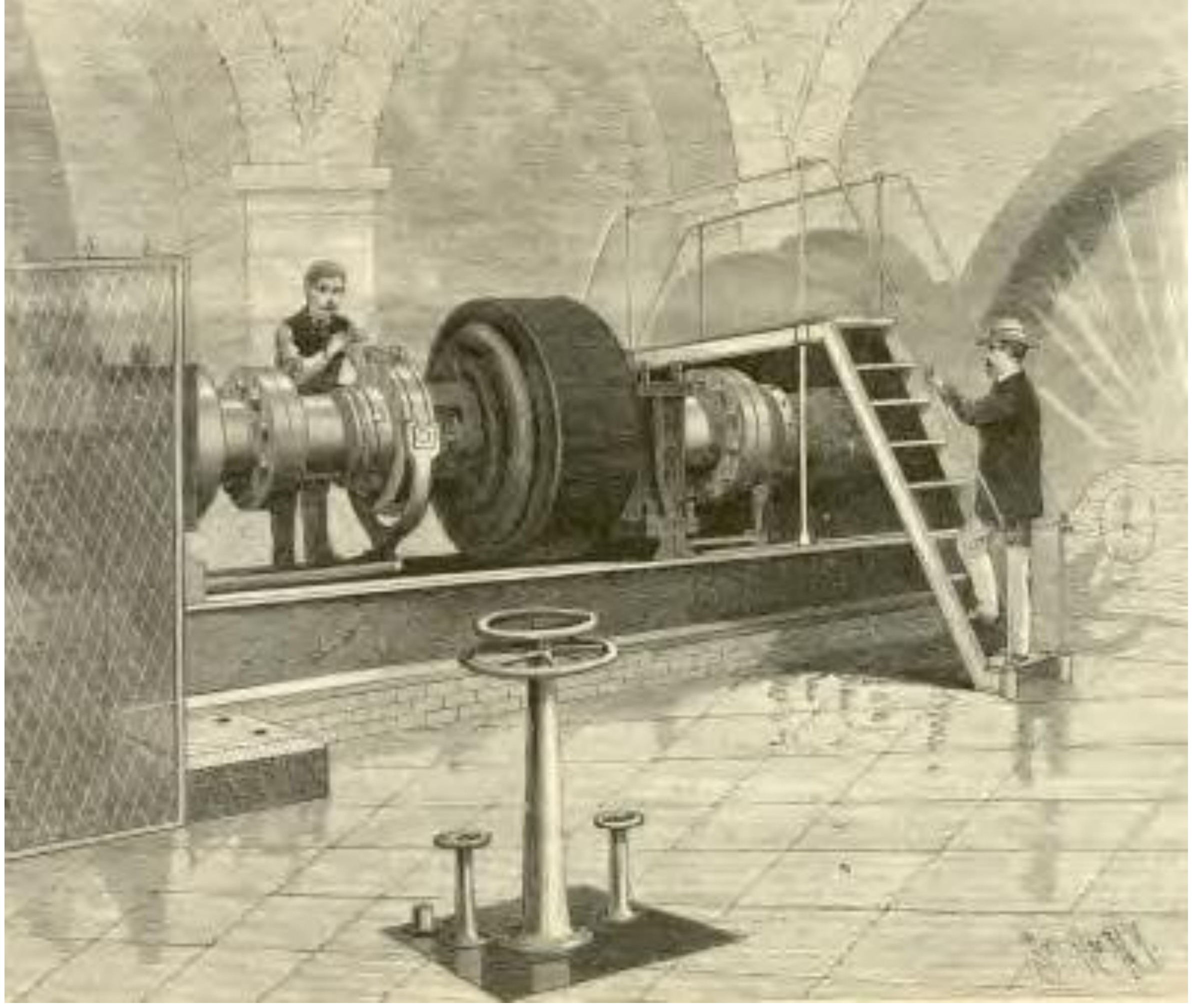
The dynamos used to power the electric lamps of the bridge were located in this building. The Brooklyn Bridge was the first bridge to be lit with electric lights (Thomas Edison lost the contract to a competitor whose light bulbs offered a more diffuse light). The only design requirements imposed on JAR by the Bridge Company were that the bridge be illuminated at night, have a substantial railing (at its perimeter) and be finished by a certain date in 1867, all else was by his determination (save for the *Army Corps of Engineers*).



Powerhouse Dynamos



THE N.Y. & BROOKLYN BRIDGE,
LIGHTED BY
"70 WESTON ELECTRIC LIGHTS,"
FURNISHED BY
THE UNITED STATES
ELECTRIC LIGHTING CO.
59 & 61 LIBERTY ST.
NEW YORK.



Friction Clutch

Colonel Paine was instrumental in designing an accurate wire testing apparatus and, also, the major components of the cable-car drive system for the Brooklyn Bridge. He would later go to San Francisco to help create their cable-car system.

Fulton Ferry Terminal

Despite the success of the Brooklyn Bridge, it did not put the ferry service out of business. In fact, it was thriving due to heavy use of the bridge, public fears and apprehension about it's safety and the pre-bridge daily commuter's preference for the familiar. Ferry service extended well into the 20th century and would have remained save for the building of additional East River bridges and tunnels and the expansion of the NYC subway system.

A choice of bridge or ferry service to/from Brooklyn

On-going ferry service
(20th century)

Present-day Ferry Building

Part 21

The Second Oldest Profession

"The best way to secure rapid and effective work is to get a new Chief Engineer"

New York Star

"Man is after all a very finite being in his capacities and powers of doing actual work, but when it comes to planning, one mind can in a few hours think out enough work to keep a thousand men employed for years…Continuing to work has been with me a matter of pride and honor! You must trust me in so far that the moment I am unable to do full justice to my duties as Chief Engineer, I shall give you ample warning"

WAR – November 1876

RE: Excerpts from a letter to the Board of Trustees concerning their hiring of a "consulting engineer" (to look over his shoulder), he resented this greatly

"All of which is bosh...We have as much sympathy for Mr. Roebling as other people...But, we submit, that the work is entirely superior to any man or all of the men concerned in its construction, and it cannot, nor any part of it, be subordinated to the whims, fancies, or caprices of a sick man."

Brooklyn Union & Argus, 1877

"...We declare the great East River Bridge in peril, because it has no head, because its wires of control run into somebody's closely guarded sickroom, because it is certain that a sick depressed tone runs through all its engineering discussions, from this cause... The sooner we have a live, active chief engineer in full powers on the bridge work, the better the public of two cities will be pleased with the prospect."

***The Union*, January 18, 1877 – editorial excerpt attacking WAR**

Steinmetz: ***"I represent the people of Brooklyn"***

Kingsley: ***"You represent nobody"***

Steinmetz: ***"You are no gentleman"***

Kingsley: ***"You are a blackguard"***

Steinmetz: ***"I am Comptroller and I represent the citizens of Brooklyn"***

Kingsley: ***"I say you represent nobody – nobody at all"***

Steinmetz: ***"I can afford to take that from you"***

Kingsley: ***"Of course you will"***

Board of Trustees Meeting, October 1881

RE: Angry exchange between W.C. Kingsley and Brooklyn Comptroller William Steinmetz. over Steinmetz' unfound and wild accusations against WAR's management of the bridge.

"I am convinced, that at every possible point there is a weakness in the management of the Brooklyn Bridge. The engineering part of the structure – the most important – is in the hands of a sick man."

Seth Low, Mayor of Brooklyn, August 22, 1882 – B of T meeting where he offered resolution to remove WAR as Chief Engineer

"...were so weak and childish he finally abandoned all attempt at argument and said, 'Mr. Roebling, I am going to remove you because it pleases me.'"

Washington Roebling, August, 1882 – excerpt from private notes on meeting with Mayor Seth Low of Brooklyn while in Newport

Brooklyn Mayor Seth Low

"I also think the work should be pushed, but I do not think it would be using Mr. Roebling justly to oust him from his position now that he is about to reap the full benefit of his labors. If he had been in any way guilty of delaying the bridge, I should be in favor of retiring him, but there is not a shadow of a charge upon which to base such action. In fact, Mr. Roebling has done much toward pushing the bridge along. Let us not act summarily toward him after his thirteen years of service. If someone will tell me how an engineer is going to build a bridge without material I shall be pleased. Mr. Roebling did not have the material and so he is made a scapegoat for others sins."

Ludwig Semler, Comptroller of Brooklyn, August, 22, 1882 B of T meeting

"…As you are a stranger to Mr. Roebling all that you said was doubly appreciated. There are some few old friends in the Board of Trustees who know him well and who have always stood by him in the many attacks that have been made on him in the past ten years, but we never expect such consideration and kindness from those who have never seen him."

Emily Roebling, August, 1882 – excerpt from letter to Ludwig Selmer

"…You want to remove him; to drive him out. For what? Why? As a bridgebuilder he has not had his equal on the face of the earth. I defy contradiction!…But our friend Mr. Low goes down to Newport and demands his resignation! By what authority? Have you any law for it? If you have I should like to see it. I should like to know by what parliamentary usages three or four represent the wishes of the board? I consider you are bringing an innocent man and holding him responsible for the delay and losses we have gone through here…"

William Marshall, September 11, 1882 – B of T meeting to vote on resolution to remove WAR as Chief Engineer – addressed directly to Mayor Low of Brooklyn, Mayor Chase of NY and Comptroller Campbell of NY

"If his intellect has been impaired, I should consider myself a happy man if I had what he lost. He spoke to me with clearness, and exhibited a memory which was something astonishing…He said that under no circumstances should he take any other position than Chief Engineer"

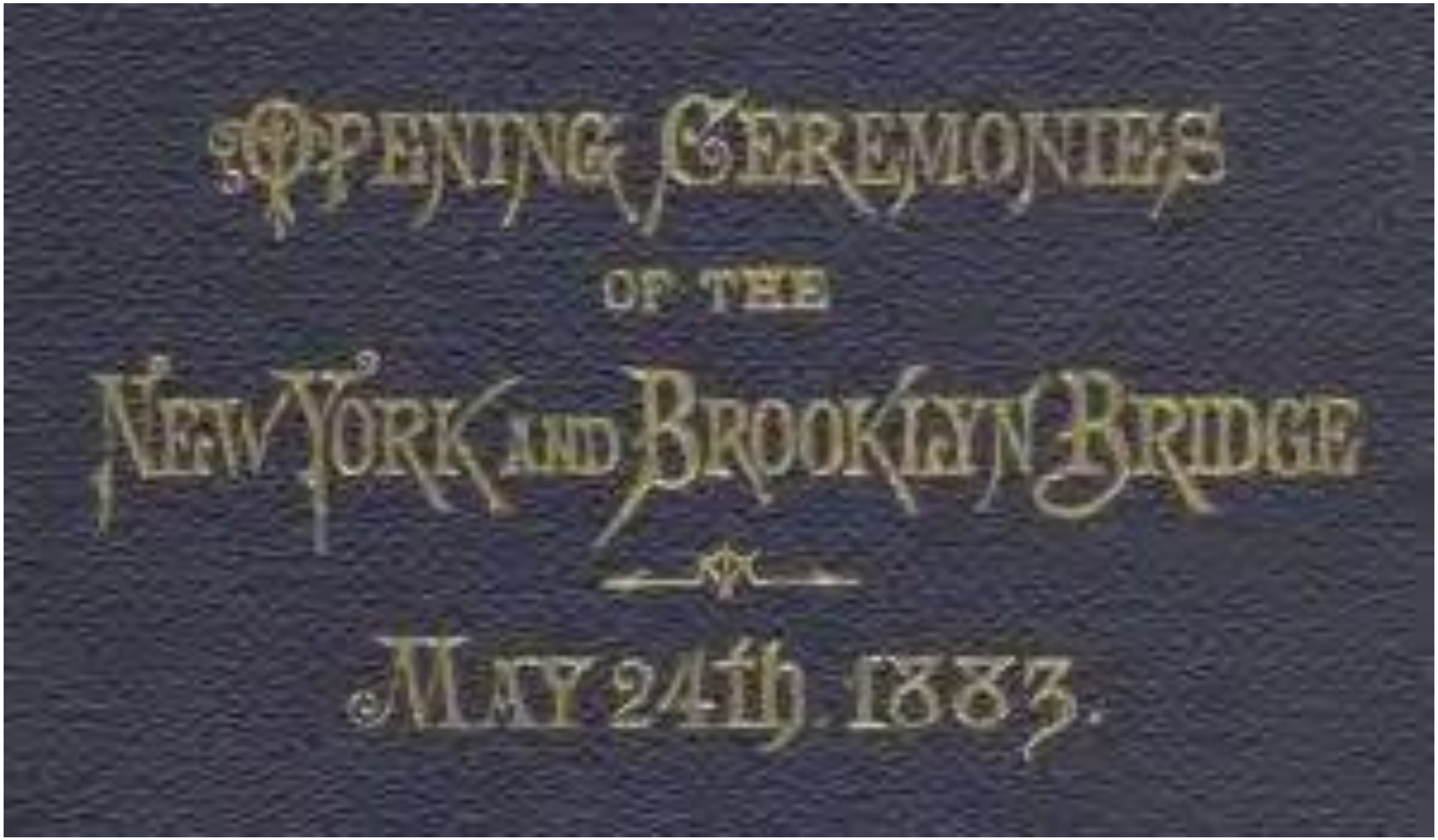
Ludwig Selmer, September 7, 1882 - RE: comments made at Board of Trustees meeting concerning his personal meeting with WAR

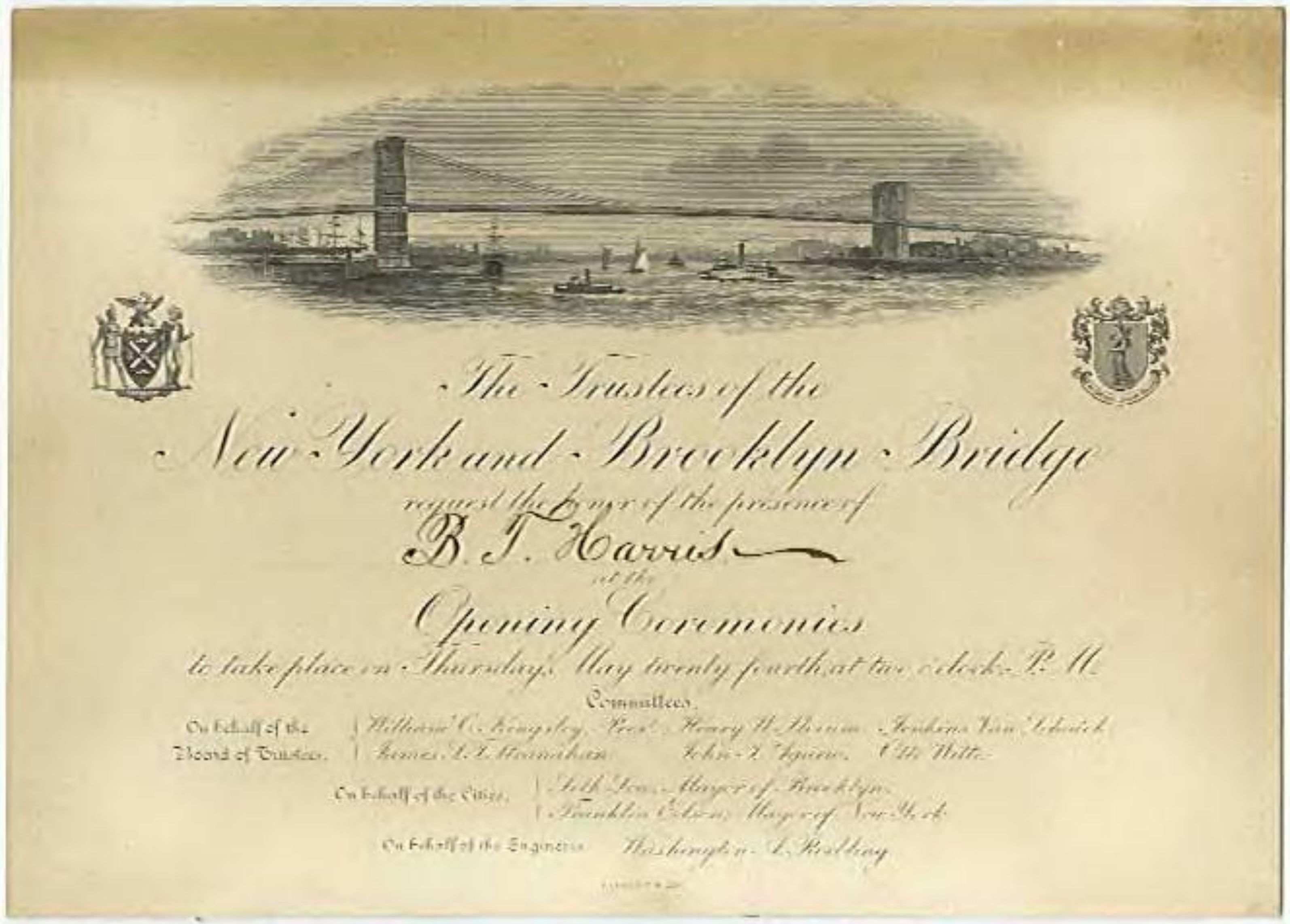
"I have over and over again been interviewed by the trustees who when they found themselves face to face with me and found me a live man and not the driveling idiot they had expected, had very few questions to ask and scarcely anything to say about the bridge in any way."

Washington Roebling, Summer, 1882

Part 22

The People's Day


Opening Ceremonies
of the
New York and Brooklyn Bridge
May 24th 1883.



The Trustees of the

New York and Brooklyn Bridge

request the honor of the presence of

B. T. Harris

at the

Opening Ceremonies

to take place on Thursday, May twenty fourth, at two o'clock P. M.

Committees.

On behalf of the Board of Trustees. | William C. Kingsley, Pres't. Henry W. Slocum. Jenkins Van Schaick. James S. T. Stranahan. John T. Agnew. Otto Witte.

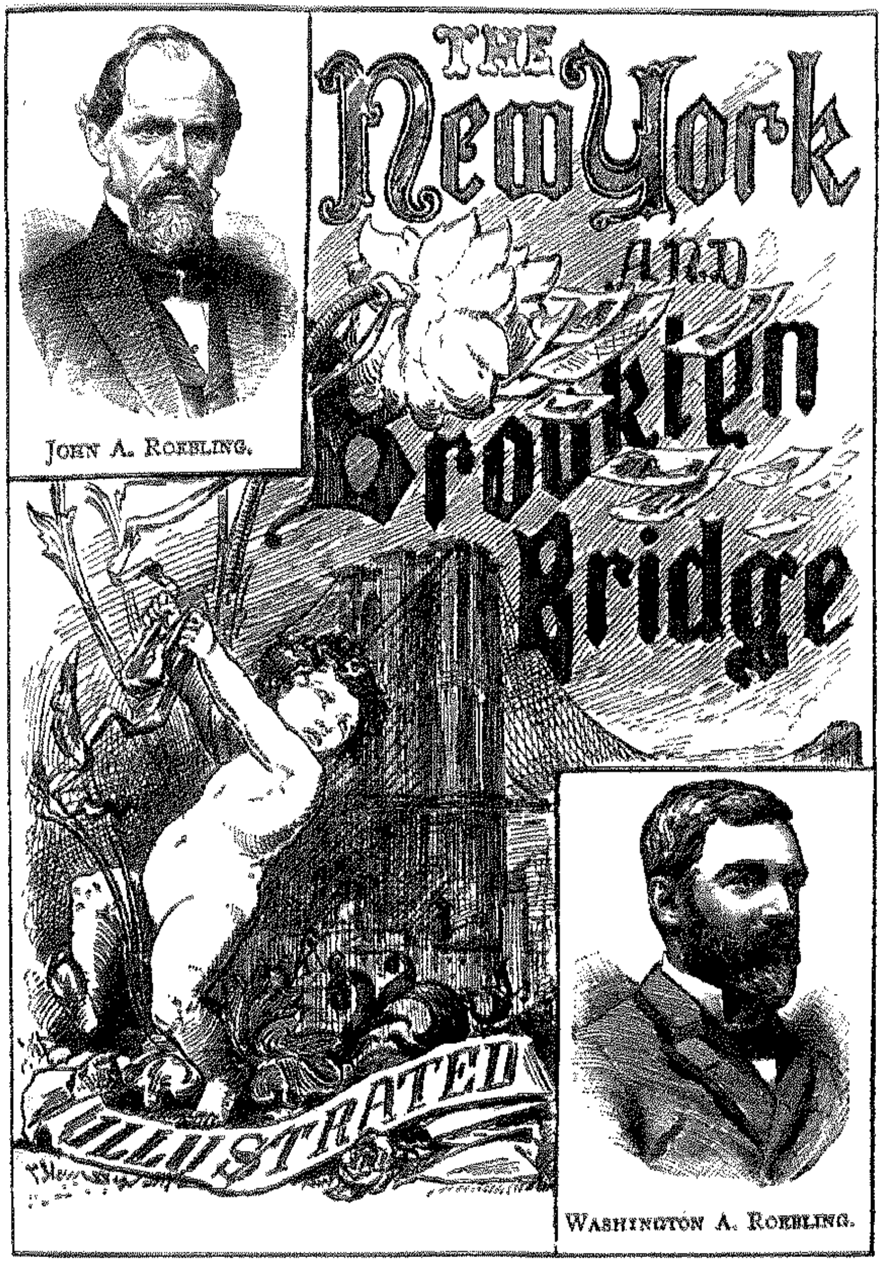
On behalf of the Cities. | Seth Low, Mayor of Brooklyn. Franklin Edson, Mayor of New York.

On behalf of the Engineers. Washington A. Roebling.

"At the clubs and other places where men gathered, the deceased was the general topic of conversation"

***The Brooklyn Eagle*, December 1882**

RE: The untimely death of Bridge Company President *Henry Cruse Murphy*, on December 1st 1882



Souvenir Booklet

Dynamite Patriots

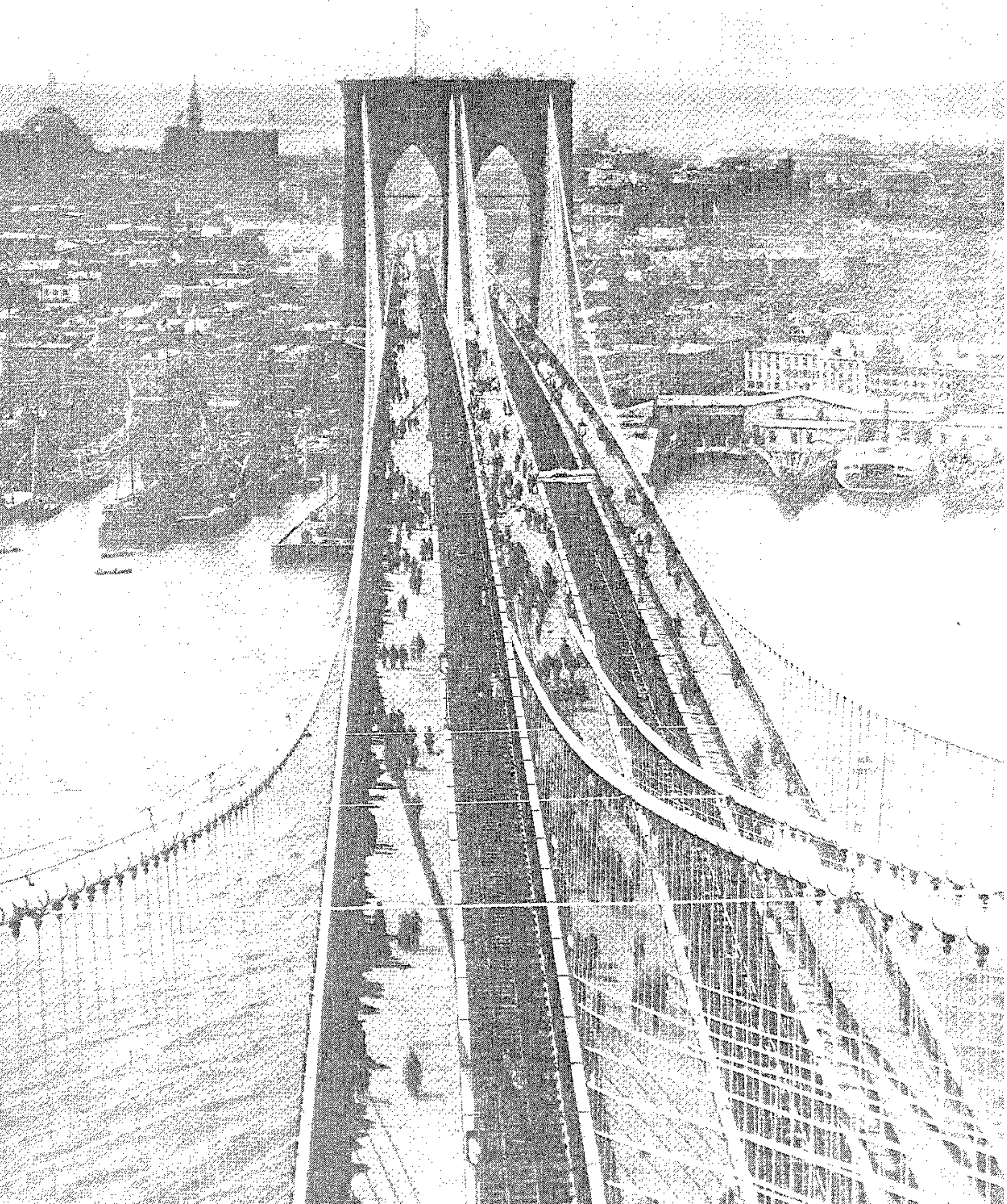
"all good men and women in both cities to remember this latest insult of the would-be aristocratic element in our midst."

Central Labor Union, 1883 - RE: May 24, 1883 celebrations of bridge opening coinciding with Queen Victoria's birthday

"it would be difficult, perhaps impossible, to fix upon a day that did not commemorate something or other unpleasant for Ireland."

***New York Tribune*, 1883 – RE: May 24, 1883 celebration of bridge opening coinciding with Queen Victoria's birthday**

Despite threats to blowup the bridge with dynamite (because the date selected for the opening insulted NY’s militant Irish), the day was a great success. It was filled with speeches by dignitaries, military bands and highlighted by President Chester A. Arthur’s walk across the bridge to the salute of an honor guard.



May 24th 1883

All four vehicle lanes (carriageways) and elevated promenade open to pedestrians. Not since the opening of the Erie Canal had NYC seen such an elaborate celebration. It was fondly remembered by the generations that witnessed the day's grand events.

President Chester A. Arthur walks across the bridge

Along with President Arthur, 150,300 people and 1,800 vehicles crossed the bridge on the first full day it was open. The following Sunday – May 27th 1883, 163,500 pedestrians went for a stroll on the elevated promenade.

"A fairer day for the ceremony could not have been chosen. The sky was cloudless, and the heat from the brightly shining sun was tempered by a cool breeze."

May 24, 1883 – "The People's Day"

Fireworks at night & the river filled with ships of all kinds

(May 24th 1883)

"A festival so unique New York has seldom seen…"
Harper's Weekly

"Hardly had the last falling spark died out, when the moon rose slowly over the further tower and sent a broad beam like a benediction across the river."

May, 24, 1883 - at the conclusion of the fireworks display

Calamity

Calamity on the Bridge

On Thursday, May 31st 1883 - just a week after the bridge opened, it was crowded with about 20K pedestrians off of work for the Memorial Day holiday. At about 4:00pm, two large groups of people (from opposing directions) met at the stair to the promenade (where the NY approach ends). A woman tripped and people started pushing then someone yelled that the bridge was collapsing. Panic set in and twelve people were trampled to death.

Stair where the calamity occurred

“That was my first view of a great calamity, I did not sleep for nights”

Alfred E.Smith

RE: Recalling in later years (as NY State Governor) the May 31st 1883 panic on the Brooklyn Bridge that he personally witnessed as a child

Calamity Aftermath

Part 23

The Man Who Outlived His Generation

Sinking of the Titanic, April 1912

Some people believe that WAR went down with the Titanic, but this is not so. One of his brothers had named his son in WAR's honor thus, it was WAR's nephew: *Washington A. Roebling II*, that did indeed die that faithful night.

"Oh no. This is his last as well as his greatest work. He will need a long rest after this is over. He needs it and he has certainly earned it."

Emily Roebling, May, 1883 - response to a reporter's inquiry as to whether WAR would soon be undertaking another great work

"...these relationships are those of the heart, not governed by reason or judgement. A second marriage late in life cannot be judged by the standard of the first because its motives are usually quite different."

Washington Roebling, 1908 – excerpt from letter to his son – JAR III, concerning his marriage to a young widow

"Soon I will be the last leaf on the tree."

Washington Roebling, 1908 – upon the death of Wilhelm Hildenbrand

"A little old soldier of 84, Colonel Washington A. Roebling, the man who built Brooklyn Bridge and the son of the man who planned it, is fighting today his last fight, is fighting to get his work done in spite of all his enemies – illness, debility, pain, loneliness, bereavement, the terrible depression of the man who has outlived his generation."

***New York World*, 1920 – upon WAR's taking charge of JAR&S at age 84 – after the death of his brothers earlier and sudden death of his nephew Karl Roebling**

Washington A. Roebling
1837 - 1926

Part 24

Icon

Culture

THE BRIDGE

A POEM

by

HART CRANE

~~With a Frontispiece from the Painting of Brooklyn Bridge~~
~~by JOSEPH STELLA~~

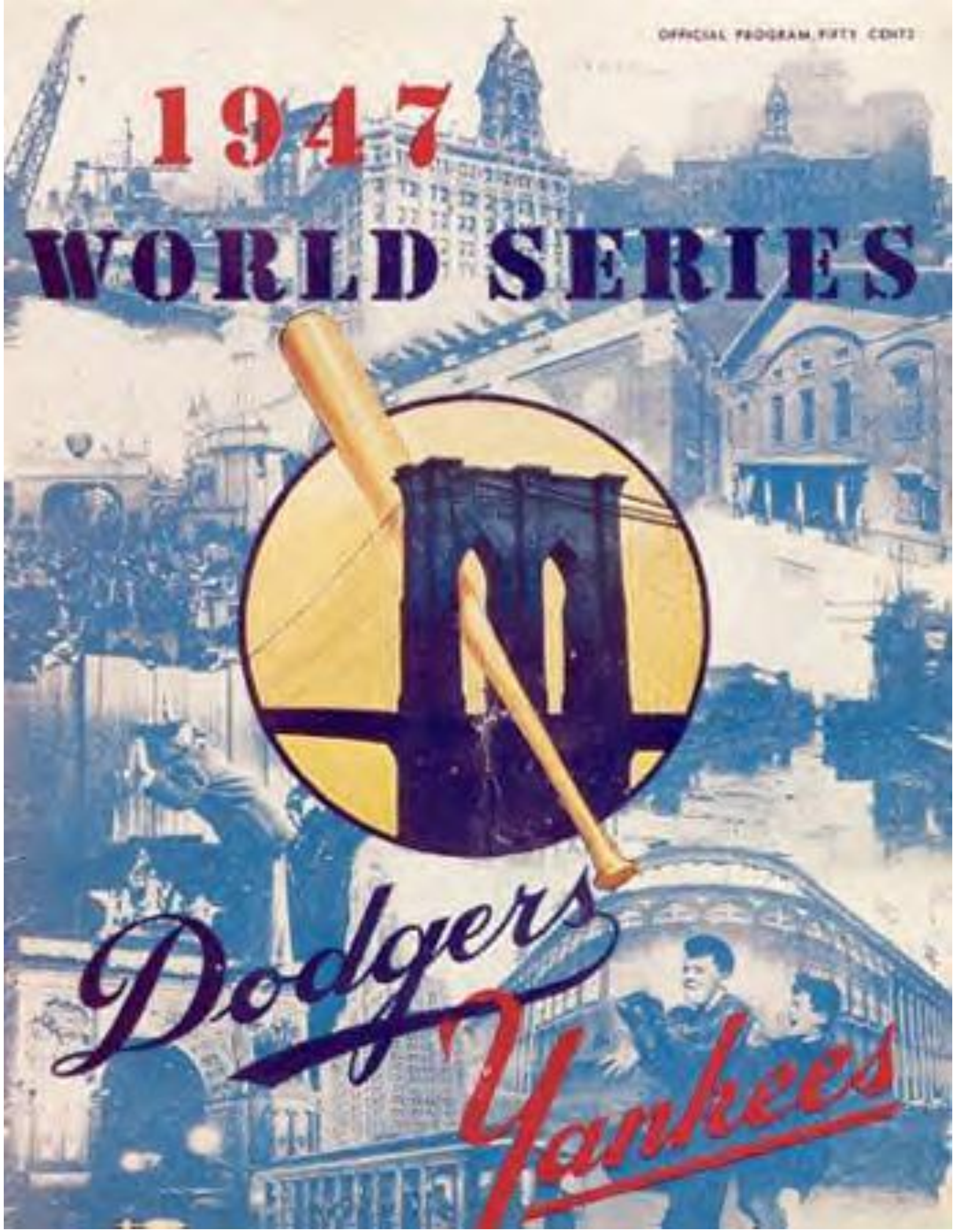
WITH THREE PHOTOGRAPHS BY
WALKER EVANS

The Black Sun Press
Rue Cardinale
Paris
MCMXXIX
XXX

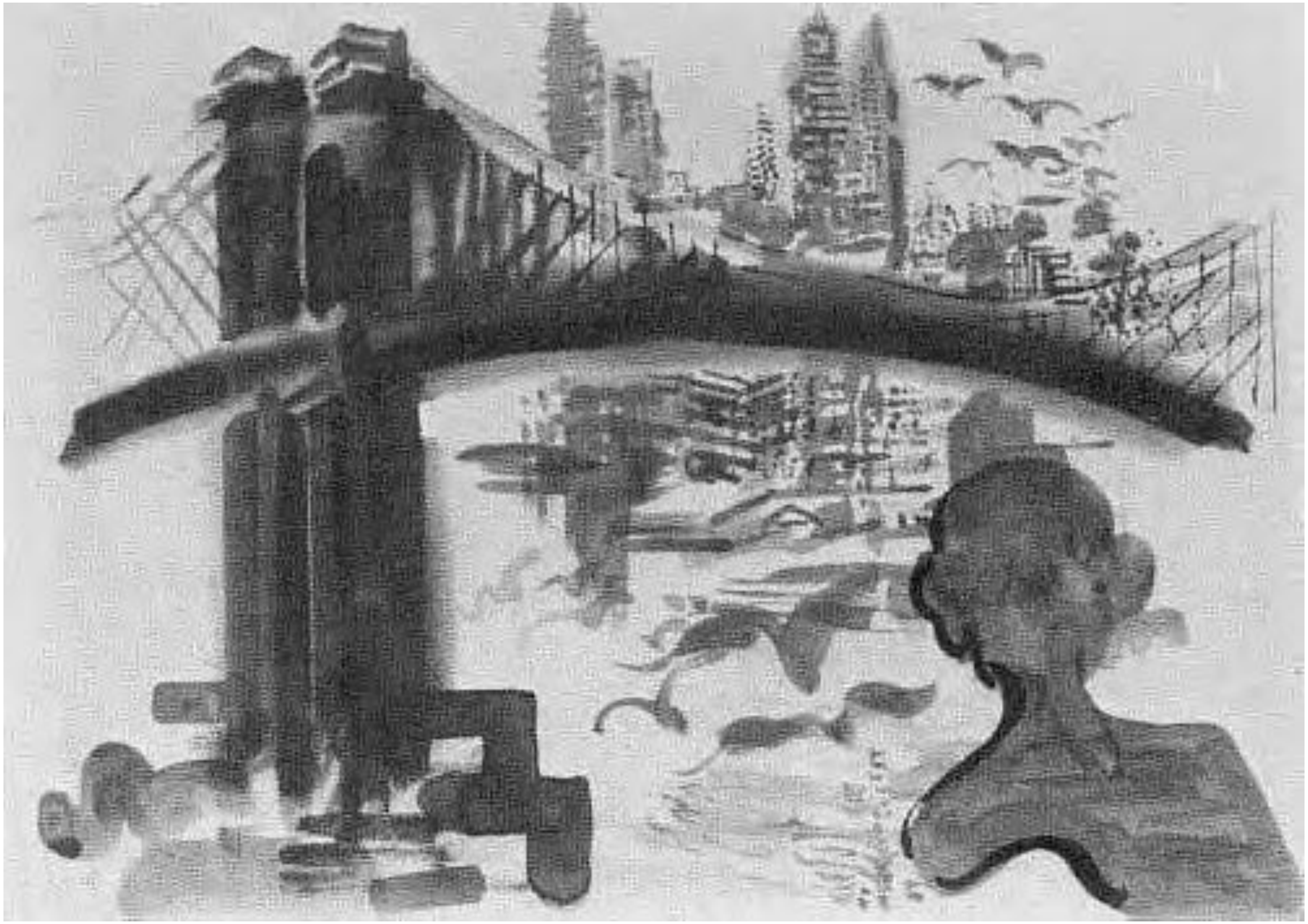

Johnny Maestro
and
The
Brooklyn
Bridge

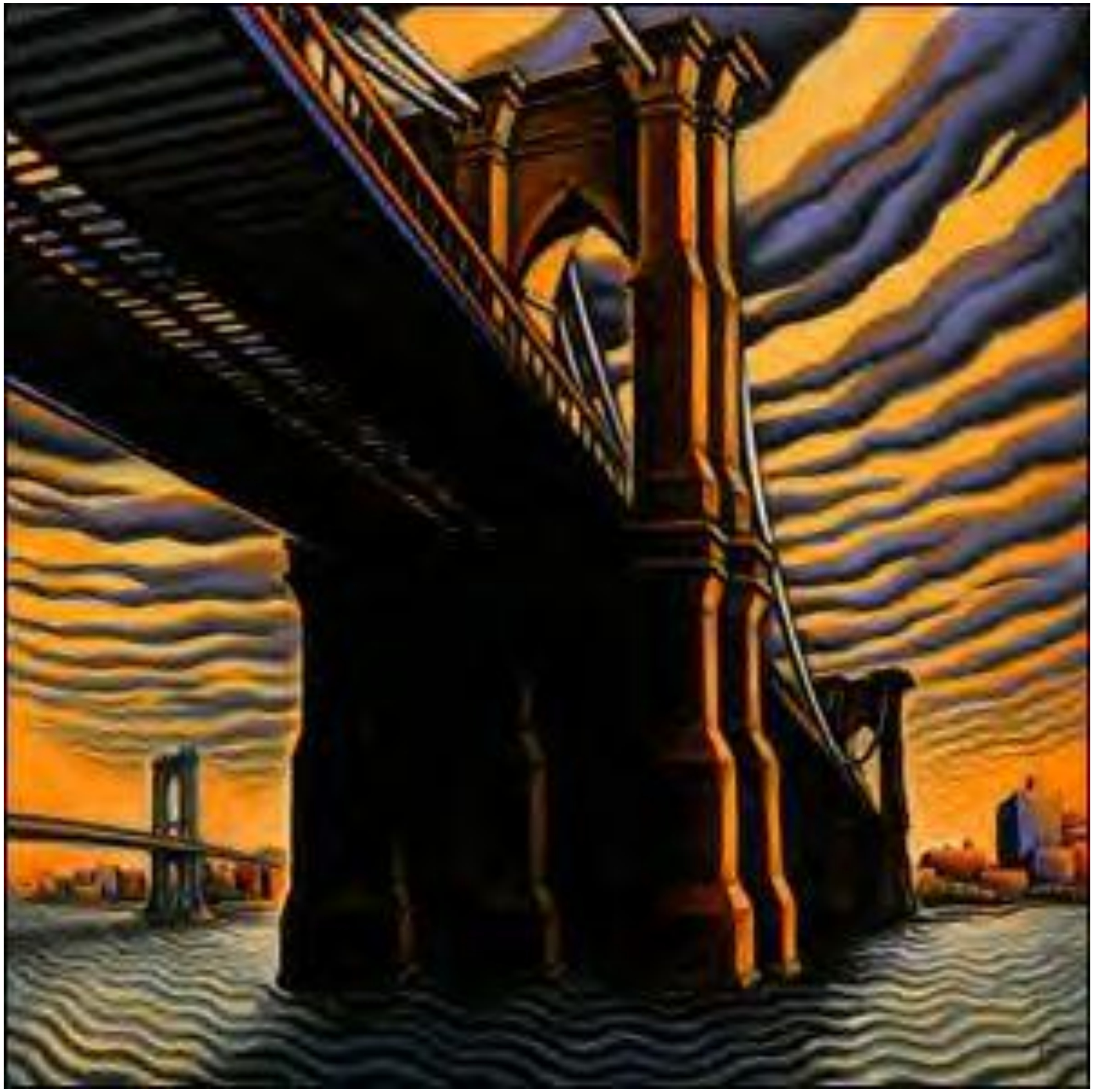

THE EAST SIDE KIDS
'NEATH BROOKLYN BRIDGE


Brooklyn Bridge
USA 20c


OFFICIAL PROGRAM FIFTY CENTS
1947
WORLD SERIES
Dodgers
Yankees

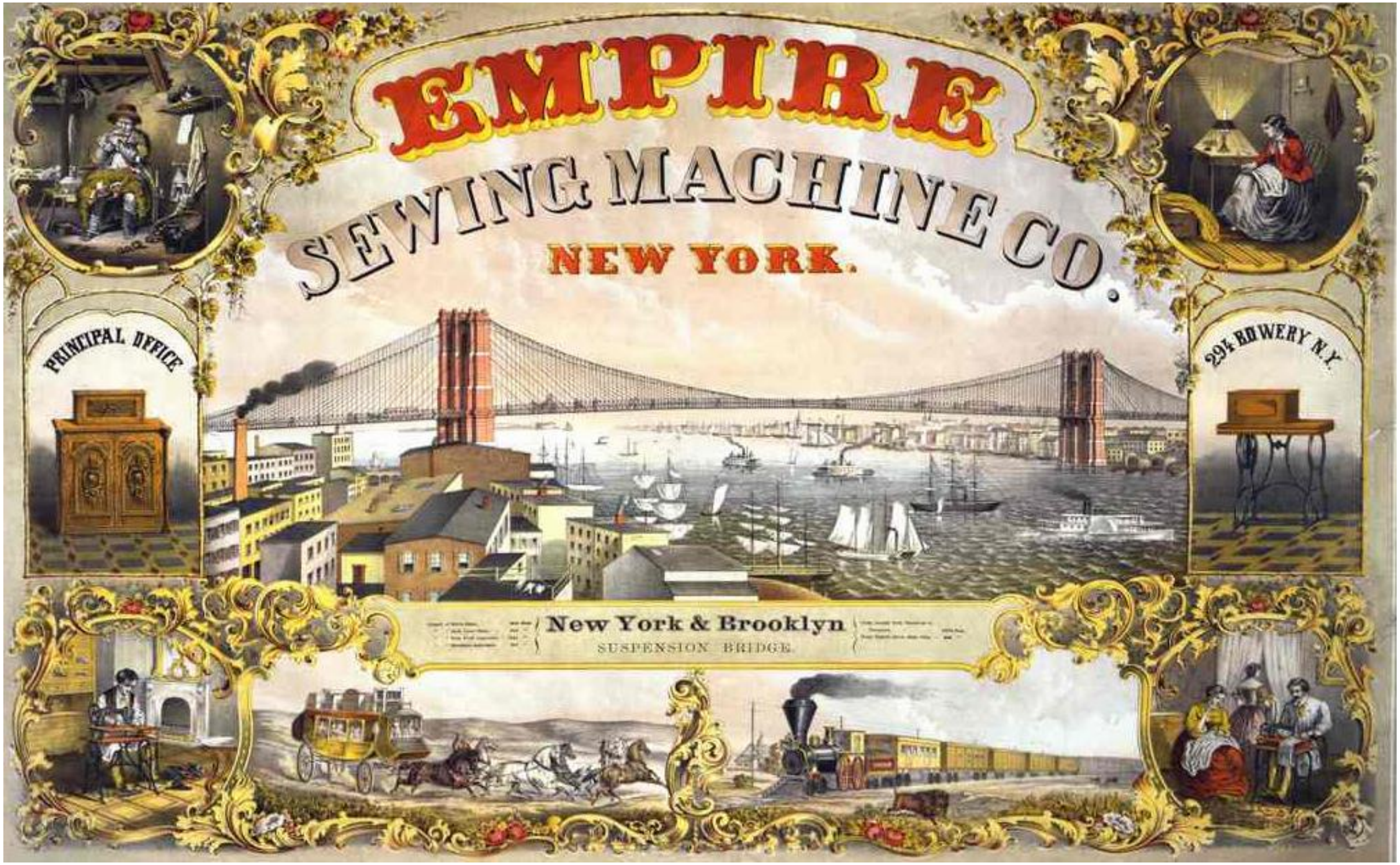
Art



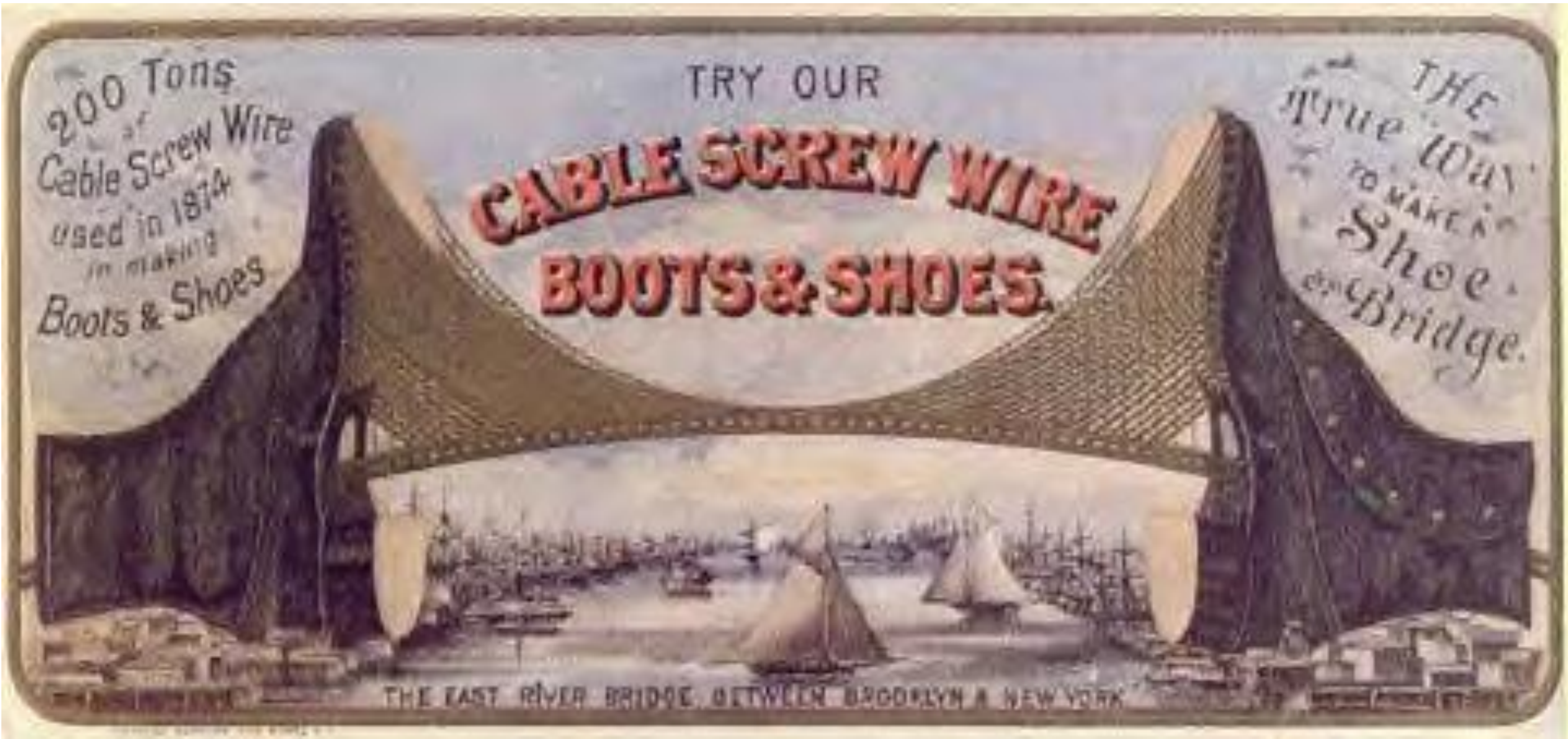


Advertising


EXCELSIOR


EMPIRE
SEWING MACHINE CO.
NEW YORK.
PRINCIPAL OFFICE
294 BOWERY N.Y.
New York & Brooklyn
SUSPENSION BRIDGE

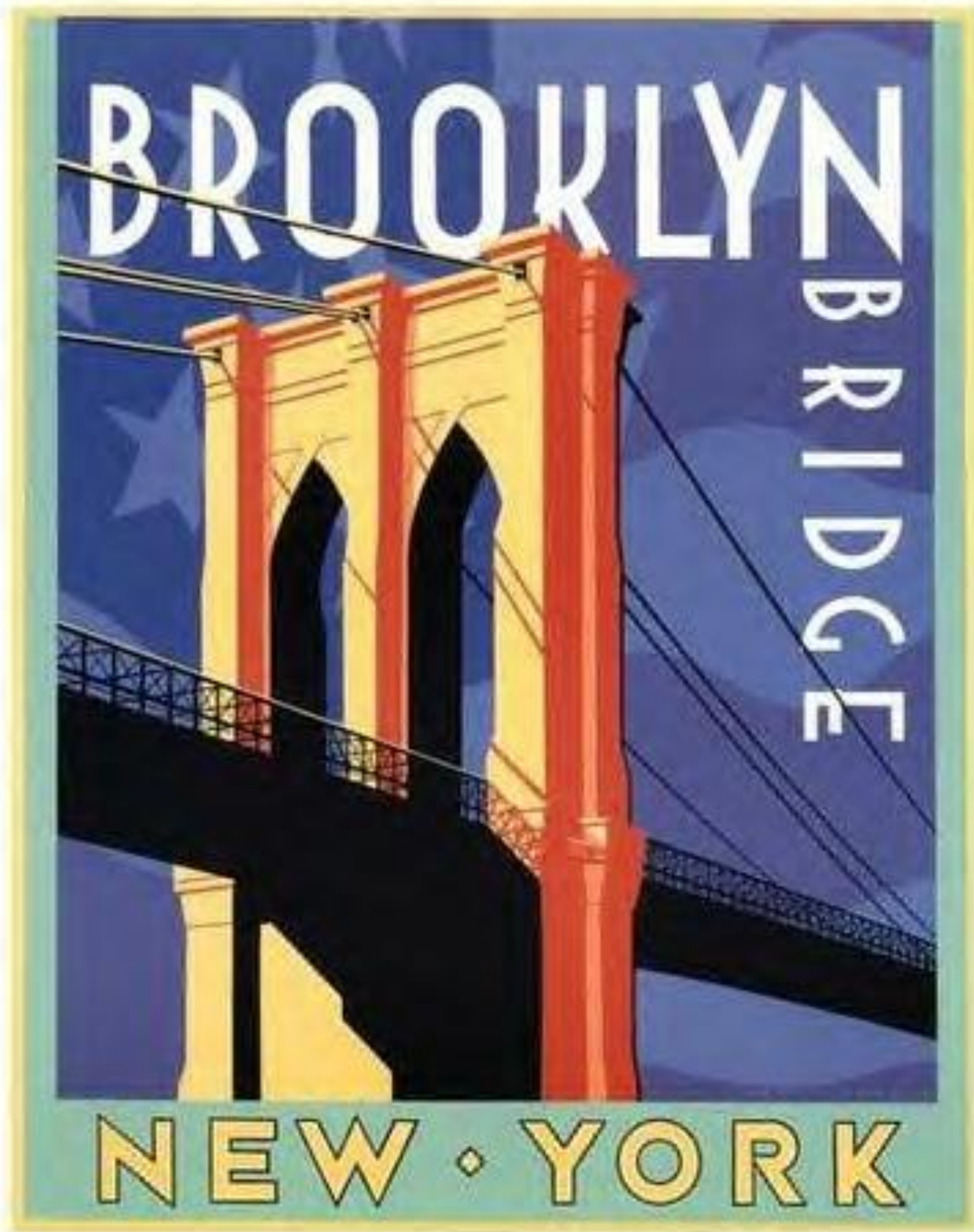

MULFORD, CARY & CONKLIN,
Leather and Findings.
NEW YORK.



200 Tons of Cable Screw Wire used in 1874 in making Boots & Shoes
TRY OUR
CABLE SCREW WIRE
BOOTS & SHOES.
THE True Way TO MAKE A Shoe or Bridge.
THE EAST RIVER BRIDGE BETWEEN BROOKLYN & NEW YORK

Photography


PENNSYLVANIA
RAILROAD
BALTIMO


BROOKLYN
BRIDGE
NEW · YORK