## 1. NAME OF PROPERTY

Historic Name: Brookline Reservoir of the Cochituate Aqueduct

Other Name/Site Number: Brookline Reservoir Gatehouse

## 2. LOCATION

Street & Number: 1 Warren St. Not for publication:

City/Town: Brookline Vicinity:

State: Massachusetts County: Norfolk Code: 021 Zip Code: 02445

## 3. CLASSIFICATION

| Ownership of Property | | Category of Property | |
|---|---|---|---|
| Private: | ___ | Building(s): | _X_ |
| Public-Local: | _X_ | District: | ___ |
| Public-State: | ___ | Site: | ___ |
| Public-Federal: | ___ | Structure: | ___ |
| Object: | ___ | | |

Number of Resources within Property

| Contributing | Noncontributing |
|---|---|
| | ___ buildings |
| _2_ | ___ sites |
| _1_ | ___ structures |
| ___ | ___ objects |
| _2_ | ___ Total |

Number of Contributing Resources Previously Listed in the National Register: 3

Name of Related Multiple Property Listing: "Water Supply System for Metropolitan Boston Thematic Multiple Properties Submission"

DRAFT

## 4. STATE/FEDERAL AGENCY CERTIFICATION

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this ____ nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property ____ meets ____ does not meet the National Register Criteria.

Signature of Certifying Official Date

State or Federal Agency and Bureau

In my opinion, the property ____ meets ____ does not meet the National Register criteria.

Signature of Commenting or Other Official Date

State or Federal Agency and Bureau

## 5. NATIONAL PARK SERVICE CERTIFICATION

I hereby certify that this property is:

___ Entered in the National Register
___ Determined eligible for the National Register
___ Determined not eligible for the National Register
___ Removed from the National Register
___ Other (explain): _____

Signature of Keeper Date of Action

## 6. FUNCTION OR USE

Historic: Industry/Processing/Extraction Sub: Waterworks

Current: Landscape Sub: Park

## 7. DESCRIPTION

ARCHITECTURAL CLASSIFICATION: Renaissance Revival (lower gatehouse) / other (upper gatehouse)

MATERIALS:

Foundation: granite (lower gatehouse) / granite (upper gatehouse)
Walls: granite (lower gatehouse) / granite (upper gatehouse)
Roof: wrought iron roof on wrought iron trusses (lower gatehouse) / granite (upper gatehouse)
Other: earth and granite (reservoir embankment/dam) / brick (aqueduct)
Rosendale hydraulic cement mortar for all masonry work (both gatehouses and aqueduct)

**Describe Present and Historic Physical Appearance.**

Introduction

Boston's municipal waterworks system, represented by its nationally-significant frontispiece and reservoir in Brookline, is the oldest substantially surviving municipal aqueduct system, including its terminal reservoirs and gatehouses, in the U.S. The 1848 Lower or Principal Gatehouse of the Brookline Reservoir of the Cochituate Aqueduct (pronounced "Co-chit-u-it") is a relatively small but impressive two-story granite Renaissance Revival building that is integral to the historic reservoir then, as now, also a public park. At the south end of the reservoir basin is the small granite Upper or Influent Gatehouse. The aesthetics of the Principal Gatehouse pay homage to the monumentality of classical architecture and to the engineering behind the civic monuments of the era. The combination of architectural ideals and public works recognized in classical times influenced civic projects like the aqueduct system planned for the city of Boston. The Principal Gatehouse of the Brookline Reservoir of the Cochituate Aqueduct is the architectural frontispiece to the oldest, substantially surviving municipal aqueduct system in the U.S., and the gatehouse gives architectural expression to the commitment of Boston to its citizenry through form and materials and through a largely-unseen engineered waterworks system as refined as the building Bostonians could see. Distinguishing this gatehouse are the oldest surviving wrought iron roof trusses and iron roof, as well as the oldest iron staircases intended for public use, in the U.S. It also retains its original water flow control gates. The Brookline gatehouse exhibits significant engineering achievement as measured on a national scale and in context of international technological advances, as well as a remarkable level of architectural integrity for both the building and its site.

Boston's municipal waterworks system differs from Philadelphia's earlier system in that the Philadelphia waterworks pumped water from the Schuylkill River instead of using an aqueduct. And, while New York City's Croton Aqueduct, completed in 1842, predates Cochituate, only the smaller secondary gatehouses along its length (for overflow "waste weirs" etc.) survive. The Croton Aqueduct's inlet gatehouse and dam were submerged below a later reservoir; the original receiving reservoir and distribution gatehouse in Central Park (counterpart to the Brookline gatehouse and reservoir) were replaced in 1940 by Robert Moses' Great Lawn.[1]

In addition to the larger context of municipal waterworks, the building materials and technologies used in the Brookline gatehouse reinforce the public aspect of the civic program: public works for public good. The Brookline gatehouse encapsulated that duality - the benefit of the city and the city's benefit as its citizens admired what was constructed and provided – and the prominent use of iron symbolized this civic ideal as well as represented what was achieved in the engineering of the aqueduct. For example, the gatehouse's "iron roof" of wrought-iron roof trusses, supporting an externally visible, stitch-riveted, wrought-iron plate roof was regularly noted at the time. As is discussed in detail in Section 8 below, there were only two known earlier non-industrial U.S. buildings with wrought iron roof trusses (both long lost). One was Harvard University's Gore Hall Library, whose truss design is possibly related to that of the Brookline gatehouse roof. The other was Isaiah Roger's monumental Boston Merchant's Exchange. However, whereas the Brookline gatehouse trusses are simple and very modern in conception and execution, the Merchant's exchange trusses were of an idiosyncratic design that must have been expensive to fabricate and have no evident line of successors. The Merchant's Exchange also had the only earlier identified U.S. iron plate roof surface. The gatehouse, moreover, contains a double set of entirely iron stairs. These are the oldest surviving examples intended for public use in the U.S., with only one or two possible earlier examples known, none of which are documented as to their design or construction. The Brookline gatehouse, therefore, is nationally significant for its architecture and

[1] By comparison, the only components missing from the Cochituate Aqueduct are the two gatehouses at the ends of the still surviving inverted siphon spanning the Charles River (which remains in use as a sewer force main) and the nearby Cedar St. underpass arch.

engineering as suggested by its place in the development of municipal waterworks and as a particularly important example of building technologies worked in iron.

The engineering aspects of the Principal Gatehouse, including its gate mechanisms are remarkably intact. So too is its entire original site, including the reservoir, its park-like grounds, that portion of the aqueduct within the site, the stone roofed smaller gatehouse where the aqueduct emptied into the reservoir, a bypass conduit under the reservoir embankment allowing direct water flow from the aqueduct to the Principal gatehouse, and the valves and pipes that connected the reservoir to the rest of the city. In fact, one of the three original 165-year old cast iron water mains leading towards the city from below the gatehouse was recently cleaned and remains in service. Thus the integrity of the Brookline gatehouse and reservoir is exceptionally rare, and a description of the appearance of the Principal Gatehouse, Brookline Reservoir of the Cochituate Aqueduct follows this introduction. The entire complex forms one contributing structure, of which the Principal Gatehouse is the most significant component.

Present and Historic Physical Appearance:

The Principal Gatehouse faces north-by-north east at the intersection of Warren St. and Boylston St (Route 9) in Brookline and is prominently visible to passing traffic.[2] (For convenience, descriptions of the building herein treat the street façade as oriented due north.) Set between Green Hill (NRD) and Fisher Hill (NRD), the site is located where Boylston St., the old Worcester Turnpike, rises up from the lower ground bordering Boston's Back Bay to the elevation of about 120 feet that was needed for the Cochituate Aqueduct's terminal reservoir. The gatehouse, angled to face two of the oldest roads in Brookline, was effectively the architectural frontispiece Boston's first municipal water supply system. The rear of its lower story is set into the dam/embankment that impounds the reservoir.

The building was intended to be open to visitors and therefore was fully architecturally finished internally, including a symmetrical pair of cast iron staircases. It also had a much noted "iron roof" consisting of both an externally visible continuous sheet iron roof surface and a set of 21 wrought iron Howe roof trusses supporting it.[3] Both the stairs and the roof were extremely unusual at the time and now appear to be the oldest extant examples of their type and use in the U.S. The site as a whole is a well-maintained municipal park. At the other end of the reservoir is the small Upper Gatehouse marking the end of the 15-mile long belowground Cochituate Aqueduct.

In addition to the aqueduct's surface structures, most of which survive, the project is recorded in a sumptuous folio of large ink-wash presentation drawings, entitled *Structures on the Western Division of the Boston Water*

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[2] The best early source on the Boston Waterworks is Nathaniel Jeremiah Bradlee, *History of the Introduction of Pure Water into the City of Boston* [*etc.*], (Boston: Alfred Mudge & Son, 1868).

Other early accounts include: "The Water Works" *Boston Daily Advertiser*, (Friday Morning, Nov. 17, 1848); "The Water Works" *Evening Transcript*, (Friday Evening, Nov. 17, 1848); "Brookline Reservoir" *Gleason's Pictorial*, (July 16, 1853); "Annual Visit of the City Government to the Cochituate Waterworks" *The Boston Harold*, (Sept. 22, 1854); "Water Works" *Bacon's Dictionary of Boston*, (Boston: 1868), 430-432; "Old Brookline Reservoir" *The* [*Brookline*] *Chronicle*, (Saturday morning, Aug. 22, 1908).

An excellent recent discussion of the project is in Michael Rawson, *Eden on the Charles: The Making of Boston*, (Cambridge: Harvard University Press, 2010), 75-128. Nelson Blake, *Water for the Cities, A History of the Urban Water Supply Problem in the United States*, (Syracuse: Syracuse University Press, 1956), places it into the national context.

[3] All of the following sources refer to its "iron roof" or "roof of iron": *A Gazetteer of Massachusetts* [etc.], (Boston: John P. Jewett & Co. 1849), 447; *Report of the Cochituate Water Board to the City Council of Boston*, (Boston: 1852), 22; *A Gazetteer of the United States of America* [etc.], (Hartford, Conn.: Case Tiffany & Co., 1853), 297; *The New England Gazetteer* [etc.], (Boston: Otis Clapp, 1857), 68; Bradlee, *History of the Introduction*, 251; *Engineering New-Record* V (1878), 103; *Description of the Boston Water Works* (Chicago: Engineering News, 1878), 14.

*Works including Lake Cochituate & Brookline Reservoir, E.S. Chesbrough, Engineer, 1849.* Considering their generally pristine condition and taking the date at face value, they appear to be an "as built" record of the project's main visible structures, despite a few minor inconsistencies.[4]

Site: The site includes the entire Brookline Reservoir Park, of 32.12 acres. Its boundaries have remained substantially unchanged (other than minor street line adjustments) since the time of the completion of the reservoir in 1848. It is bounded on the east by Warren St., on the north by Boylston St. (state Route 9 and originally the Worcester Turnpike), on the west by Lee St., on the south by Dudley Way and Dudley St., and on the southeast by four house lots interrupted by a short tangent section of Walnut St. These roads are lined by residential buildings facing the reservoir, except for the Walnut and Warren street sections that back-up to the gatehouse property. There is access to the reservoir park from Dudley Way, Dudley St., Walnut St., and Warren St.

**The Brookline Reservoir**

The surface area of the reservoir is 21.1 acres. The kidney-shaped basin is surrounded by a gravel path and park with grass and trees with a gravel footpath around the perimeter of the reservoir. While the reservoir was open as a park since its inception, no evidence has come to light of an original or later formally designed landscape when the property was acquired by the town in 1903. The original capacity of the reservoir was 120 million gallons and its original maximum depth at the principal Gatehouse was 26 feet.[5] Water presently comes into the reservoir from three sources: from ground infiltration into about a mile of the Cochituate Aqueduct owned and controlled by the town of Brookline; from catch basin street drainage from one or more of three surrounding streets, Lee St., Dudley Way, and Dudley St.; and from the surface area of the park and reservoir. There is an overflow spillway in a cove in the southeast quadrant of the reservoir into a piped stream (now a storm sewer) between the Dudley and Walnut St. sections of the site boundary. The reservoir can also be drained through an 8" line connected to the original center-most of the three original water mains leading from the gatehouse. The two "gates" in the gatehouse leading to that main are partly open. In the event of draining the reservoir the flow of water would be controlled by a valve in a pipe below the gatehouse.

It passes around that side of the Influent Gatehouse that is away from the reservoir but between the Principal Gatehouse and the reservoir. Beginning from the reservoir's overflow spillway and continuing past Walnut and Warren streets and thence approximately half way along the Boylston St. boundary, the reservoir is contained by a dam/embankment with the path on top of it. Along the Warren St. frontage and part of the Boylston St. frontage, the lower slope of the embankment is held back by a retaining wall of rough dressed, randomly polygonal, granite blocks, with rough dressed granite cap stones, that meet the side walls of the Principal Gatehouse. Lying in the embankment eight feet directly below the path surface between the two gatehouses along the Boylston St. side of the reservoir there was installed at the time of construction a brick conduit to permit a flow of water to bypass the reservoir. The circular cross section area of this conduit was less than half that of the aqueduct. At a relatively early date this bypass conduit was determined to be unsatisfactory, its use was discontinued, and its opening into the principal gatehouse was sealed with masonry.

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[4] This volume of 30 drawings in the Massachusetts Water Resources Authority (MWRA) archives includes eight of the Brookline Reservoir's lower or principal gatehouse, and one dating from 1856 of its added circular screening device. The index page also dates from 1856.

Sean Fisher, archivist of the Department of Conservation and Recreation (DCR) and former archivist of the Metropolitan District Commission (MDC), identified the existence of this critical volume and provided invaluable insights and access to other archival resources.

[5] Photographic documentation of the reservoir was taken when the water was completely drained in circa 1926. These photographs are in the collections of the Brookline Preservation Commission.

Above and below the water line, the embankment of the entire parameter of the reservoir is revetted with a 14 ft. band of random granite slabs 18" thick. The lower portions of the embankment and the bottom of the reservoir are lined with puddled clay.

Shortly after Brookline acquired the reservoir from Boston in 1903, the original fence around the property was removed. Perhaps at that time the present path leading up to the reservoir from Warren St., just to the south of the Principal Gatehouse, was added. Possibly in 1926 when internal changes were made to the Gatehouse for recreational uses, a short dock for recreational purposes was extended into the reservoir from a point just opposite the top of the path. At some point after World War II, the dock was removed. Except as noted, the reservoir is otherwise essentially unchanged since the time of its construction.

Within the boundary of the park, but not visible, is the entirety of the short section of the aqueduct between the site boundary and the influent gatehouse. It reflects the aqueduct's typical egg-shaped tube cross-section of brick masonry laid with Rosendale cement mortar, with the point of the "egg" up. It is five feet wide by six and a half feet high. (Just beyond the site boundary is a one of two sections of the aqueduct that were tunneled through Roxbury puddingstone.) Between the upper gatehouse at the end of the aqueduct and the site boundary there is a square hinged iron plate access hatch (possibly original) set in a granite curb that is almost flush with the ground surface. It is typical of such hatches that were placed at quarter-mile intervals along the entire length of the aqueduct's brick sections. Reportedly, this section of the aqueduct is essentially unchanged since the time of its construction.

**The Upper or Influent Gatehouse**

This small building projecting slightly into the reservoir is constructed of a single thickness of fully hammer dressed, uniform sized, granite blocks, with an iron plate access door (possibly original) facing the pond above two rectangular, door sized openings at the level of the aqueduct. It is about 11 feet wide by 12 feet long by 11 feet high on the side abutting the path. Its roof consists of four 11 foot long spanning granite slabs with their upper surfaces given very flat pitches from a central ridge line. The only suggestions of architectural ornamentation are two narrower, slightly projecting, belt courses below the eves. The general appearance and size of the building are reminiscent of the simplest possible granite mausoleum. The interior of the building is a single chamber with paired vertical sets of slots in the lower walls for the insertion of trash racks and/or stop logs to control the flow of the water coming from the aqueduct. The building is essentially unchanged since the time of its construction.

**The Lower or Principal (or Effluent) Gatehouse**

***Exterior elevations and masonry:*** This gatehouse is a temple-form rockfaced granite structure lined with brick; it originally had a fully plastered interior. The excellent present condition of its masonry is due in no small part to the use throughout the aqueduct project, including the gatehouse, of hard fired bricks and of the then relatively recently discovered "hydraulic" Rosendale cement mortar. Rosendale is a natural cement, similar to that used by the Romans, which can set under water and is comparable to modern Portland cement in durability under harsh conditions. Had the gatehouse been made with the typical lime mortar of its period, its walls probably would not have survived the decades of water pouring down them from the failed gutters and decades of freeze-thaw cycles.

The building's exterior walls are grey rock-faced granite with the quoins and other smooth surfaced moldings and architectural elements seemingly picked out in what has often been taken to be a lighter toned grey granite. The aqueduct project, as a whole, used Quincy and Rockport granite but it is not clear that both were used in

this one building. Close visual inspection suggests it is more likely that the smooth surfaces refract light differently and do not hold dirt and pollutants, as much as the rock-faced surfaces do. This two-toned appearance is evident even in the 1876 photograph. The exterior walls are of cavity wall construction backed with hard fired brick and the two materials are tied together with iron cramps.

The consistency and precision of the granite work reflects the high state of craftsmanship that had been achieved in early nineteenth century Boston under the influence of architects such as Solomon Willard, Alexander Parris, and Gridley J.F. Bryant. Despite this, the great difficulty in working granite is made evident by the rough quarry-faced surfaces that remain on the backs of the cornice stones and rear surfaces of the two front façade niches where they project through the vestibule brickwork. These unfinished surfaces were originally hidden respectively behind the interior plaster ceiling and staircase walls. The other hallmark of Boston granite masonry of this period is the greater scale of the pieces that were sometimes worked and used, especially as spanning members. This is most evident in the massive roughly dressed columns and lintels that support, out of sight, the entirely granite wall between the vestibule and bulkhead chambers, and in the granite floor slabs spanning the higher and lower portions of the bulkhead chamber.

The building's front (north) elevation is two stories while the lower half of its rear (south) elevation is buried in the embankment of the reservoir. On either side of its arched lower level main entrance doorway (1 Warren St.) are banded columns, flanked by sepulchral niches. The architectural language of the sides and rear of the gatehouse is a subtle simplification of its Renaissance Revival front elevation. All the upper level round-arch topped window and door openings are the same 36 inches in width and reach the same height. However, instead of the three front windows' frames and entablatures, all seven openings on the sides and rear are recognized only by subtly rendered voussoir arches in the rock-faced wall masonry. Similarly, the belt course (above which the two story front façade's quoins are subtly smaller than those below) changes its role, but not its form, to become a solid plinth where the single story rear façade and rear portion of the sides sit atop the dam. And instead of the front façade's more formal full pediment, the rear has simpler eve-returns extending only above the quoins.

***Windows and doors:*** Presently, the two upper doors' openings on the side elevations are filled with plywood. Only part of one door frame remains. (Water leakage from the failed gutters did much more damage to wood features on and in the side walls than is true of the end walls.) The original upper level doors were double-leafed and unglazed, with each leaf 18 inches wide. The three 10/6 arch-topped windows facing the reservoir are preserved behind woven heavy-gauge iron-wire-mesh grills — most likely of the nineteenth or early-twentieth century. Their sashes, which appear salvageable, are covered with plywood and need to be restored. Because of ongoing humidity issue inside the building, the two arched side window openings towards the front, whose sash had been lost, have recently been fitted with well-crafted, fixed, louvered mahogany shutters, made as final thesis projects by graduating students of the North Bennett Street School. The three front window sash have been restored and/or replicated, as need be, by North Bennett Street students and are fixed in place. One original leaf of the lower level front door is original. The other has been replicated in mahogany by North Bennett Street students and both are now mounted on a structurally functional mahogany frame. The massive pair of doors opening from the lower level of the stair hall into the bulkhead chamber that is described below appear to be in need only of repainting, although their pintle type hinges need to be freed up. All of the restored or replicated doors and windows have been painted a dark green found on the surviving door leaf.

Restoration work calls for the three surviving windows to be restored, while two pairs of doors remain to be replicated as part of the ongoing program.

***Iron roof with built-in gutters and iron roof trusses:*** As first built, the gatehouse's iron roof surface was externally visible — virtually smooth and seamless, and probably painted the verdigris green that is still visible under the present standing seam roof. Internally the roof and its supporting iron trusses were originally unseen, because of the original plaster ceiling. Early accounts all speak of an "iron roof" not an "iron truss" roof. However, in the usage of the time the term "iron roof" clearly was comparable to the term "timber roof" in referring to a roof structure not a roof surface. A light gauge non-structural sheet iron roof would typically have then been called a "tin roof" or "metal roof." It is not known when the present standing seam roof was first applied over the iron plate roof surface. It probably was done in response to damage to the roof that is evident near the southwest corner of the building. One possibility is that acid smoke from leaking coal stove pipes weakened the roof in that area, which is close to the historic chimney location at the south end, and/or there may have been storm damage. (Brookline, for example, suffered considerable losses from fallen trees in the Great Hurricane of 1938.) The stovepipe did not always run the length of the room, from the stove's only possible location nearer the stairs, to the chimney at the south end; there is a stovepipe hole cut into the iron roof above where the stove would have been. The use and subsequent disuse of that hole predates the standing seam roof which covers it.

The edge of the roof plate incorporates built in "Yankee" gutters hidden above and behind the cornice. These failed and were repaired at least twice, based on the evidence of old repairs. They may have failed at the time the building last went out of use in the 1960s. It is clear that by the mid-1980s they had been leaking a long time, resulting in great internal damage to plaster and woodwork. If the gutters were again repaired in the mid-1980s, it did not last. By 2005 they were severely leaking again. They have since been capped, as a temporary measure pending a complete repair/restoration of the entire roof system.

With the plaster ceiling gone, the iron roof trusses and stitch-riveted, approximately 1/16" thick, continuous-membrane, "sheet iron" (wrought iron) roof they support are now the dominant feature of the principal space inside the gatehouse. The roof is supported by 21 lightweight, six-panel, Howe roof trusses assembled from square and rectangular wrought iron bars.[6] Because of the plastered ceiling, the trusses were invisible and forgotten, for the approximately 110 years the building's interior was actively used. Only now, with the ceiling gone, can they be seen and appreciated.

The trusses are spaced 24" on center and span about 23 ft. The top chords are pairs of 2" x 3/8" bars and the bottom chords pairs of 2" x 1/4" bars. The trusses have 2-1/2" x 3/8" vertical members mid-span and 1/2" square verticals at the quarter-spans, with 3/4" square diagonals connecting the bottoms of the mid-span verticals to the tops of the quarter-span verticals. The ends of the diagonals are flattened to fit between the paired top and bottom chord bars. All connections between truss members are single rivets. The trusses have an additional short 1" x 1/2" vertical near each end, where the trusses are supported. Three of the trusses, one above the north end of the granite slab floor area and two near the north wall, have their end verticals located about a foot further from the truss's ends as compared to those in the other trusses. Presumably they were the initial batch — mis-constructed but too valuable not to use.

The trusses sit on single or sometimes stacked bricks on the irregular undressed granite tops of the walls. The bricks set all the trusses at the same level. There is no sill plate or tie between the adjoining truss ends. The

[6] These are clearly Howe type roof trusses, to apply the term used today, but in the mid-nineteenth century the name "Howe" was applied to a type of bridge truss with parallel upper and lower chords. The uppermost and lowermost lines of members or sets of members of a truss between its end supports are its upper and lower chords. In the structural analysis of a truss its "panels" are the truss's inherently rigid triangular basic units. Each panel consisting of three linear members continuously joined end-to-end. A truss is, then, just an assemblage of such rigid triangular panels, with each panel sharing each of its structural members with its abutting panels, except for those members that may be part of a top or bottom chord.

only ties between the trusses, other than the iron plate roof to which they were attached by irregularly spaced clips, are the approximately 2" x 1/4" bars which connect them mid-span, at both the tops and bottoms of the center vertical members. Despite their irregular placement and the existence of the upper center-span ties, it is possible that the clips were part of the original design and were meant to brace the upper chords against buckling and/or were intended to hold the roof on. Likely, they were added during construction to prevent buckling of the upper chords under compression.

In sum, over 90% of the iron plate roof area, excluding the failed gutters, appears to be intact and sound, based on both visual evidence and information from engineers and roofers who have inspected and been on it, with most of the broken or replaced material limited to one area. Similarly, over 90% of the trusses' fabric is also intact, with the compromised material all at the truss ends. The clips attaching the trusses to the roof have mostly failed. An engineering design exists for applying relatively inconspicuous splints to the tress ends as needed and for adding new, identifiably different clips to re-secure the plate roof to the trusses.[7]

***Entrance vestibule and bulkhead chamber:*** Immediately inside the building, opposite the street level front entrance, is a smooth, unadorned, granite wall, containing a vault-like archway closed by a pair of massive, metal studded, verdigris green wooden doors. These swing open into the void of a deep chamber enclosed with rockfaced granite and spanned by granite slabs (the "Bulkhead Chamber"). The 26 foot high "bulkhead" wall opposite the archway holds back the reservoir. Built into the bottom of this wall are three large, pipe-like iron fittings, two of 30" diameter flanking one of 36", with flared inner ends and belled outer ends. They are designed to mate with the three cast iron water mains passing through the bottom of the chamber that once supplied all of Boston's water.

The rusted remains of self-evidently early rectangular wrought iron floor beams and fragments of wood floor planks clearly show there was once a floor in this chamber at the entrance level. The absence of evidence of a guardrail in the archway suggests the floor was not added later. However, the 1849 drawings of the gatehouse, which generally can be considered "as built," show no such floor. In addition, an admittedly not always accurate, contemporary guidebook calls attention to the "chilly" bulkhead chamber and suggests it was floorless — saying "you may see the vast pipes" below.[8] Except for its symbolic image of timeless solidity and security, there is no apparent functional reason for making such a display of this vault, with or without the now-missing floor. And, with the floor in place there would have been less symbolic reason for displaying such a blank walled room. Perhaps significantly, there is no recognition of any floor level in the rock-faced bulkhead back wall of the chamber, which runs uninterrupted and undifferentiated in appearance from the top to the bottom of the space. In addition, the bulkhead and side walls of the space are of a more carefully dressed rock-faced appearance than the interior of the fourth wall (the one with the arched opening), suggesting that those three walls were meant to be seen through the arched opening — but not from inside the space, where the fourth wall would have been visible. The only illumination would have been available light coming down from the five

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[7] Structures North and EYP. *Brookline Reservoir Gatehouse Conditions Assessment Report*. Brookline: 2009.

[8] *A Description of the Boston Water Works* [*etc.*], (Boston, Geo. R. Holbrook & Co., 1848), 27. This guidebook undoubtedly was written as the project was being built. While clearly placing the reservoir in the right location, it misidentifies it as being on Corey Hill, a previously considered location. It also says there are stone steps in the gatehouse — possibly just a reasonable assumption, or possibly an indication that, like those in Alexander Parris' Mt. Desert Rock Lighthouse (discussed below), the intention was changed at some point between initial design and construction.

This guidebook also erroneously says that "you may see the vast pipes by which the water enters and leaves the [gate] house," whereas the water only left through those pipes. The author might have been confused by a drawing or description of the bypass conduit connecting the reservoir's upper and lower gatehouses. It would have looked pipe-like in a drawing, but it cannot be seen in the bulkhead chamber.

Another indication that the book was based upon drawings and/or visits to construction sites is that its two illustrations of the inverted-siphon over the Charles River between Needham (now Wellesley) and Newton show it as consisting of two uncovered pipes, rather than three bermed-over pipes, as built.

large windows above the staircases. As gaslight had yet to reach Brookline in 1848, the space could not have been artificially illuminated, except under unusual circumstances.

There is almost no recognition in the pattern of blocks in the bulkhead wall that behind it are three separate 26-foot deep water-filled chambers, each feeding one of the pipes. (Except near the top, those underwater chambers are lined with and separated by brick masonry, not granite, and any such expression in this granite wall would only have been symbolic.)

Although that part of it is not visible from the doorway, the bulkhead chamber extends under the stair vestibule to the building's front foundation wall. Significantly, the stonework in that area is less finished than in the rest of the chamber, again suggesting that the part of the chamber visible from the archway was intended to be seen. The floor of the stair vestibule is granite slabs spanning the bulkhead chamber's extension below. Both the floor and the granite wall with the arched opening, and in turn the granite slab roof over the main part of the bulkhead chamber, are ultimately supported on two rough monolithic square granite columns that stand, out of sight, under that wall, between the cast iron pipes.

Originally the two side walls and the entry door wall of the vestibule space were plastered over wood lathe, with the lath mailed to vertical furring strips which in turn were nailed onto brick-sized nailer blocks substituted for regular bricks at regular intervals in the inner wall face. All of that has been lost at the lower vestibule level.

***Staircases:*** Flanking the arched opening into the bulkhead chamber is a symmetrical pair of delicately pierced cast iron staircases. Such formality is consistent with the role of the gatehouse as a symbolically important, public building. The stairs lead to the main room above — and to the light which would have poured down from it. These cast iron staircases are the earliest known surviving examples intended for the general public in the U.S. The only surviving earlier U.S. examples are spiral or circular staircases in four lighthouses and one pair of straight run stairs in Eastern State Penitentiary, Philadelphia.

As is discussed below, while the stairs bear no foundry marks, there is a clear stylistic link and circumstantial evidence which identify the manufacturer with reasonable certainty. The gatehouse stairs are clearly related to a better-documented, almost contemporaneous spiral staircase at the Boston Athenaeum. It is likely that they came from the same manufacturer, Smith & Lovett, which specialized in architectural iron. There is a Boston Water Works payment voucher for "iron work" to "D. Stafford & Co.," an older name for Smith & Lovett. (The evolution and variations of this firm's name is reviewed below.) Although possibly it could have been for one of the gatehouse roofs, most likely it was for the Brookline gatehouse staircases or the matching handrail in the Lake Cochituate Gatehouse at the upper end of the aqueduct.

Unlike all earlier U.S. iron staircases, these have an apparently continuous supporting stringer, hidden behind which is a continuous wrought iron bar, creating a conventionally supported run. The stringers are only on one side of each run because, like most of the straight and curved earlier U.S. examples, these stairs are supported by a wall on their other side. The upper and lower straight runs of each staircase are joined by two 90° winder sections. The wrought iron structural connectors to the square winder-posts seem more ad hoc than the rest of the assemblage. That could be just some not-well-resolved details, but it suggests that a pre-existing casting pattern for the post was adapted to this purpose. The railing, spindles, and winder posts all look like those components of the railing around the inlet to the aqueduct in the Lake Cochituate gatehouse.[9] The balustrades are plain, heavy round wrought iron rods. While the small scale of the drawings prevent clear documentation,

[9] However, they may not be identical. For instance, the Lake Cochituate Gatehouse posts appear less tapered. Also the generally accurate 1849 drawings do not show any railings in the Lake Cochituate Gatehouse. Thus they might have been added, perhaps as an afterthought during the original construction or perhaps during the1859 reconstruction.

the balusters were presumably identical to the now-lost railing that encircled the water-filled gate chambers in the upper level of the Brookline gatehouse. It is not immediately obvious why the more expensive and less decorative wrought iron would have been used, rather than cast iron, unless there was a desire for greater strength and impact resistance.

The tops of the stair treads have a checked non-slip pattern. The perforated ornamentation of the risers and stringers, also the first known U.S. example, includes a round-arched arcade motif, in an abstract Romanesque-like style, reminiscent of the "Rundbogenstil" of that period — as differentiated from the more muscular, sculptural Richardsonian Romanesque which emerged 30 years later. (In addition, to saving weight and cost, the risers of iron staircases came to be commonly perforated like these to permit the penetration of light below the staircase, as would have been desirable here.) The conical newel-posts at the base of each staircase reflect the plain, heavily proportioned, domestic Neo-Classicism of the period — the American variant of the Biedermeier. Their form is almost reminiscent of an industrial machine spindle. The lower half of their radically tapered upper part is fluted and separated by a deep groove from a band of ambiguously matching convex counterparts to the flutes above. The staircases as a whole could be a "marriage" of the presumably recently designed Rundbogenstil stringers and risers with the pre-existing Biedermeier newel-posts and the square-bottomed winder posts, both of which might have been previously designed for stone staircases.

The western staircase is essentially intact up to the common landing where the two staircases join one riser below the upper floor level. The eastern staircase has had two treads at the bottom broken and several other treads and risers in the upper winder section broken where a plumbing waste stack was put through it. In 1926 toilet rooms were built over both staircases (discussed further below), completely flooring over the eastern staircase and flooring over the space above the lower run of the western staircase. As a result, the handrail of the upper run of the floored over eastern staircase is missing, as are the railings at the common upper landing that continued around the rest of the upper part of the stair well.

Excluding the missing railings, at least 90 % of the existing staircase components are present and usable. It is intended to eventually remove the remaining vestiges of the 1926 toilet rooms over the staircases and to disassemble and restore the staircases.

***Interior of the gate control room:*** One 23 foot by 40 foot, room occupies the entire upper level of the building. It is illuminated by eight tall arched windows, making it brightly lit compared to the unlit bulkhead chamber or even the top-lit vestibule below. Five of the windows are above the staircases and three face south across the often shimmering, glinting water of the reservoir. As built, the room's plastered ceiling was generously coved into plastered walls below. Based upon the one surviving example of original moldings, the window surrounds had faux-grained trim and paneling. The center north window at the head to the staircase still retains the original grained-painted wood architrave trim, an indication of the formal elegance of this interior space. On the center of the west wall was a now-missing marble dedicatory plaque. In the center of the room, between the railings around the chamber and stairwells, there would have been a coal stove, connected by a long horizontal stovepipe to the flue in the west wall. The upper level doors were in pairs with each leaf only 18" wide, to clear the railing encircling the primary sets of water-filled chambers. They were not glazed.

The northern-most section of the room was open downwards into the stair vestibule and separated from it by a railing. Adjacent to that was the granite slab-floored space spanning above the bulkhead chamber. These two areas accounted for half the room. A railing surrounded most of the remaining area, in the southerly half of the space, leaving passage all around between it at the walls. Within that railing the visitor could observe water welling up at the reservoir end of three parallel sets of water filled gate and screening chambers, then flowing through screens (after 1856 through rotary screens), and passing on towards the fittings in the bulkhead that fed

the three water mains leading to the city's three distribution reservoirs. The floor outside of the railing was also granite, except below the three windows at the reservoir end, where it was iron grating over three additional chambers. Below these three grates was the first set of "guard gates" that were open when water was flowing, which meant that the three "composite" (bronze) lead screws which controlled the gates would normally have been in the raised position with their top end several feet above the floor level. Three similar screws operating the second set of "regulating gates" were inside the railing, next to the screens, and would normally have been in the lowered position.

The three large windows on the pond end assured that strollers on the peripheral path could see inside, even if the building was closed.

In the 1926 conversion (discussed below) the railings around the wells were removed. Some floor grates spanning the chambers inside the railing also seem to be missing. It is not known whether the floor grates below the reservoir end windows are missing or not because that location is covered with the current floor.

Except for some small areas at the head of the stairs and in the eastern toilet room, all of the plaster is now gone. Most, perhaps all, of that loss has been attributed to the leaking gutters. There is no plan to restore the plaster except, perhaps for a limited section to show what was originally there. Eventually the present non-historic flooring will be replaced. Because of the need to protect the roof and stairs from excessive moisture a solution to stabilize humidity levels must be developed.

***The iron roof surface and iron roof trusses:*** As the roof was originally only visible from outside, the roof, gutters and roof trusses are all discussed together, above.

*Gate and screening chambers:* Below the present temporary plywood floor, there are ten interconnected, largely water filled, 26-foot deep chambers. An inlet tunnel leads to the gatehouse from the lowest part of the reservoir at the base of the dam. A crosswise distribution chamber at the end of the tunnel lies just outside the full width of the building's south wall. It is has narrow access openings from above (in the narrow walkway between the rear of the building and the edge of the reservoir) and is fitted with slots to permit the insertion of stop logs or trash racks. Stop logs are modular planks that can be dropped horizontally into stop log slots and stacked to control the level of water flowing over them or to block the flow entirely. Trash racks are course screens or grates, intended to prevent larger material from entering the system. They can be dropped into the same slots. The openings in the walkway giving access to the chamber are now covered with aluminum diamond pattern plates — originally there were iron grates. Although this distribution chamber is partly partitioned into three sections, corresponding to the three arched inlet openings into the building, the walls between the sections are only structural buttresses.

The three arched inlet openings admitted water from the distribution chamber into three "guard gate" chambers just inside the west wall. On the downstream (north) side of the bottom of each guard gate chamber is another opening that can be closed by a vertically sliding iron "gate," operated from above by a screw, for controlling or stopping the flow of water. Its location on the downstream side of the chamber assured that water pressure would create a seal when the gate was closed. The tops of the three guard gate chambers were originally covered by iron floor grates.

The guard gates were normally open and water flowed through them into three "regulating gate" chambers whose gates — also on their chambers' downstream sides — were normally closed. Unlike the guard gate chambers the top of the walls between the regulating gate chambers do not reach full height. Removable segmental partitions made up of modular of "stop-logs" atop the less-than-full-height masonry partitions

between them, could allowed the three regulating gate chambers to be united into a single cross-wise distribution chamber fed by the by-pass conduit that ran under the embankment on the northwest side of the reservoir from the upper gatehouse. When so used, this crosswise distribution chamber was undivided down to the depth of the "invert" (bottom) of the by-pass aqueduct.

Downstream from the guard gate chamber was the inlet chamber from which the water flowed into the mains feeding the city's three distribution reservoirs. The walls between each regulating gate chamber and its inlet chamber also do not reach full height. Originally they would have been fitted with a screen to keep fish and other debris out of the system. These screens would have been cleaned from an iron grating catwalk above them, either by removing objects while they were pressed against the screen by the flow of water and/or by shutting off the water and lifting the screen out. There is no evidence of any sort of lifting device for the screens and stop-planks, either in the building or on the 1849 drawings. All the lifting and cleaning would have been done from the grating catwalk above the screen chamber.

Around 1856, squirrel-cage-like, drum type screen devices of about 7'-3" in diameter, which could be cleaned without interrupting the flow of water or lifting them out, were fitted into each of the final chambers. The City of Boston's annual auditor's report for 1857-58 includes the following note with reference to the Brookline Gatehouse: *" . . . the new circular screens were put into the gate house . . . Leaves, rubbish, and fish are much more easily removed from them than from the upright ones. They can also be more easily repaired when necessary."*[10]

In the center of the side walls of each screen chamber are vertical grooves, like those for stop-planks or screens (Some of these grooves are either damaged or not well cut.) They terminated, not far below the present water level, in an apparently bronze fitting that was a bearing axel mount for the screen. The top-most portion of the side-walls of the screen chambers has a thin lime-like coating. (It is also on the exposed upper south wall of the cross chamber where it appears to be flaking-off.) On the side walls of the screen chambers there is a clear demarcation line between this surface and the granite below, for the full length of the walls. The middle of this demarcation edge arcs upwards, with the arc centered on the pivot point. Just below the top edge of this arc is a series of holes, suggesting that there was a former circumferential metal fitment related to an edge seal that was on the screen drums. Some distance below the pivot, lying close against both side walls of the center chamber there appear to be iron support bars with long-radiused, downward-arced upper surfaces that must relate to the shape of the screen once mounted above them. This is visible, if not very intelligible, in underwater video images. In addition to screens, there were originally also flow meters for each pipe; nothing is known about where they were located.

As described above, when stop-log walls were in place between the regulating gate chambers, the three fully separated sequences of chambers directed in-line water flows from the inlet tunnel through the screen chambers and into the water-mains leaving the building. For normal operation the regulating gate chamber's outlet gates would be closed and the water would rise up through that chamber and over the sill atop its east side wall to pass thru the screen and then on down into the pipe at the bottom of the chamber. This makes sense in terms of easy access to the screens for cleaning. However, it would only work if the reservoir was assumed always to be full — which is inconsistent with the reservoir's role as a reserve in case the aqueduct was shut down, which did happen periodically.

Presently the gates of the side chambers are closed and those chambers are semi-filled with fallen plaster and debris from the 1926 conversion (discussed below). The condition of the chambers has been recorded on disc

[10] *Auditor's Forty-Sixth Annual Report of the Receipts and Expenditures of The City of Boston and the County of Suffolk for the Financial Year 1857-58* (Boston, 1858) p. 215

by a video-equipped remote controlled mini-robotic submarine. The screws for the two center chambers' gates are in the raised position but it appears that the gates have become detached. One is half fallen, still allowing for the passage of water in the event the reservoir would need to be drained. The other had a hole torched into it with an underwater torch in the mid-1980s. The center gate chambers are reasonably clear from debris because they were cleaned out in the mid-1980s. (Discussed below.) One vertical screen, presumably postdating 1903, remains in the central chamber.

***Later history of the Brookline Reservoir:*** Boston's requirement for water soon outstripped the capacity of the Cochituate Aqueduct and Brookline Reservoir. By 1870 the much larger Chestnut Hill Reservoir had been built about a mile away. Its two basins flanked and received the water flow of the Cochituate Aqueduct, as well as receiving water from newer Sudbury Aqueduct. From then on, any water flowing through the Brookline portion of the Cochituate Aqueduct to the Brookline Reservoir came from the Chestnut Hill Reservoir. Shortly thereafter a new 48" main connected the Chestnut Hill Reservoir directly with the three pipes feed by the Brookline Reservoir, which was thus bypassed and became a backup reservoir.

By the end of the century a new Metropolitan Water Works and Sewerage Board was established. It acquired those parts of Boston's water supply system outside of the city that were then still in use. The Brookline portion of the Cochituate Aqueduct and the Brookline Reservoir were left in the possession of Boston, which soon declared them surplus. To protect the site and prevent its development, in 1903 Brookline bought the reservoir for park use. The price was $150,000, of which $50,000 was raised by Brookline residents, including not a few nearby property owners.[11] The surrounding fence was soon removed.

Integrity

In 1926 the interior of the gatehouse was modified by the town to support the swimming and skating activities which it sponsored at the reservoir from 1903 until as late as the 1960s. The conversion floored over the eastern set of iron stairs with a men's toilet room. As noted above, in the process the stairs were damaged by the instillation of plumbing; by the removal their upper handrails; and possibly by corrosive fumes from a water heater below that staircase. The space above the lower run of the stairwell containing the western staircase was floored over for a smaller women's toilet room. A wood floor was installed over the water-filled chambers containing the gates. Also, the gate-screw operating pedestals and the railing around the combined chambers were removed. It is likely that the main space was partitioned to provide changing rooms for swimming as well has a warming room for skating. A concrete dock was also built at the head of the path leading up from Warren St. Skating continued there until a rink was constructed in the town's Larz Anderson Park in the 1950s. There were swimming races from the dock every Fourth of July into the 1950s and during that time the reservoir was also used for swimming when the Brookline's "town tank" (indoor swimming pool) was out of commission.

After World War II there was a proposal for a War Memorial Recreation Center of some sort in the park and a perhaps related one for a swimming beach on the shallow end of the Reservoir. Nothing came of those plans, but in 1955, the fishing-oriented "Sportsmen's Club of Brookline" began using the building as its "club room." The town's annual reports for 1955 and 1956 indicate that they "redecorated the entire interior" making a "complete transformation," and installed electric lights — and added the sign over the front door. In 1952

[11] The Brookline resident contributors included: Ernest W. Bowditch, civil engineer and land planner; Charles C. Soule, publisher and national library movement activist; Barthold Schlesinger, sometime German Counsel; Amy Lowell, poet; George B. Harris investment banker; Henry Varnam Poor, attorney, editor, reformer, financial analyst, founder of Standard & Poor; John C. Olmsted, neighbor and landscape architect; Dr. Walter Channing, client for H.H. Richardson's only Brookline building; Edward Atkinson, abolitionist, founder of the Anti-Imperialist League which opposed the Spanish-American War; Moses Williams, attorney, legislator, banker.

incorporation papers for the club had been filed with the Secretary of the Commonwealth. The club used the building at least into the 1960s but was inactive by sometime in the 1970s.

At some point water ingress into the building from failed gutters seriously compromised the ends of the iron trusses and led to the loss of virtually all the original plasterwork and half of the wood doors and windows. As the failed gutters were repaired at least twice, the loss of some or all of the plaster might have predated the Sportsmen's Club's "redecoration." The fact that part of the 1926 floor, and perhaps any partitions above it were found to have rotted sufficiently to have fallen into the water filled chambers by 1984 suggests substantial ingress after the Sportsmen's Club era. In the mid-1980s a new temporary plywood floor with an access opening was installed. (Some of the 1926 floor remains in situ below the new floor.) Despite 25 additional years of leaking gutters, the new temporary floor appears to be sound.

Because Rosendale mortar was used, the masonry is generally in very good condition. While 90% of the trusses' fabric is sound, most of the trusses are seriously compromised at their ends. The roof system as a whole is also compromised by the failure of the clips that attached the trusses' top chords to the roof and thus braced the trusses against buckling.

As noted above, restoration of doors and windows is ongoing. In 2009 a Historic Structures Report was undertaken, jointly funded by the town of Brookline and a grant for the Massachusetts Historical Commission.[12] It proposed a methodology for repairing the roof.

The Principal Gatehouse of the Cochituate Aqueduct together with the aqueduct's terminal reservoir and its original park-like setting constitute a remarkably intact and technically important landmark in the development of American urban infrastructure technology and architectural technology, particularly with respect the gatehouse's structurally efficient and efficiently fabricated wrought iron roof trusses, its self-spanning wrought iron plate roof, and its iron staircases — all early examples as well as the oldest surviving examples of their kind in the U.S. Over the last decade, the building's internal gutters have been covered and secured from leaking. There is an ongoing program of authentically restoring the doors and windows using traditional materials and techniques based on existing components. The roof structure also has been shored to secure it against extremely heavy wet snow loads, and the Town of Brookline has included funds in its long term capital budget for permanent roof structure stabilization.

[12] Structures North and EYP *Brookline Reservoir Gatehouse Conditions Assessment Report*, (Brookline: July, 2009) includes a detailed analysis of the roof, stairs, and masonry as well as CAD drawings.

## 8. STATEMENT OF SIGNIFICANCE

Certifying official has considered the significance of this property in relation to other properties:
Nationally: X Statewide: _ Locally:

| | |
|---|---|
| Applicable National Register Criteria: | A_ B x C x D |
| Criteria Considerations (Exceptions): | A_ B_ C_ D_ E_ F_ G |
| NHL Criteria: | 4 (architecture and engineering) |
| NHL Theme(s): | Expanding Science and Technology: technological applications |
| Areas of Significance: | Architecture; Engineering; Community Planning and Development |
| Period(s) of Significance: | 1846-1848 |
| Significant Dates: | 1848 |
| Significant Person(s): | |
| Cultural Affiliation: | |
| Architect/Builder: | John Bloomfield Jervis, feasibility and system specification engineer of the aqueduct; Ellis Sylvester Chesbrough, chief design and construction engineer of the aqueduct; Charles E. Parker, architect of the principal gatehouse of the Brookline Reservoir; Ebenezer Johnson contractor for the gatehouse |
| Historic Contexts: | XVIII. Technology (Engineering and Invention)<br>K. Water and Sewerage |

**State Significance of Property, and Justify Criteria, Criteria Considerations, and Areas and Periods of Significance Noted Above.**

The Brookline Reservoir and its Principal Gatehouse is of national significance under Criterion 4 because of its contribution to our understanding of the development of early nineteenth water supply systems and how such systems were designed to inform the public. The Principal Gatehouse is also nationally significant as an early surviving example of the use of iron in architecture and engineering. Constructed as part of Boston's Cochituate Aqueduct (NR, 1989), the property includes the most intact original (1846-1848) component of the water supply system that served the City of Boston. The rapid urban expansion of the of nineteenth century American cities was impossible without an adequate water supplies and Boston demonstrated that an adequate water supply made annexation very attractive to less well supplied surrounding communities. The Cochituate Aqueduct also initiated the development of a model regional water supply system that has followed the same model to the present day, moving westwards in three stages to encompass ever larger and more pristine catchment areas: the Sudbury River aqueduct of 1870-75 and its system of seven reservoirs; then the Wachusett Dam and Reservoir of 1897-1905, the largest of its kind in the world when constructed; and finally the Quabbin Reservoir of 1930-39. Because of the policies begun in the 1840s with the decision to build the Cochituate Aqueduct, today no major U.S. metropolitan area has as a comparable source of unfiltered, minimally treated pure water and Massachusetts Water Resources Authority remains a national model metropolitan water and sewer system. The Brookline Reservoir remains as the most intact visible component that represents the original system completed in 1848.

The Cochituate Aqueduct was designed by two pioneering engineers, John B. Jervis and Ellis S. Chesbrough, was the second major U.S. municipal aqueduct and the earliest surviving. In the case of the Croton Aqueduct, the only earlier major U.S. municipal aqueduct, which was also designed in part and built by John B. Jervis, the original reservoirs at both its upper and lower ends have been lost, only the aqueduct itself remains. The Cochituate aqueduct and both its reservoirs are intact, with two exceptions: a) a short elevated street crossing section at Cedar St. in Wellesley and b) the two terminal gatehouses of its inverted-siphon crossing of the Charles River, one of which was lost in an 1859 accident. The inverted-siphon's 165-year old iron pipes, still carried on their triple arched granite bridge, remain in service, repurposed as a regional sewer connector. In Wellesley the aqueduct has been repurposed as a conduit for utilities. Elsewhere it still carries drainage water and the overflow from Lake Cochituate, which is now a state park. Those non-tunnel sections of the aqueduct that exist in their own rights of way, are walking trails in Wellesley and part of Newton, and those trails are being extended.

Although the entire Cochituate Aqueduct system is listed in the National Register, the most significant component is the Lower or Principal gatehouse of the aqueduct's Brookline Reservoir. Despite the loss of its interior plaster finishes, it retains a high degree of integrity of location and setting which are almost unchanged, of design, material and workmanship (with the iron trusses visible as they were not before) and association. Its wrought iron roof truss system is the oldest extant in the U.S., a distinction further accentuated when considered with the oldest wrought iron plate roof together with the oldest extant U.S. cast iron staircases intended for public use (all unmoved in their original setting). While an earlier example could exist, there appears to be no identified other surviving pre-1848 U.S. wrought iron roof trusses or structural iron roof decks.[13] Taking the known extant European examples into account, these are among the twenty oldest known surviving wrought iron-roof trusses anywhere. Although eventually forgotten, these stairs, and more so, the building's "iron roof," were significant and noted at the time.

[14] Many minds and various shared visits to the Brookline gatehouse contributed to an increasing knowledge of this important structures. Sara Wermiel confirmed an initial suspicion of the significance of the iron roof, and then noted that its staircases were comparably early examples of their type.

Two other early municipal water supply aqueducts are NHLs. The earlier is the surviving portion of New York's "Old Croton Aqueduct," completed in 1842 and also associated with engineer John B. Jervis. Now missing its original reservoirs and principal gatehouses and, like the Cochituate, no longer in service, it was designated an NHL in 1992. The Washington Aqueduct in Georgetown, District of Colombia, was begun in 1853 and put in service in 1864, and in its present form is still in use with the modifications and additions that have necessarily been required, was also designated an NHL in 1973.

**Historical Context**

Compared to New York's 1837-42 Croton Aqueduct (NHL), its only U.S. predecessor, Boston's 1846-48 Cochituate Aqueduct is less well known and less studied, even though its terminal features survive largely intact. Given Jervis' involvement in the conceptual design of the Cochituate Aqueduct, it is not surprising that the two systems were operationally similar. It is clear however, that the Cochituate's use of iron in its gate mechanisms, as well as its architectural components, was more advanced. Another notable difference from the New York and Philadelphia systems, although not part of the aqueduct per se, is that Boston's water distribution system was intended from the outset to supply every property in the city.

This nomination arises from the discovery of this surviving early iron architectural technology in the Brookline Reservoir's Principal Gatehouse.[14] It notes below the European context and considers how the Cochituate examples relate to heretofore largely unknown U.S. predecessors, as well as to identified designers and fabricators. While nineteenth-century gatehouses were usually constructed of substantial masonry and employed an architectural language suggesting permanence, and sometimes monumentality, they typically simply sheltered the prosaic "gates" that regulated the flow of water, together with other utilitarian devices. They were, in effect, substantially-built sheds.

Although the Cochituate Aqueduct fed a spectacular jet of water in the Boston Common Frog Pond, which continued to play for half a century (and at a modest scale still exists), recent investigation of the Brookline Reservoir Gatehouse, together with the rediscovery of a folio of original drawings and other source material, indicates that the gatehouse was open to the public and that it intentionally shared the Frog Pond jet's honorific role as a public representation of the otherwise largely unseen aqueduct and waterworks.

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[14] Many minds and various shared visits to the Brookline gatehouse contributed to an increasing knowledge of this important structures. Sara Wermiel confirmed an initial suspicion of the significance of the iron roof, and then noted that its staircases were comparably early examples of their type.

Research included a review of surviving nineteenth century financial records of the Cochituate project in the City of Boston Archives. Not every month's Water Works vouchers or invoices for the periods of interest were in the many partially organized, unindexed storage boxes covering the periods of interest.

For the construction period, the surviving documents (standardized payment vouchers) are not always very informative. Edwards & Holman, a maker of fireproof safes, was paid for "iron doors, gates, and crates." Iron doors could have been on buildings such as the Brookline Reservoir's small inlet gatehouse. "Iron work" was an unusual description and might have included the Brookline iron roof structure. Other vendors of "iron work" were Walworth & Nason, a pioneer in central heating systems; Hittinger & Cook, who advertised everything from steam engines to iron fences to ice harvesting tools; Shepply Kimball for "iron works materials"; and just one for "D. Safford" (an old name for Smith & Lovett), which may well have been the transaction for the iron stairs. Other identified local vendors of iron pipe and machining work could have fabricated the roofs. These included South Boston Iron Works, which built everything from lighthouses to cannon; the Lowell Machine Shop, which built canal lock gates, railroad locomotives, and mill machinery; and the Ballard Vale Machine Shop, which made a similar range of items. Vendors of pipe and castings from outside of New England that could have provided the roof components included Merrick & Towne of Philadelphia, whose predecessor firm built an iron roof there in the mid-1830s. (Discussed below.)

Virginia E. Jacobs, who also did other research, and Lori Ferris assisted in the search through the banded packets containing thousands of pigeon-hole sized folded paper slips. Neither the City of Boston Archives, the Boston Public Library, nor the Boston Water & Sewer Commission knows of any additional original relevant documents.

In addition to the building's high standard of interior and exterior architectural embellishment, it had and still possesses both an "iron roof" (a contemporary term then applicable to its continuous wrought-iron roofing surface and, even more so, to the wrought iron trusses supporting it) and a then-equally unusual, symmetrical pair of cast-iron staircases. The Lake Cochituate inlet gatehouse retains a wrought iron roof truss system of an entirely different design, which however never had the possibility of being as influential as it was never open to the public.

Until now, the little known, long lost, wrought-iron roof trusses of the Philadelphia Gas Works' retort houses were the only recognized earlier U.S. examples. The preparation of this nomination has for the first time identified in the literature of the period, or recognized as significant, six additional 1848 or earlier, now-lost U.S. "iron roofs." Also newly recognized here is a slightly later surviving iron roof that predates the oldest previously recognized surviving U.S. example. At least six of these now-identified early iron roofs were entirely wrought iron, two combined cast and wrought iron. Significantly, regarding the later diffusion of iron architectural technology, the two earliest such roofs on non-industrial buildings were in or near Boston.

Some earlier, wholly or partially iron U.S. staircases, also mostly identified for the first time, are discussed below, again to make the context more understandable. This nomination establishes a clear link between the Cochituate staircases and those in the Boston Athenaeum. Also, a circumstantial link is suggested between those buildings and the Middlesex County Courthouse, the first building by the influential architect Ammi B. Young to make significant use of iron.

***A note about the Cochituate Aqueduct's Upper or Influent Gatehouse***

The Aqueduct's Upper or Influent gatehouse is located 15 miles away on Lake Cochituate, which was a remote, not readily accessible, setting in 1848. It has an iron roof structure of a totally different design that never supported an iron roof deck. It also has stone steps, a plain brick interior, and clearly was not intended to be visited by the public. In 1859 the building was disassembled and reassembled on the same site but at a slightly higher elevation when the dam was raised. Some components were replaced, although the present roof structure is probably the original. However, there is no indication that the more limited use of iron in the remote Lake Cochituate gatehouse roof had a comparable potential to influence the evolving architectural use of iron. Also, as will be discussed below, its roof structure was arguably not as forward looking in its design and fabrication. The Lake Cochituate Gatehouse is not a subject of the present nomination and is only considered here as part of the context of the Brookline Principal Gatehouse.

The Cochituate Aqueduct

On October 25th, 1848, one hundred thousand people gathered on Boston Common to see a 90-foot high column of water from the Brookline Reservoir of the Cochituate Aqueduct gush into the air from the Frog Pond.[15] The Brookline Reservoir was the terminus of the fourteen-mile long Cochituate Aqueduct, Boston's first public water supply aqueduct, and after New York's 1837-42 Croton Aqueduct, the second major municipally owned U.S. aqueduct. (Philadelphia's earlier public water system did not involve an aqueduct. It drew water from the adjacent Schuylkill River and pumped it.)[16] Prior to 1848 Boston's only reservoir was

[15] On the Water Celebration in particular and the project as a whole, see: "The Water Celebration" *The Boston Post*, (Tuesday Evening, Oct. 24, 1848); "The Water Celebration" *Daily Evening Traveller*, (Tuesday Evening, Oct. 24, 1848); "Cochituate Water" *The Boston Harold*, (Oct. 25, 1848); "The Water Celebration" *Daily Evening Traveller*, (Thursday Evening, Oct. 26, 1848); "Grand Celebration of the Introduction of Pure Water into the City [etc.]" *Evening Transcript*, (Thursday Evening, Oct. 26, 1848).

[16] Martin V. Melosi, *Precious Commodity: Providing Water for America's Cities*, (Pittsburgh: University of Pittsburgh Press, 2011), 49-51. Roger W. Moss, *Historic Landmarks of Philadelphia*, (Philadelphia: University of Pennsylvania Press, 2008), 74-78.

Jamaica Pond, which along with a limited wooden pipe distribution system, belonged to a private company. But for the severe financial panic of 1837 Boston's waterworks might have been built years earlier. The Cochituate Aqueduct cost $1,720,000, Boston's greatest public investment to that time. The entire aqueduct and distribution system required no pumps.

The aqueduct's three major above-ground structures were the Infuent Gatehouse at Lake Cochituate, Echo Bridge carrying the aqueduct (in inverted siphons) over the Charles River (built 1875-1877 NR), and the Principal Gatehouse of the Brookline Reservoir. Being a true aqueduct, the system operated by gravity, dependent on the difference in height between Lake Cochituate and the distributing reservoirs on Beacon Hill and elsewhere in Boston. There were no pumps. Like the ancient Roman aqueducts, the Cochituate Aqueduct was a man-made stream, carefully engineered to a gradual consistent slope of three and one-half inches per mile.[17] For most of its length it ran as below-grade brick conduits and unlined rock cut tunnels. It was large enough to allow the passage of a small boat for inspections and could deliver ten million gallons of water per day.[18]

In two places, where the Romans would have been required to build the sort of above-ground multi-arched structures that are popularly associated with aqueducts, Boston's engineers had the advantage of pressure-containing iron pipe. It allowed them to build inverted-siphons to carry the water down through, rather than over, low areas and back up to almost the same height on the other side, without pumping. One such place was the Charles River Valley between Newton and what was then part of Needham, now Wellesley, where three parallel pipes went down 52 feet and back up again. The others were from the Brookline Reservoir to the reservoir atop Beacon Hill, as well as two other reservoirs in Boston. A pipe went down 120 feet, to sea level in the Back Bay before going back up to the Beacon Hill Reservoir which was only four feet lower than the Brookline Reservoir.

**The Brookline Gatehouse as the Aqueduct's Frontispiece**

The Brookline Reservoir Principal Gatehouse controlled, screened, and measured the flow of water from the reservoir into three large cast iron pipes that supplied Boston's distribution reservoirs. The "gates" are iron plates moved vertically, to control water flow, by "composite" (bronze) nuts turned by handwheels that lift and lower non-rotating threaded bronze rods attached to the gates.

Significantly, the Principal Gatehouse also offered public access to the promenade around the then fenced-in reservoir, as illustrated in an 1853 issue of *Gleason's Pictorial Drawing Room Companion.*[19] Captioned "Large Reservoir at Brookline," it showed fashionably dressed citizens promenading around the reservoir. Except for the missing fence (referred to as a "stockade") that then surrounded it, the reservoir today looks almost exactly

[17] A fall of three and one half inches per mile is an extremely flat gradient — a design decision that must have been made by Jervis. The Croton aqueduct had a fall of 13 inches per mile, which was comparable to other later-nineteenth century aqueducts. Per Marcis Kemp of the Massachusetts Water Resources Authority (MWRA), this was necessitated by the relatively small fall available from the reservoir at the upper end of the aqueduct to the Brookline Reservoir if its water was to reach the height of the reservoir on Beacon Hill. The slower water flow of this flatter gradient necessitated a larger aqueduct in relation to the rate of water delivery.

[18] Two sections were tunneled through "hard rock" (puddingstone), one in Newton and one in Brookline. However, for most of its length it was an egg shaped, brick tube following the contours of the land and not too deeply buried. When cut through a hill, the cutting was not always back-filled but was sometimes left as an excavated defile — which, after 160 years, is not as regular in shape nor as self-evidently man-made as those bermed sections that occur where the aqueduct runs above the original grade. An above-grade section can be seen in Brookline, where the small Webber's Weir Gatehouse sits atop it. See Appendix A for a description of the course of the Aqueduct from Lake Cochituate to Brookline, i.e., Wayland to the Brookline Reservoir.

[19] "Brookline Reservoir" *Gleason's Pictorial*, July 16, 1853.

as it did in the nineteenth century. It provides the most important element of the gatehouse's context, and directly connects it to the smaller gatehouse marking the terminus of the aqueduct itself.

Internally and externally the gatehouse was the elegant, substantial, architectural frontispiece of this largely hidden, engineering project and major civic investment — much as Renaissance Rome's aqueducts were terminated by architectural fountains. The fountain role was fulfilled by the jet of water rising from the Frog Pond, with no sculptural or architectural embellishment. Through the late nineteenth century, views of the Common and birds-eye views of Boston showed the Cochituate Fountain jet rising to as much as a reported 92 feet, although it probably spouted only on special occasions. There was a set of interchangeable nozzles. Although no longer remembered as such, the more modest spray fountain in the Frog Pond still marks its location. There were also a few, relatively small, cast-iron "Cochituate" fountains erected in Boston's public green spaces following 1848.

The gatehouse's iron roof surface was externally visible — smooth, virtually seamless, and painted verdigris green. Internally, the iron trusses, the true "iron roof," were unseen above the plaster ceiling. At the time, "iron roof" (as distinct from "tin roof" or "metal roof") typically referred to the supporting structure, regardless of whether it was cast or wrought iron, rather than to its covering weather surface. "Iron roof" was comparable to "timber roof," which invariably referred to a timber roof structure. No early written reference to the Brookline trusses, other than to the "iron roof" has been found. Only one reference to the gatehouse staircases as being of iron has come to light.[20]

Inside the building, opposite the street-level front entrance, a smooth, granite wall contains an unembellished archway closed by a pair of massive, metal studded, verdigris green wooden doors. These swing open into a deep chamber of rock-faced granite, spanned by granite slabs. A 26-foot high bulkhead wall seen through the archway holds back the reservoir. Passing through this wall are three large pipe-like iron fittings, flared at their inlet ends. They mate with pipes passing through the chamber that supplied Boston's water.[21]

Flanking the arched opening is a pair of delicately pierced cast iron staircases, whose symmetrical formality is consistent with the importance of the gatehouse. These lead to the main room above and to the promenade around the reservoir. The plastered upper-level room was illuminated by eight large windows, of which five are above the staircases. On the center of the north wall was a marble dedicatory plaque. The iron staircases are the earliest known surviving U.S. examples intended for public use. There are relatively few earlier in Europe.[22]

**The Engineers and Architect**

***John Bloomfield Jervis (1795-1885)*** — In May 1846 Boston's Water Commissioners hired Jervis to develop a conceptual design for what would become the Cochituate Aqueduct, including its source, route, and storage capacity, because he had designed and overseen construction of New York's 1837-42 Croton Aqueduct — although its route had been surveyed and conceptually designed by another engineer. Jervis initially gained his engineering education working on the construction of the Erie Canal. He started as a surveyor's axman and

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[20] Bradlee, *History of the Introduction*, 251.

[21] Boston Water Works payment vouchers from the original construction period indicate iron pipe was purchased from as many as two-dozen vendors — many of which do not appear in city directories under the names shown on the vouchers. Some apparently were interrelated companies or brokers. Major vendors included South Boston Iron Co., Lincoln Drake/New Market Iron, Lowell Machine Shop, Ballard Vale Machine Shop, and Merrick & Towne of Philadelphia (a firm discussed in another context below), with the latter alone supplying upwards of nine thousand tons.

[22] David S. Mitchell, Head of Conservation Research and Resources for Historic Scotland, an expert on nineteenth century British cast iron construction has communicated that the stairs do not look British. If British, they would have carried foundry and/or design registration markings.

eventually became a divisional superintending engineer. The Erie Canal's method of contracting out many small sections, supervised by engineers hired by a commission, was carried over to the Croton Aqueduct and then to the Cochituate. Jervis was also an engineer of railroads; in 1830 he had designed "the Experiment," the first U.S. steam locomotive with independently pivoted leading wheels (the so-called 4-2-0 configuration) for operation at speed on curves, which became the standard U.S. type for decades.

In his memoir Jervis refers to "drawings and papers I have sent for deposit to the American Society of Civil Engineers."[23] Today it has no such collection. Jervis also endowed the Jervis Public Library in Rome, NY. It incorporates his own house, which he designed, and has a substantial archive of his books, drawings, and letters. Inquiries suggest that most likely these are the materials said to have been donated to the American Society of Civil Engineers.[24] It is a substantial archive of material from throughout his career, including drawings labeled "metal roof" which were only metal cladding over wood. None of those hundreds of drawings appear to be directly related to the Cochituate Aqueduct but there are some for the Croton Aqueduct. Although the two projects were similar, there were significant differences. The construction shown in the Croton working drawings seems less sophisticated in its detailing, especially of some of the masonry.[25] It also used more wood and less iron. Jervis Library drawing #189 "Elevation of regulating gates at Croton Dam" shows a massive wood cross-beam supporting rack and pinion lifting mechanisms with the racks attached to wood lifting rods reaching into the water to the gates. The Brookline gates use stationary lead screws with bronze lifting nuts similar to modern mechanisms, mounted on substantial cast iron beams, all still in good condition, although not usable. In the Jervis drawings the larger gatehouse roofs are of wood covered with tin.

Jervis had minimal involvement with the Cochituate project after the initial feasibility consultation stage and was only a "consultant" during its construction. At that time he was fully engaged in pushing what would become the mainline of the New York Central Railroad up the east bank of the Hudson River.[26] Design and construction of the aqueduct and the distribution system within the city were divided respectively between two younger engineers, E.S. Chesbrough and W.S. Whitwell. Nonetheless, Jervis received a $3,000 per annum salary during that phase, which equaled each of their salaries.[27] It is reasonable to assume that Chesbrough and Whitwell, most likely would have been familiar both with the Croton Aqueduct and Reservoirs and with Jervis' drawings.

***Ellis Sylvester Chesbrough (1813-1886)*** — Chesbrough was chief engineer for the design and construction of the Cochituate Aqueduct, including the Brookline Reservoir. He too began as a surveyor's chainman, on the Baltimore & Ohio Railroad (B&O) and other lines, working under railroad construction engineers such as Capt. (later Gen.) William Gibbs McNeill and Lt. (later Major) George Washington Whistler. As the principal engineer, Chesbrough was ultimately responsible for the specification and/or design of the gatehouse's iron roof structure. Later he went to Chicago, where he undertook his best-known work, building a two-mile long tunnel under Lake Michigan to supply Chicago's drinking water and creating an elevated sewer system, which required lifting up entire city blocks of buildings in the Loop. His work also led to the reversal of the sewage-

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[23] Neil Fitzsimmons, ed., *The reminiscences of John B. Jervis, Engineer of the Old Croton*, (Syracuse: Syracuse University Press, 1971), 128.

[24] Lori Chein of the Jervis Public Library generously assisted with access to the Jervis archive. Both the drawings and letters are indexed on the Jervis Library web site and some drawings can be viewed on line. (http://www.clrc.org/digital/jervis/jervisindex.htm Accessed June 19, 2007) Only two indexed letters relate to its construction phase.

[25] Kevin Bone, Gina Pollara, and Albert F. Appleton, *Water-works: the architecture and engineering of the new York City water supply*, (New York: the Monacelli Press, 2006), also reproduces some original Croton Aqueduct drawings from the archive of the New York City Department of Environmental Protection.

[26] Communication from Prof. F. Daniel Larkin, author of *John B. Jervis: An American Engineering Pioneer*, (Syracuse: Syracuse U. Press, 1971)

[27] Bradlee, History of the Introduction, 95-96.

laden Chicago River, so it no longer fouled Lake Michigan but rather flowed through a canal towards the Mississippi.[28]

***William S. Whitwell (1809-99)*** — Whitwell, another former railroad construction engineer, oversaw the Eastern Division of the project which, beginning from its connection to the Brookline gatehouse, included all the pipes in Boston and distributing reservoirs on Beacon Hill and elsewhere in the city. An obituary credits him as the designer of the then much admired (now demolished) fortress-like reservoir on Beacon Hill, although possibly that may have been more with respect to the structure's engineering than its architectural refinement.[29] Whitwell's family and that of S.V. Merrick, who built in Philadelphia the first documented U.S. wrought iron truss roofs (discussed below), were both from Maine, where the families were closely connected. Whitwell's sister, Lucy, was married to William Parker, also a railroad engineer, who had previously worked closely with Whitwell and in 1849 became superintendent of the B&O Railroad. While there is no self-evident technical or other close link between the Philadelphia and Cochituate Aqueduct roofs, in 1835, with Merrick's roofs planned, if not under construction, Lucy Whitwell Parker visited Mrs. Merrick in Philadelphia. It is thus plausible that Whitwell (and thus also Chesbrough) directly or through Parker knew, more than casually, of Merrick's roofs.[30] There doesn't seem any obvious familial connection between the architect Charles E. Parker and the engineer, William Parker.

**Charles E. Parker (1826-89)** — Parker was architect of the Principal Gatehouse. Trained by both Richard Bond, with whom he was later briefly in partnership, and Gridley J.F. Bryant, Parker had only the previous year listed himself as an architect.[31] His connection with Bond (discussed below) suggests him as possible designer of the gatehouse's iron roof. The design of the building's complex, water-filled chambers was probably closely overseen by Chesbrough. The same may have been true of the roof structure, although given the significant differences between the aqueduct's two iron roofs, that is not so clear. Parker is the only architect identified with any part of the Cochituate project. For designing the "architectural" part of this relatively small building, and perhaps attending to its excellent stonework, he was paid $500, then a substantial fee for that size building.[32]

**Contractors and workers**

Following the model of the Erie Canal, multiple contracts were let for various section of the project — and notably, given the date, a number of Irish names appear among the contractors. The contractors ranged from individual carters to major contractors, like Ebenezer Johnson, who collectively built the gatehouse. Contrary to the experience of New York's Croton Aqueduct, as well as some of Boston's later waterworks projects, there is no evident record of labor difficulties during the construction of the Cochituate Aqueduct. Conditions were particularly difficult in several locations. For three-fourths of a mile the aqueduct followed the course of Snake Brook, lying some 20 feet below the brook's normal water level; there were periodic overflows and collapses due to quicksand and five steam pumps with a total capacity of 12 million gallons/day supported round the

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[28] "Ellis Sylvester Chesbrough" [obituary], *Proceedings: American Society of Civil Engineers*, Nov.-Dec. 1889, 160. *The National Cyclopedia of American Biography* 9, (New York: James T. White & Co., 1899), 35-36. Louis P. Cain, "Raising and Watering a City: Ellis Sylvester Chesbrough and Chicago's First Sanitation System" in *Sickness and Health in America*, Judith Walzer Leavitt and Ronald L. Numbers, Eds., (Madison: University of Wisconsin Press, 1978), 531-39.

[29] Francis Blake and Ernest W. Bowditch "William Scollay Whitwell" [obituary], *Journal of the Association of Engineering Societies* 24, (1900), 233.

[30] A lengthy genealogical/memoir letter dated "Brookline, October 1890", addressed to "My Children," published on the internet as "The Diary of Lucy C. Whitwell Parker" (http://www.bambinomusical.com/Scollay/Diary.html, Accessed Nov. 25, 2008)

[31] Roger G. Reed, *Building Victorian Boston: the Architecture of Gridley J.F. Bryant*, (Amherst: University of Massachusetts Press, 2007), 81. James O'Gorman, *On the Boards: Drawings by Nineteenth Century Boston Architects*, (Philadelphia: University of Pennsylvania Press, 1989), 36 & 77. Reed says Parker worked for Bond before working for Bryant.

[32] Uncatalogued Water Works vouchers, City of Boston archives.

clock operations in that section. The two hard rock tunnel sections totaled 3500 feet in length and took 18 months to complete with men working simultaneously in ten tunnel sections at once. Those working the central sections, at the bottoms of shafts up to 70 feet deep, proceeded in both directions towards the adjoining sections. There too, excavation continued in three shifts, round the clock. Again, unlike reports of conditions on the Croton project, Mayor Quincy asserted that the work was "performed without the stimulus of intoxicating liquor," that "the hire [wages] of its laborers had never been kept back an hour" and that the project "had never been suspected of being used as a political engine." [33] No published accounts contradict any of those assertions.

**Wrought Iron Roof trusses and Iron Roofs**

Just as the "iron age" of the Industrial Revolution came to initial fruition in Britain, so too the structural use of iron building framing generally appeared there first. Thus, due to risk of fire, "iron roofs" for gas-works retort houses were taken as a given in the earliest British technical treatises on commercial coal gas manufacture.[34] In addition to fire, those structures were subjected to acidic gases, which may account for several reported collapses of such roofs.

Structural iron building components were generally slower to appear and be adopted in the U.S., due in part to the abundance of heavy timber and early adoption and codification of slow-burning construction for mills and other buildings. Often cited as the earliest U.S. architectural cast iron columns are those used in 1820-22 by William Strickland, to support, with minimal visual obstruction, the balconies of Philadelphia's rebuilt Chestnut Street Theater.[35] These columns appeared shortly after the first U.S. manufacture of iron pipes in New Jersey, in 1816, for Philadelphia's waterworks.[36] The mid-1830s saw the first use of cast iron façade elements in the U.S. — because they were "fireproof" and due to cast iron's ability to inexpensively mimic ornamental stone detail. In 1848 James Bogardus established his foundry and began producing cast iron facades, although initially his buildings had wood floor construction.[37] The U.S. development and production of iron facades always exceeded that of Europe, despite the large-scale British production of iron buildings and building frames. But by 1848, the longest span U.S. cast iron floor beam was still only 20 feet — less than the 23-foot interior span of the Brookline Gatehouse. Wrought iron I-shaped floor beams were not rolled in the U.S. until 1854.[38] In both the U.S. and Britain there were also some well-publicized collapses of iron roofs and whole iron-framed mills — which in the U.S. may have slowed adoption of structural iron. Two widely publicized collapses of iron-framed mills were Radcliffe's Mill at Oldham, Lancashire in 1844 and the Pemberton Mill in Lawrence, Massachusetts in 1852. The Oldham collapse came after 50 years of iron framed mill development in Britain, whereas the Pemberton Mill, which collapsed eight years later, was one of the first iron-framed mills in the U.S.[39] Slow burning heavy timber construction continued to predominate in the U.S. throughout the nineteenth century, having been codified by insurance regulations, and was used well into the twentieth century. Earlier, in 1828, the wrought iron roof of the Brunswick Theatre in London notoriously collapsed three days after it had opened. Although a wall failure may have caused it, the ensuing sensational stories focused on the roof, which was commonly described as "heavy."[40]

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[33] "Water Celebration, The" Daily Evening Traveller, (Thursday Evening, Oct. 26, 1848)

[34] E.g., Fredrick Accum, *Description of the Process of Manufacturing Coal Gas* [etc.], (London: 1819), 334.

[35] Sarah Bradford Landau and Carl W. Condit, *Rise of the New York Skyscraper: 1865-1913*, (New Haven: Yale, 1996), 22. They also note a contemporaneous example in a New York theater.

[36] Jesse Garrett, "Making Cast Iron Pipe," *Journal of the New England Waterworks Association* XI No. 1 (Sept. 1896), 40.

[37] Winston R. Weisman, "Mid-19th Century Commercial Building by James Bogardus," *Monumentum 9* (Brussels: Conseil International des Monuments et des Sites, 1973), 63-76.

[38] Charles E. Peterson, "Inventing the I-Beam [etc]" *APT Bulletin* XII No. 4, (1980), 13ff.

[39] Tom Swailes, Joe Marsh, University of Manchester, Historic Structures Group, *Structural Appraisal of Iron-Framed Textile Mills*, (London: Telford Publishing, 1998), 35 and 41 respectively.

[40] "Fall of the Brunswick Theater" *Mechanics Magazine Vol. 9*, (London) 1828: 94-95, 110-25., 134-36, 153-55, 173-74, 201-04

As will be discussed below, while the Cochituate Aqueduct's wrought-iron roof structures are important rare, early survivors, we now know they were not alone. Earlier or contemporaneous U.S. wrought iron roof structures, some reflecting inventive designs, have remained unknown or unrecognized until now. They too need to be considered, to place the Cochituate "iron roofs" into context. Some of these recently recognized American iron roofs are worthy of comparison with their better-known European contemporaries. For instance, the folded-plate roofs of the long lost Boston Merchants Exchange of 1842 and the extant Savannah Custom House of 1851, both discussed below, appear to anticipate by 100 years the mid-twentieth century explorations in ferro-concrete of folded-plate roof structures.

***Wrought iron versus cast iron***

Too often both original and more recent sources touching on the early use of iron in buildings fail to adequately, if at all, distinguish between and/or identify cast versus wrought iron. Although cast iron has only about one quarter the tensile strength of wrought iron, which can equal that of steel, it offered lower cost, decorative potential, and was excellent for components loaded in compression.[41] Unlike the entirely-wrought iron roof trusses of the Cochituate gatehouses, early structural uses of wrought-iron were usually in combination with cast iron or timber, with the wrought iron reserved for members in tension.

***"Roof truss"***

With respect to the period in question and earlier, the term "truss," where used in modern descriptions of historic roof structures, is often loosely applied to other types of multi-member, spanning structures. For the purposes of this study (and, for simplicity, ignoring lateral bracing, gussets, etc.) a true roof truss is a planer structure, of multiple linear elements, which spans between supports and collects and carries the roof loads to those supports without creating lateral thrust. Its linear elements compose a sequence of triangles arranged so that, theoretically, if there was a hinge at each joint (in the plane of the truss), the truss would remain rigid and functional. (See the drawing attached: *1903 drawing of iron truss and rafter system of the Lake Cochituate Gatehouse*. It shows the two types of simple trusses used on that roof. Considered only diagrammatically, the lower example is like the Principal Gatehouse trusses.

With the possible exception of a trusses' top chord, which may have roof loads (absent the roof framing having purlins), as well as any ceiling loads on the lower chords, the members of such a truss should not have to resist bending moments, other than those caused by the tendency of linear structural elements in axial compression to buckle. For those unfamiliar with the terminology, the chords of a truss are the uppermost and lowermost linear sequences of members connecting the points of support at each end. The upper chord(s) is normally in compression and the lower normally in tension. Purlins are beams at right angles to the plane of the truss that rest on the hinge points ("panel points") of its upper chord(s). They both carry the roof's load to the truss and support the truss laterally to keep it from twisting out of plane or falling sideways.

An arched truss, which uses its arched form to carry the load, and its trusswork primarily for stability, is basically an arch. A Vierendeel truss of rectangular panels that depends on rigid joints, is not a true truss in this sense, nor is a structure that incorporates both an arch and a truss. Systems of rafters, including those tied by ceiling joists or collar ties or supported by knee walls or knees, are not true trusses as long as either the rafters have no intermediate truss support points throughout their full lengths or some portion of the assemblage is

[41] Margot W. Gayle et al, *Metals in America's Historic Buildings*, (Washington, D.C.: National Park Service, 1992), 130-31; Clive Richardson, "An Iron Will," *Building Conservation Directory 2005*, (Tisbury, Wilts.: Cathedral Communications Ltd., 2005), table 1.

dependent upon rigid joint connections to resist bending moments.[42] Absent complete evidence, it is not possible to say if some of the trusses or "iron roofs" identified in this study meet this definition of a truss in all respects. Technically, the Brookline trusses' short vertical members above the leveling bricks near their outer ends create a quadrilateral panel. However, they are so close to the ends that they act more as gussets might. They are a concession to the reality that those trusses could not bear at their very ends, which are approximately above the outer faces of the walls.

***Early wrought iron roof trusses in the U.S.***

Pre-1848 wrought iron truss roof technology in continental Europe was mostly used in high prestige settings (See Appendix C). Yet Britain remained both America's principal industrial trading partner and its primary technology information exchange partner. Thus, it offers the most relevant comparison. Iron roof structures were more common in Britain than on the Continent but excepting the two classes of trusses – the Tomlinson/Wellington trusses and the Euston type - noted above, most British iron roof structures continued to incorporate the less expensive cast iron for members in compression. That was consistent with the generally overwhelming use of cast iron for most British architectural iron structural applications at that time, including for beams. There is no question that in 1848 British iron production and construction technology was still in advance of that in the U.S., but during the 1850s that gap would begin closing as America more readily accepted first wrought iron, and later in the century steel, for architectural construction.

Prior to the rediscovery of the two 1848 Cochituate Aqueduct gatehouses truss roofs and of the pre-1852 Savannah roof (discussed below), the oldest known extant U.S. wrought iron roof trusses were those of William Strickland's Tennessee State capital, installed in 1852 — although Strickland made and exhibited a model of the truss in 1850.[43] These trusses are assembled from simple, heavy, flat wrought iron bar stock bolted, not riveted, together using flat semi-circular gusset plates, with the upper chords loosely braced by purlins of round, wrought iron bars — a simple system not dissimilar from the Tomlinson/Wellington type trusses that Strickland might well have seen in England. However, unlike the Tomlinson/Wellington trusses, these trusses' purlins are well attached to a heavy plank roof deck that might offer some diaphragm-like stiffness to the total assembly.[44] (It should be noted, that the building was constructed using convict and slave labor and that the Cumberland Iron Works in Tennessee, which supplied the truss bars, also depended on slave labor.)

Also of 1852 were the wrought iron roof trusses spanning Thomas U. Walter's entirely iron post-fire reconstruction of the Library of Congress room in the west front of the U.S. Capital. (It is not clear that those survived subsequent reconstruction of the space into committee rooms.) The wrought iron trusses of the monumental St. Louis Courthouse only began to be installed in 1854, although an earlier date is sometimes cited. Except perhaps for a few over a portico, they were lost in a 1940 reconstruction.[45]

Heretofore, it seemed that the earliest known, but no longer extant, wrought iron truss roofs in the U.S. were also Strickland's — those of his 1835-37 Philadelphia Gas Works retort houses. Strickland had traveled widely in England in 1825, based on which he published *Reports on Canals, Railways, Roads, and other Subjects*,

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[42] A collar tie (or ceiling joist) is like the crossbar in the capital letter "A." The upper part of the "A" is a rigid triangular shape but for stability the "legs" of the "A" (the rafters of the roof) must be rigidly attached to the upper part and thus will experience bending stresses, which should not exist in a truss. Knees or the knee walls that enclose the low space where roof framing approaches the floor, have a similar effect. They form a ridged triangle incorporating the lower end of the rafter, but because the remainder of the rafter is not part of a similar rigid triangle, the rafter will remain subject to bending stresses.

[43] Correspondence with James Hoobler, Senior Curator of Art and Architecture, Tennessee State Museum.

[44] See HABS photo TN-SI-11

[45] Concerning early U.S. iron roof trusses, including Walter's Capital trusses see Charles E. Peterson, "Iron in Early American Roofs," *Smithsonian Journal of History, 3*, No. 3, (Fall 1968): 52ff.

whose plates include a gas retort.[46] In 1834, just before the gas works project, he described and may have built an iron market hall and "shambles" in Philadelphia, a 336 foot long by 28 foot wide set of 48 structural bays, purportedly with an iron roof structure supporting a corrugated iron roof, although the proffered evidence for their actual construction seems less than convincing.[47] The entrepreneur/engineer of the Philadelphia Gas Works was Samuel Vaughan Merrick. He traveled widely in England and on the continent visiting gas works, from which he developed his designs. One specifically cited and clearly self-evident source was the Imperial Gas Light & Coke Co. plant on the Regent's Park Canal. It had composite iron truss retort house roofs from which arose gigantic, Doric column-form smokestacks, which Strickland replicated at the Philadelphia gas works.[48] Strickland's *Reports, Specifications and Estimates of the Public Works of the United States of America*, of 1841 includes drawings of Howe type wrought iron roof trusses spanning his Philadelphia Gas Works retort houses.[49] Scaled from the drawings, they spanned approximately 50 feet. The spacing between trusses is not given and no purlins are shown. The drawings do present some technically questionable or at least unresolved connection details, although those may have resulted from improvisations by an English draftsman with inadequate information. There is no reason to assume the trusses would have been any more technically sophisticated than those Strickland used a decade later in the Tennessee Capital. Almost nothing else is known of them, except that they were subject to significant corrosion and apparently did not long survive the relocation, within two decades, of the gas works.[50] Acidic coal smoke may have become a disincentive to using wrought iron in such settings.

Research leading to this nomination now suggests that Strickland's were not the first U.S. retort house roof trusses. The 1845 guide book *Norman's New Orleans* says the New Orleans Gas Works had in 1834 a "wrought iron roof" on a retort house, which it says was the "first . . . in this country" and that it had "served as a model for all since built." It also notes a smokestack based on "Trajan's Column" which quite possibly refers to a column of Trajanian size — but perhaps not of specifically Trajanian features.[51] While not explicit, the term "wrought iron roof" and the British gas industry's built precedents and textural injunctions noted above for iron retort house roofs strongly suggest it was more than simply a sheet metal or corrugated iron roof covering.

The little known architect/engineer Theodore Journot is connected to the gas works through a single uncertain reference to a plan.[52] The much better known architect James Gallier, Sr. clearly worked on the project over an

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[46] William Strickland, *Reports on Canals, Railways, Roads, and other Subjects*, (Philadelphia: H. C. Carey & I. Lea, 1826.)

[47] Agnes Addison Gilchrist, "Market Houses in High Street," appendix to her *William Strickland Architect and Engineer, 1788-1854*, (New York: Da Capo Press, 1969), 306ff. Charles E. Peterson, "Iron in Early American Roofs," 54-55 and 46 respectively, seems agnostic as to whether the markets were built to Strickland's proposal drawings and doubts they were covered with corrugated iron.

[48] John L. Cotter, Daniel G. Roberts, & Michael Parrington, *The Buried Past: an Archaeological History of Philadelphia*, (Philadelphia: University of Pennsylvania Press, 1993), 313, say Merrick took "London's Regency [sic] Park Gas Works as his model". Malcolm Tucker, in correspondence, notes that is clearly a reference to an Imperial Gas Light & Coke Co. plant on the Regent's Park Canal.

Merrick's iron foundry supplied much of the pipe for the Philadelphia Gas Works. In 1835 he also supplied 1,200 tons of pipe, of up to 30-inch diameter, to the Croton Aqueduct project, of which J.B. Jervis was chief engineer. And in 1848 his firm, then Merrick & Towne, would be one of many supplying pipe to the Boston Water Works.

[49] Plate accompanying William Strickland, et al eds., *Reports, Specifications and Estimates of the Public Works of the United States of America*, (London: John Weal, 1841). Also *The Journal of the Franklin Institute*, 3d Series, No. 1 (1841): 236, noted the gasworks had "a roof composed entirely of iron."

[50] Re the corrosion see Strickland, et al eds., *Reports, Specifications and Estimates.*

[51] *Norman's New Orleans and Environs* [etc.], (New Orleans: B.M. Norman, 1845), 144. Norman's description of the roof was repeated in Nathaniel Cortlandt Curtis, *New Orleans: Its Old Houses, Shops and Public Buildings*, (Philadelphia: Lippincott, 1933), 44, but apparently otherwise went unnoticed. Peterson's "Iron in Early American Roofs," does not mention it. John T. Magill, of the Historic New Orleans Collection, knew nothing of it. Nor was it cited by anyone in response to our search for precedents.

[52] *Proceedings of the Western Gas Association, twenty-fifth Annual meeting, New Orleans, 1902*, (Western Gas Association, 1904): 542. In a welcoming speech, Bankson Taylor, of the New Orleans Gas Company, said, "Hanging in my office is a plan of the

extended period. Both arrived in the city just in time for the gas works' construction. James Gallier, Sr. (née Gallagher) had worked in England for J. P. Gandy and William Wilkinson. Through them he presumably would have become familiar with the latest uses of iron. The quality of Gallier's London experience and his talents and/or ambitions, are suggested by the fact that, upon arriving in New York in 1832, his first employer was James Dakin, partner of Ithiel Town and Alexander Jackson Davis. Then, after only several months, Gallier formed a partnership with Minard Lafever. Thus during two brief years in New York, Gallier was associated with some of its most important architects. In addition, while there Gallier also assembled *The American Builder's General Price Book and Estimator* [etc.], (Boston: M. Burnes, 1833). Gallier's *The Autobiography of James Gallier, Architect*, (Paris: 1864) is mute, however, with respect to any iron roof structure at the New Orleans Gas Works, even while touching on the saga of its multiply rebuilt chimney.[53]

*Norman's New Orleans* further says that in 1835 the gas works was sold to new owners who, "finding the buildings insufficient, constructed them anew." However, the enterprise was merely recapitalized (as a hybrid gas works and bank following local custom) by actor-entrepreneur John H. Caldwell, who retained control and who later developed gas works in Mobile, Cincinnati, and Havana. "Constructed them anew" might have arisen from the chimney having been rebuilt three times due to foundation problems. The last time in 1842 was "on a much larger scale." It was described by the *Daily Picayune* as a "handsome white chimney" that "resembles more some hero's monumental pillar."[54] A surviving drawing in the Southeastern Architectural Archive at Tulane University by Gallier of a gigantic Doric column on a tall base with a probably cylindrical cap, has been conventionally identified as possibly the base of a monument. It could as easily have been a counterpart to the Doric column retort house chimneys in London and Philadelphia.

At least two other retort houses with iron roof structures were built in the 1840s, both in New York State — both apparently un-noted until now. An "iron roof" built for The Manhattan Gas Light Co., in 1846 by Mott & Ayres, also sometimes called Chelsea Iron Works collapsed in 1854.[55] An 1848 gas works in Buffalo had a "wrought iron roof covered in slate."[56] Neither survives.

Perhaps the earliest known U.S. iron roof trusses of any sort that are thoroughly documented by drawings were the composite cast iron and wrought iron trusses for two 30-foot span roofs, of probably ca. 1840-41 (and not earlier than 1839), designed by the Prague-educated, Austrian-born engineer/architect John Rudolph Niernsee for the Baltimore & Ohio Railroad. One was for an engine house in Frederick, Maryland, the other for a 350-foot long, freight depot in Washington, D.C. Although an extremely detailed plate and article describing these very similar truss systems were published by Niernsee in the *Allgemeine Bauzietung* of Vienna in 1842, they seem to have escaped the notice of Peterson and others. In both buildings the trusses supported cast iron purlins, which supported cast iron rafters. The Fredrick building was roofed with self-spanning two-foot wide,

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company's property dated 1836 and signed 'Journot Architect'." "It is entitled 'Plant Belonging to the Gas Light and Banking Company, together with the Buildings and Improvements Thereon'." Gary Van Zante has communicated that he has seen a ca. 1900-10 reproduction of a bird's eye perspective with that title and date — a date he does not wholly trust, as he believes it may have been an advertising image. He recalls no specific indication of an iron roof. John T. Magill reports nothing else is known to connect Journot with the Gas Works.

[53] Gary Van Zante first mentioned to us the Gallier connection and John T. Magill mentioned Gallier drawings of an administration building for the gas works.

[54] Keli E. Rylance, of the Southeastern Architectural at Tulane University made us aware of the *Daily Picayune* article and of a foldout base that is part of column drawing.

[55] *Documents of the State of New York, Seventeenth Session 1847 VII*, Nos 151-171, (Albany: 1848), 198.

[56] *Transactions of the New York State Agricultural Society* [*etc.*] *VIII — 1848*, (Albany: 1848), 124. (Ammonia fertilizer was a gas works byproduct.) It was demolished ca. 1980. The HAER has two 1971 aerial photos of the gasworks but makes no mention of its iron retort house roof structure.

lapped zinc sheets with turned-down edges that fit into grooves in the tops of the rafters. The curving D.C. building was roofed with large self-spanning slates. Neither survives.[57]

A 122 foot diameter "iron roof" of an unknown type on an engine house (apparently a round house with internal turntable) of the Philadelphia, Wilmington, & Baltimore Railroad in Wilmington, Delaware, of 1847 (demolished 1862), is the only other identified pre-1848 iron roof structure associated with a U.S. railroad.[58] After 1848 the pace of construction of railroad buildings with iron roofs began to pick up. Additional iron roofs were erected in the next few years by the Philadelphia, Wilmington & Baltimore, the B&O, the Pennsylvania, and the Reading railroads. For engine houses and station sheds the use of cast iron principal members, often together with wood secondary members, persisted because they were more resistant than wrought iron to sulfurous gases.

Two drawings by James Dakin, dated January 1, 1846, for his unrealized version of the New Orleans Custom House clearly show iron roof trusses. Also shown are iron floor beams, iron columns, and possibly an iron staircase.[59]

**Boston Precedents**

Two buildings in or near Boston had the only identified built, pre-1848, U.S. iron roof structures on non-industrial buildings. The earlier was Gore Hall, the Harvard College library, of 1837-40 (roof structure replaced 1895, building demolished 1913), designed by Richard Bond. The other, Isaiah Roger's 1841-42 Merchants Exchange, is discussed below in connection with its self-spanning roof surfaces.

The Gore Hall roof structure was said to have had:

> ". . . no wood whatever, except the boards or laths to which the slate are fastened. The place of rafters is supplied throughout, by trusses made of light bars of wrought iron, which are supported by the walls and by iron purlins ranged through the building on the tops of the Gothic columns which rise through the ceiling for this purpose. The thrust of these trusses is prevented by iron rods, which take the place of tie beams of a wooden roof." [60]

This description was repeated verbatim in other sources. The building's galleries also had iron floor beams and railings. The iron roof structure was hidden above plaster gothic vaulting. The form of its trusses is unknown— and their being supported by "purlins" seems to invert the normal structural logic or, at least, nomenclature ordering of its parts. None of the few surviving Bond drawings in the Harvard Archives, nor those for later additions, nor numerous archival photographs of the building cast any light on Bond's hidden roof structure. A possible ancestral relationship to the closely spaced, light Brookline trusses is suggested by the light construction and apparently "rafter"-like spacing of Bond's trusses. As noted above, Charles E. Parker, architect of the Brookline gatehouse, worked for Bond, early in Parker's career but almost surely a little after Gore Hall's construction. Later, in 1850-53, Parker was briefly Bond's partner. Parker would certainly

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[57] They finally came to light with the 2006 publication of Randolph W. Chalfant and Charles Belfore, *Niernsee and Neilson Architects of Baltimore*, (Baltimore: Baltimore Architecture Foundation, 2006). Their list of Niernsee's (and Neilson's) works give the date of construction for both roofs as 1842. That seems likely to be just be the publication date of Niernsee's article. D.G. Cornelius brought these sophisticated roof truss systems to our attention.

[58] *Ninth Annual Report of the Philadelphia, Wilmington & Baltimore Rail Road Co.* [*etc*] (Philadelphia, 1847), 9 & 13.

[59] "Longitudinal Section of Design for New Orleans Custom House J.H. Dakin, Archt. 1/1/46" and "Transverse section of a Design for the N.O. Custom House Jas. H. Dakin, Archt. N.O., 1/1/46," James Harrison Dakin Collection of Architectural Drawings, New Orleans Public Library.

[60] Isaac Smith Homans, Isaac F Shepard, *Sketches of Boston, Past and Present* [*etc.*], (Boston: Phillips, Sampson, and Co.; Crosby & Nichols, 1851), 76-77. Sara Wermiel brought to our attention that in 1895 Bond's roof structure was replaced when the building's central space was filled with iron book stacks.

have known about the Gore Hall roof. By the time of its 1913 demolition, Bond's naïve, wedding-cake gothic was long out of favor by architectural critics and historians — something which generally remains true. Perhaps that affected consideration of its original iron roof structure by a twentieth century architectural culture prone to conflate technical and aesthetic innovation. Bond's roof structure was noted several times after 1913, but only in passing and only in the context of the building's semi-fire resistant construction, not as a structural innovation.[61]

***Early wrought-iron self-supporting roof surfaces in the U.S. and Europe***

"Tin" and "zinc" roofs had become relatively common for urban and/or better-built buildings in the 1830s. They were, however, normally thin non-structural coverings for wood sub-construction. The use as a building- and roof-material of sheets of corrugated iron, little different from that still made, was patented in Britain in 1829. However, the manner of its first use, ca. 1830, on a London dock warehouse, was structurally far more radical than the limited patent claim made for the material. Corrugated sheets were rolled into arc sections and riveted together to form a tied, linear vault of about a 28 feet span with no internal support.[62] As early as 1836 there was exported to Australia "two large stores [storage buildings], in the form of halves of horizontal cylinders of corrugated iron" — which directly anticipated the British World War I Nissen Hut and U.S. World War II Quonset Hut.[63] Tied, supported, and unsupported, corrugated-iron vaults have roofed buildings ever since. Most commonly, corrugated iron sheets, whether used flat or curved, have simply self-spanned between purlins, typically without sufficient fastening to create structural continuity from sheet to sheet. However used, corrugated iron's great advantage is that it is roofing and roof deck in one.

Due to patent control, corrugated iron was not widely manufactured or exported until the 1840s.[64] As noted above, in 1834 William Strickland proposed an iron "shambles" market for Philadelphia that was to have a corrugated iron roof. However, given the then tight patent control, that seems unlikely to have been realized. There seems no documented U.S. use of it until the California Gold Rush of 1849. That was the first of several gold rushes that initiated a massive export trade in British pre-fabricated iron buildings. Buildings with arched and pitched corrugated roofs were shipped to California by several English manufacturers. And hundreds of small, corrugated iron buildings were sent from New York by Peter Naylor, a roofer. That same year the U.S. Army imported arch-roofed, corrugated iron warehouses from England.[65]

Perhaps, in part, because of the post-1848 diffusion of corrugated iron, the Brookline's Principal Gatehouse's continuous, self-spanning, flat plate, type of iron roof may be extremely rare, if not unique. Comparably unique in Britain are Jesse Hartley's well-known, self-supporting, internally ribbed, iron plate vaults (reminiscent of inverted, boat hulls) covering his, 1845-46, Albert Dock warehouses in Liverpool.[66] William Strickland knew and felt so close to Jesse Hartley that Strickland named his son Jesse Hartley Strickland.

Two U.S. buildings having large-scaled "corrugated," iron plate roofs, of a type seemingly unique to them have been identified for the first time in connection with research into the Brookline gatehouse roof. One of these

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[61] Most conspicuously, Bainbridge Bunting, with Margret Floyd ed., *Harvard: an Architectural History*, (Cambridge: Harvard, 1985), 45, mentions it, but seems unaware of it as a structural innovation, while rightly praising, for its innovative structural iron and glass stack system, the building's 1877 wing designed by the important firm of Ware & Van Brunt.

[62] Mornement and Holloway, *Corrugated Iron*, 10-13.

[63] [James Backhouse] *Extracts from the letters of James Backhouse* [*etc.*], third ed., (London: Harvey & Darton, 1838), fifth part, 14. See also Miles Lewis, "Australian Building: A Cultural Investigation," section 8.4.2-8.4.5 (http://www.mileslewis.net/austrailian-building, accessed October 11.2012)

[64] Mornement and Holloway, *Corrugated Iron*, 20, 30-32.

[65] Peterson, "Iron in Early American Roofs," 41, 45-47.

[66] For the Liverpool Docks see: Joseph Sharples, *Liverpool: Pevsner City Guide*, (New Haven: Yale University Press, 2004), 102-09.

roofs was specifically identified as "corrugated" by its architect.[67] Both roof systems are pitched, not arched, and involve supporting wrought iron trusses. The earlier, on Isaiah Roger's Boston Merchants Exchange Boston, is no longer extant. The other, on the Savannah Custom House, slightly postdating the gatehouses, survives. These roofs are characterized by flat-faced pleated surfaces, rather than the typical corrugated plate's curvilinear sine-wave surface. The pleats have three to four times the pitch width of the largest-sized conventional corrugations — but, like conventional corrugated iron, they have an approximately 4:1 pitch to depth ratio. Each plate is one corrugation wide, although the entire roof was riveted into a single unified structural membrane, as was the case with the Brookline roof but not with the typical corrugated iron roof. The spans between supports are commensurately larger than those of conventional corrugated iron. The true significance of neither of these roofs appears to have been recognized in the literature before. Jane Kamensky, writing about a previous Boston Merchants Exchange, appears to be the only recent scholar to note the iron roof of Roger's Merchants Exchange, and then only in passing with respect to it being fireproof.[68] The Savannah Custom House roof is described and shown in photographs on the Government Services Administration (GSA) website with no recognition heretofore of its historic technical significance, as has been confirmed in communications with the GSA.[69]

The earlier of these two roofs — chronologically Boston's second identified iron roof structure — was on Isaiah Rogers' Merchants Exchange, of 1841-42, one of ante-bellum Boston's most important and grandly-scaled commercial buildings (roof partly destroyed 1872, building demolished 1889). The building was advertised as "fire-proof," and its roof routinely described as "constructed of wrought iron and covered with galvanized sheet iron." Its ground floor housed the Post Office and had cast iron columns supporting masonry vaulting, very probably carried on iron beams. Its staircases were described as "iron and stone," suggesting something like those of the, then just completed, Pennsylvania Hospital for the Insane, discussed below.[70] Although

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[67] John Norris, "Dimensions of the Custom House," *The* [Savannah] Daily *Morning News*, July 31, 1852: A transcription is appended to James R. Abrahamson et al "U.S. Customs [sic] House Restoration Survey Report," unpublished student project concerning a lost courtroom ceiling, Savannah College of Art and Design, 2004

[68] Jane Kamensky, *The Exchange Artist* [*etc.*] (New York: Viking Press, 2008), 303,

[69] "Historic Buildings" section of the GSA web site: http://www.gsa.gov/portal/ext/html/site/hb/category/25431/actionParameter/exploreByBuilding/buildingId/881# , accessed November 18, 2011.

[70] "The New Exchange," *Boston Evening Transcript*, (July 22, 1842); "Merchants' Exchange," *Boston Evening Transcript*, (December 31, 1842); "The Merchants Exchange," *The Boston Directory Containing the City Record* [*etc.*], (Boston: George Adams, 1850), 7.

In "the Boston Post Office," *Hunt's Merchants Magazine and Commercial Review V 14*, (New York, 1846), 129 footnote, its author describes it when opened as "A large vaulted, fire-proof room, lighted on every side by spacious windows, and having a superficies of 4,000 feet." Additionally, concerning the vaulting, see John Hayward, *A Gazetteer of Massachusetts* [*etc.*], (Boston, 1846), 50.

R. L. Midgley [pseudonym of David Pulsifer], *Sights in Boston and suburbs* [*etc.*], (Boston: John P. Jewett & Co., 1856), 17ff, contains the only pre-fire interior view of the "reading room." James F. O'Gorman has communicated that Hammatt Billings, who had worked for Rogers (and about whom more below), may have drawn the unsigned illustration.

The Boston Athenaeum has a ground floor plan of the building drawn by N.J. Bradlee & W.J. Winslow, dated February 1873, that incorporates proposed post-fire modifications at the rear of the building and perhaps to the post office in the central section, above which was the reading room. It shows a row of hollow iron columns, 10 feet on center, along the long side window walls of the post office, creating 10 x 10 foot structural bays. Down the center of the space is a 12" thick wall with piers aligned with the columns, with every alternate pier appearing to encapsulate an iron column. The *Hunt's* description seems to suggest the wall was not original, although other descriptions mention a public passage through the length of the building, suggesting the post office space was not all contiguous. Absent the wall, and if all piers indicate original support locations, the central section of the space had 10 x 18 foot structural bays. The building's "first" or principal floor level [second floor in current U.S. terminology] aligned with its conventionally framed neighbors. The apparent eight foot floor-to-floor height of its ground floor, which was up several steps from the pavement in front of the building, makes 18-foot span all-masonry vaults improbable. That suggests a tied jack-arch floor vaulting system with cast-iron beams, and presumably 10 x 18-foot bays, comparable to the vaults-on-beams used in the Savannah Custom House (see below). Sara Wermiel knows of only two U.S. buildings from before the mid-1840s with "floors made of iron beams and

construction of Roger's New York and Boston Merchants Exchanges overlapped, the New York building apparently did not have a comparable roof, despite two suggestions to the contrary.[71] The entry for January 30, 1841 in Rogers' unpublished diaries at the Avery Library includes the following concerning his New York Merchants Exchange, which was then under construction, apparently with a conventional wood roof deck; "Went with Mr. Pierson on the roof and tried to persuade him that copper was better than sheet iron galvanized, but he would not yield." Then Rogers continues, "Worked on plans of Exchange for Boston in the forenoon." The diaries, which are often devoted as much to expenses as building details, make no mention of any iron roof structures.[72]

In the Great Boston Fire of 1872, part of its Merchants Exchange roof was blown up with gunpowder by fire fighters. Testimony following the fire described the roof as "a good, substantial, flat iron roof" and "an iron roof, and wrought iron girders, trestle girders."[73]

A photograph of the semi-collapsed roof at one end the building's reading room-cum-exchange hall (then housing the U.S. Sub-Treasury) provides the only evidence of the roof's design and construction. (See photo attached: "Roof of the Boston Merchants Exchange.") The room was a 58 by 80 foot, two story, colonnaded space. The photograph indicates accessible space containing the roof trusses between the iron roof and its domed ceiling. Occupying the perimeter of the top floor, presumably at that level, were hotel rooms. At the time of the fire they were used for storage and their contents burned, apparently causing the domed ceiling to collapse and accounting for the burnt debris in the photograph of the otherwise seemingly-unburnt reading room. Secondarily, it appears from post-fire testimony, that the portion of the iron roof seen in the photograph was torn loose by the gunpowder explosion.[74]

Hanging down in the photo is a large section of roof including a raised ten-foot square clearstory roof-monitor, with central ventilator. There were gas chandeliers at each end of the room. By extrapolation from what can be seen, the monitor in the photograph would appear to have been one of two flanking and illuminating the dome, and incorporating ventilators for the two chandeliers. The monitor had iron-framed clearstory glazing on all sides. The ridges of the roof's pleats appear to be have been 15 inches apart.[75] It appears that the seams, which were just below the ridges, were stitch-riveted, like both the Brookline and Savannah roofs. Continuous iron bars bridged between the tops of the pleating ridges. There is no clear indication in the photo of what was

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brick arches." She has identified them in communications as the headhouse engine room of Alexander Parris's Charlestown Naval Shipyard ropewalk in Boston, of 1834-38, which would have been known to Rogers, and John Notman's Academy of Natural History in Philadelphia, of 1839-40. Regarding both, see Sara Wermiel, *The Fireproof Building,* (Baltimore: Johns Hopkins University Press, 2000), 47-48.

[71] An advertisement in *A.E. Wright's Boston, New York, and Philadelphia Commercial Directory* [*etc.*] (New York & Philadelphia, 1840), 186, by Sumner & Naylor for "galvanized iron tinned plate" roofing cites "Isaiah Rogers, architect of the [presumably New York] Merchant's Exchange, (9,000 Sq. feet covered)." Given the date and roof area cited, this may refer to an earlier building. The Boston Merchants exchange covered 13,000 sq. feet of land. The New York Merchants Exchange was larger. (Peter Naylor is also noted above in connection with later pre-fabricated iron buildings.) This advertisement may be responsible for the statement in George Dodd, *Curiosities of Industry* (London, George Routledge, 1858), 11, that the New York Merchants Exchange had a galvanized "iron roof."

[72] Roger Reed brought Roger's diary entry to our attention.

[73] Clearly "flat" is in contradistinction to steeply pitched, notwithstanding the roof's pleated surface. In common usage a "girder" may simply mean a major beam although it can also mean a beam that receives the loads of other beams. The term "trestle girder" used here is likely a verbal confusion. The girders of railroad trestles, presumably the intended allusion, typically are plate girders. But often those girders were supported on tall, trussed towers. Additionally, railroad bridges were often of trussed construction. An allusion to one of those two types of trussed structures was probably intended.

[74] *Report of the Commissioners Appointed to Investigate the Cause and Management of the Great Fire in Boston,* (Boston, 1873), 172, 262, 338, 395, & 432-435.

[75] The proposed monitor dimensions and rafter spacing assumes the monitor spanned between trusses, and that the trusses were aligned with the columns.

below the bars on the underside of the roof. However, absent contrary evidence, the example of the similar Savannah roof would suggest they functioned as the upper chords of the purlin trusses.

Clearly visible are two trusses whose upper and lower chords were T-sections fabricated from flat bars apparently joined by angle-clips. A continuous bar wrapped around the narrowed end of the truss served as "cross-piece" of both the upper and lower chord T-sections. The chords were held apart by overlapping flat wrought iron rings of graduated sizes, so that the trusses' depth tapered to no more than that of the chords at its ends. The rings were spaced a half-diameter on center, with each ring riveted to the chords above and below, and at mid-height to the abutting rings to which it was tangent on either side — creating something between a double-warren and a Vierendeel truss, with mandorla shaped panel openings half as wide as high. At their deepest, the trusses seem shallow for the 36-foot span between the columns, whose spacing along the length of the room suggests five trusses, ten feet apart. (There might have been two additional trusses. The two end columns between the corner columns at each end of the room were above ground floor ceiling-beams or arches, rather than directly over columns or piers and presumably were non-structural. In addition, at least at the rear of the room, there would seem to have been some floor load above those columns that had to be supported.)

But, the trusses were far too big to be purlins and apparently were orientated parallel to the roof's pleats. Three tie rods with turnbuckles and what appear to be wall anchors at their ends are visible on the floor. It is not clear how they related to the trusses. The trusses' taper and the tie rods suggest the possibility of inverted kingpost or queen-post trusses. (The roof seems rather flat for them to have functioned as tied trussed rafters.) The span from column line to monitor was about 13 feet, and to the ridge about 18 feet. The bridging bars' locations suggest nine-foot maximum roof plate spans. In relation to the corrugations' pitch-width, that would be exactly proportional to the larger spans of the Savannah roof plate. Although the building's "iron roof" was well advertised, none of this would have been generally visible, except possibly from the hotel floor corridor.

The other, newly identified and extant, example of this type of roof construction covers the, 1848-52, Custom House in Savannah, Georgia. In 1867 it was referred to by A.B. Mullett, Supervising Architect of the Treasury, as being "of a peculiar construction of galvanized iron apparently durable and well adapted to a southern climate" — which strongly suggests he specifically did not know of Roger's Boston roof nor apparently of any other examples.[76] This roof, but not its type of construction, has been known historically because on December 22nd, 1864, General William Tecumseh Sherman walked upon it to survey his famous "Christmas-gift" to President Lincoln.[77] Like Isaiah Rogers' Boston and New York Merchants exchanges, the granite for this precisely dressed building with monolithic portico columns and double flying masonry staircase, came from Quincy, Massachusetts.[78] All its iron components, including its roof, an iron attic staircase, iron widows, and

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[76] A.B. Mullett, "Report of the Supervising Architect of the Treasury Department," *Executive Documents printed by order of the House of Representatives During the Second Session of the Thirty-Ninth Congress 1866-'67*, (Washington, 1867), 199.

Information on the building, not all entirely accurate, is at the "Historic Buildings" section of the GSA web site: http://www.gsa.gov/portal/ext/html/site/hb/category/25431/actionParameter/exploreByBuilding/buildingId/881# , accessed November 18, 2011.

The "History/Space Inventory" tab includes descriptions of parts of the building and its present condition and uses. The "Photo Gallery" includes 38 small photos — one of which, captioned "basement" appears to be of an attic space.

The upper surface of the roof is presently thickly coated with an aluminized material. The lower surface and trusses appear to have two types of red-lead-like appearing paint over the original galvanizing.

[77] William Tecumseh Sherman, *Memoirs of General William T. Sherman* V.2, (D. Appleton & Co. New York, 1875), 217.

[78] John S. Norris, Architect and Superintendent of the Savannah Custom House, to Robert S. Walker, Secretary of the Treasury, 25 October, 1848. Record Group 121, Records of the Public Buildings Service, (PI 110 Entry 26, *Letters Received by the Supervising Architect 1843-1910*, box 1196).

the iron beams supporting its brick vaults, appear to have been supplied by the J.B. & W.W. Cornell Iron Works of New York.[79]

Norris, who began his career as a mason, was from New York and always maintained connections there. However, his known work is all in Savannah and the South, beginning in 1839 with a church in Wilmington, N. C. designed by Thomas U. Walter, for which Norris was supervising architect. Walter is closely identified with the use of iron, but principally beginning in the 1850s. Prior to that his most important work was the masonry-vaulted Founders Hall of Girard College in Philadelphia, a commission he won in 1833 against 16 other competitors including, several important in the context of this nomination: Town, Davis, & Dakin, Isaac Holden, John Haviland, Isaiah Rogers, and Walter's mentor, William Strickland. Jennifer Amundson, who is researching Walter, has communicated that "Walter & the building committee considered putting an iron roof on Girard College and only changed course after Walter toured Europe in 1838 to study [programmatically] similar structures there."

In 1843 Norris, with local backing, was commissioned to design and supervise construction of Wilmington's new Custom House, which he gave a roof of apparently thick, tin plated copper.[80] As late as July 1848, at the laying of the Savannah Custom House's cornerstone, its proposed roof was to be "rafters of iron, covered with plates of copper."[81] There is no suggestion that Norris's predilection for unusual copper roofs reflected a Treasury Department preference — although lighthouses often had copper cupolas on iron armatures. If Norris was known to the eminent, Philadelphia architect Thomas U. Walter in 1839, it is reasonable that by 1849 Norris could have known of the New York-based Isaiah Rogers' then proven and perhaps more economical Boston Merchants Exchange iron-plate roof. Given the similarity of the unusual Norris and Rogers roofs, it is possible Cornell iron works supplied both. Norris's notable competitor for the Savannah Custom House commission had been Charles B. Cluskey. Another transplanted New Yorker, he had trained in the office of Ithiel Town & Alexander Jackson Davis (about whom more above and below). In 1848 he was the first to recommend replacing the U.S. Capital's original wood dome with one of iron.[82]

Upon the completion of the Custom House Norris wrote: "The roof is corrugated. The rafters [sic: ridge and purlin trusses] of wrought iron lattice work [are] covered with galvanized iron three-sixteenths of an inch thick,

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[79] Ibid. This letter also lists Cornell Iron Works as low bidder (marked with an "X") for the cast iron beams, and various fabricated iron components.

Concerning the beams, see John Norris, "Dimensions of the Custom House."

> "All the floors are arched with brick the kind called barrel arches, built between iron beams. The effect of using iron beams, and arches of this construction is that it enables the architect to have walls of less thickness to sustain the diminished trust of the arches. . . . The cast iron beams are eighteen feet in length and one foot high — weighing nine hundred pounds each and will sustain a weight of fifteen tons spread over them. The iron beams in the Collector's office are thirty-seven hundred pounds each, and are capable of sustaining a weight of one hundred and fifty tons over them."

For the "Iron Roof, Copper Gutters & Leaders complete," John S. Norris, Architect and Superintendent of the Savannah Custom House, to William M. Meredith, Secretary of the Treasury, 19 November, 1849. *Letters Received by the Supervising Architect*. Cornell is listed as the low bidder out of three The other two bidders were Worrell & Co. of New York, an iron works primarily specializing in printing presses and saw blades, and P. Morris (possibly indicated as "of New York"), a firm name that cannot be identified, unless possibly [Isaac] P. Morris of Philadelphia.

For the staircase, John S. Norris, Architect and Superintendent of the Savannah Custom House, to Thomas Corwin, Secretary of the Treasury, 19 November, 1850. *Letters Received by the Supervising Architect. Corn*ell is listed as the low bidder out of three suspiciously close bids for the "Iron staircase." Out of sight, leading up to the attic storage areas, this spiral staircase has what are said to be "tobacco-leaf" motif balusters matching those of the flying granite staircase. The other two bidders were the Columbia Iron Foundry (there were firms with that name in Manhattan and Brooklyn at the time) and, again, Worrell & Co.

"Death of William W. Cornell," *Engineering 9*, (April 15, 1870), 258, also states Cornell supplied the ironwork.

[80] A.B. Mullett, "Report of the Supervising Architect", 199.

[81] *The Savannah Weekly Georgian*, July 20, 1848.

[82] Peterson, "Iron in Early American Roofs," 66.

riveted boiler fashion . . ."[83] The roof's pleats are 24 inches wide, ridge to ridge — each pleat being one iron plate wide, with the plates lapped and stitch-riveted to their neighbors just below the pleat ridges.

Contrary to the apparent orientation of the Boston Merchants Exchange's roof trusses, the Savannah trusses run perpendicular (not parallel) to the pleats. They function as ridge beams and as mid-span purlins dividing the 30-foot eves-to-ridge spans down to about 15 feet. As the building's cross-wise masonry partitions continue to roof level, truss lengths are mostly limited. The typical ridge truss is a rectangular bar surmounted by overlapping rectangular bars bent into chevrons that collectively match the profile of the roof plate. The chevrons being riveted together at the overlaps creates a lattice truss with the conjoined bent parts of the chevrons functioning collectively as the upper chord. The roof plate rests on it, without being visibly attached. That part of the typical purlin truss below the roof plate is a rectangular bar surmounted by smaller non-overlapping chevrons. Hook-ended bolts clamp the top of each chevron through the roof plate to a continuous strap atop the roof that is the upper chord. These straps appear identical to those on the Boston Merchants Exchange roof.

The upper floor of one wing of the building was a large courtroom with a domed ceiling. Atop the latticed ridge-truss spanning this space is a smaller truss, like the other ridge trusses. It both supports the roof plate and serves as the upper chord of the larger truss — whose lower chord is strongly arched to clear the dome, leaving little truss depth at that place. Here there are more substantial parallel-chord, lattice truss purlins, about 24 inches deep, attached to the roof like the other purlins. Both these lattice trusses are far more conventional than the Boston Exchange trusses. The roof's valleys are supported by iron I-beams.

As will be discussed below, just as this building was completed in 1852, the Treasury Department was about to launch a building campaign throughout the country that specified iron beams, staircases, roofs, and other components for its buildings. However, unlike Rogers' and Norris' substantial, structurally-continuous, folded-plate roofs, those later buildings had non-continuous roofs of lapped, conventional corrugated iron, mounted on relatively light iron "frames" resting on the construction below.[84] Unlike the Savannah roof, those conventional corrugated roofs soon proved unsatisfactory. In 1867 A.B. Mullett, the then Supervising Architect of the Treasury, castigated the corrugated roofs installed by his predecessors, Ammi B Young and Isaiah Rogers, adding that because the "frames" supporting them were too light to support slate, copper had to be used as a replacement instead.[85] See "Drawing; Iron roof details, Custom House, Wheeling, Va.", attached. The construction shown supporting the corrugated iron roofing is not a truss but light wrought iron tee-beams supported by cast iron props on iron ceiling beams. The failure was probably due to extreme flatness of the roof (a style based choice) combined with the less closely spaced riveting inherent with corrugated iron sheets.

### The Brookline Principal Gatehouse Iron Roof and Roof Trusses

To an 1848 visitor, the Brookline Principal Gatehouse roof would have presented a smooth, verdigris green surface. Because of the plastered ceiling, the trusses were invisible for most of the past 160 years. But contemporary references to the building's "iron roof" would have been generally understood to mean its iron roof structure.

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[83] Norris, "Dimensions of the Custom House."

[84] *Specifications for the Rebuilding of a Custom House at Portland Maine* [*etc.*], (Washington 1855 & 1856). This is, actually, a volume of separately issued specifications for the construction of 27 Federal buildings bound with a common index. *Plans of Public Buildings in the Course of Construction Under the Direction of the Secretary of the Treasury* [*etc.*], (Washington, 1855.)

[85] A.B. Mullett, "Report of the Supervising Architect", 190 ff.

The continuous "sheet iron" (wrought iron) roof deck consists of rectangular plates, continuously stitch rived together, including the bent plates forming the ridge and the built-in "Yankee" gutter of the same material hidden above the cornice. The roof deck is supported by 21 lightweight, four-panel, Howe roof trusses, assembled from square and rectangular wrought-iron bars. While this truss configuration, in which the diagonals are in compression, has been known at least since the late nineteenth century in the U.S. as a Howe roof truss, in the 1840s the name "Howe" was only applied to versions of a timber bridge truss with uniform rectangular panels and parallel top and bottom chords, containing iron diagonal and counter-diagonal tension rods.[86] Howe developed this type of truss in the early 1840s while working with George Washington Whistler, then chief engineer of the Western Railroad of Massachusetts.

Both the lower surface of the roof deck and the trusses retain residue of what appears to have been a coating of coal tar. In addition, a grey coating of the roof deck's lower surface, visible where there is neither tar nor rust, suggests it was galvanized. As noted above, the 1841-42 Boston Merchant's Exchanges roof was said to be galvanized and Treasury Secretary architect Mullett referred to the Savannah roof as galvanized. As is true of its far simpler, more rational trusses, the gatehouse's flat-surfaced roof is the antithesis of the Merchants Exchange's pleated surfaces with external bridging bars that appear in post-fire photographs to have been the upper chords of purlin trusses.

The trusses are spaced 24 inches on center and span about 23 feet. The top and bottom chords are paired rectangular bars. Each truss has a vertical square member at mid-span and quarter-spans, with diagonals connecting the bottoms of the mid-span verticals to the tops of the quarter-span verticals. The ends of the diagonals are flattened to fit between the paired chord bars. There are no other examples in these trusses of such "blacksmithed" connections, in which the member is flattened or reshaped. (The Lake Cochituate Gatehouse roof structure has many such.) Even though by 1848 angle-irons and T-irons were available in the U.S., the designer of these trusses (unlike some British contemporaries) apparently did not appreciate that such shaped sections resist compression loads better than these relatively flat rectangles. Despite the fabricated T-sections used in the Boston Merchants Exchange truss, the first U.S.-made angle irons were rolled in Pittsburgh before 1829. By 1830s they were used in locomotives and in 1838-39 the iron river boat "Valley Forge" was built in Pittsburgh using both angle-irons and Tees.[87]

All panel point connections between the Brookline gatehouse truss members are single rivets. The trusses have an additional short vertical near each end, where the trusses are supported on leveling bricks atop the undressed granite tops of the cornice blocks. There is no sill plate or tie between adjoining truss ends. The only ties between trusses, other than the iron plate roof, to which they were riveted by irregularly spaced clips, are bars that connect the trusses at the tops and bottoms of the center vertical members, using the same single rivets that connect the verticals to the top and bottom chords. The clips connecting the trusses to the iron plate roof surface are not located consistently along the top chords, suggesting the clips were not originally intended to brace the chords against buckling under compressive loads but only to more generally attach the roof deck to the trusses. It may be that more clips were added due to observed lateral deflection of the upper chords under compressive loads.

### The Lake Cochituate Influent Gatehouse Iron Roof Trusses

The Lake Cochituate gatehouse, built at the same time as the Brookline Principal gatehouse, has a wrought-iron truss roof structure of an entirely different design. Its members are more substantial. Visually, it might seem

[86] Prof. Dario Gasparini of Case Western Reserve University clarified that distinction in a communication.

[87] James M. Swank, *History of the Manufacture of Iron in All Ages*, (Philadelphia: 1884), 175. Albert S. Bolles, *Industrial History of the United States* [*etc.*], (Norwich, Conn.: Henry Hill Publishing Company, 1889), 597.

more impressive. It does not have an iron roof surface and probably never did. The aqueduct's official history speaks of an "iron roof" on the Brookline gatehouse and (elsewhere) of a "metal roof, secured effectually from intrusion" on the Lake Cochituate gatehouse.[88] Given the conceptual and fabrication differences between them, the two roof structures are unlikely to have been designed by the same hand and/or built by the same fabricator. Compared to the Brookline roof, the Lake Cochituate roof also has a less clear history, involving modifications.

A 1903 "as built" drawing, and the hipped roof's structure itself, reveals a system far more complex than its Brookline counterpart, whose simple repetitive trusses seem more "modern" from a manufacturing perspective.[89] The Lake Cochituate roof has five Howe trusses of two types, plus purlin-supported iron rafters, with the sloping truss chords also serving as rafters. The three center trusses are triangular, while the central portion each end truss has a horizontal upper chord between the roof's hips. Purlins are suspended by bent forged stirrups below the top chords of the center trusses and support the intermediate rafters mid-span. At the hips, the purlins turn the corner and become the outer two trusses' upper chords, supporting end-wall rafters.

The trusses' lower chords are single rectangular bars whose outer ends, split into clevises, flank the upper chords' ends. Vertical members are paired rectangular bars — or rather each is a single bar doubled into a U passing under the bottom chord. The diagonals are round bars with forged squared ends. Diagonals of the flat-topped end trusses run down from the top of the center vertical to the bottoms of the quarter point verticals. Those of the center trusses run up from the bottom of the center vertical.

The upper chords are rectangular bars. The narrower rafters are the same height. The tail ends of both upper chords and rafters are tenoned into mortise holes in a horizontal plate atop the masonry wall and are held in place by tenon pins. This and the other anachronistic, labor-intensive connections suggest the sensibility of a blacksmith or a structural carpenter. They differ completely from the unmodified bar stock and confident straightforward single-rivet connections of the Brookline trusses. A note on the 1903 drawing describes the Lake Cochituate rivets as having been driven cold.

In 1859, when the height of its dam was increased, the gatehouse was disassembled and rebuilt on its foundations that had been increased in height. The building was rebuilt using the same stones and windows with new iron doors. The absence of any angle irons or other roll-formed sections and its archaic details, as well as the absence of documentary references suggesting it was replaced, all argue that the roof is original as well.[90] At a time when houses were routinely moved and masonry city blocks jacked up as streets were raised, removing and returning this unified iron structure would have been trivial. Lastly, the 1903 "as built" drawing bears a note saying the roof structure had "apparently" been made by a "blacksmith" in "about 1847."

Had these iron trusses and rafters ever supported a structural iron plate roof like Brookline's, it did not survive the 1859 rebuilding. The available evidence suggests that the trusses originally supported a wooden roof deck covered by a "tin" roof. An invoice from the 1859 project, for "tinning" the gatehouse's roof, must be read as installing a new "tin roof" — not tin-coating an iron roof. The "tinning" of the roof was done by Charles S. Parker & Sons, who specialized in copper, metal, and "composite" roofs.[91]

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[88] Bradley, *History of the Introduction*, 251 & 238, respectively.

[89] Inspection of the structural system was made together with then MIT student Lori Ferris. Lori Ferris, *Preservation of Early Wrought Iron Trusses: the 1848 Roof of the Cochituate Gatehouse* (http://dspace.mit.edu/handle/1721.1/62714?show=full, accessed July 24, 2011).

[90] Bradley, *History of the Introduction*, 190. The incomplete set of surviving Water Works vendors' invoices from 1859-60 do not include an identifiable bill for a replacement roof structure.

[91] Sara Wermiel concurs with this reading.

Unlike the Brookline Principal Gatehouse, there is no reason to believe that this relatively isolated, and rarely visited, building's iron roof structure had any lasting impact on the development of architectural iron technology

**Iron Staircases**

A major impetus for the development of iron staircases was that they were "fireproof" (i.e., non-combustible). This idea often arose in articles advocating "fireproof" construction.[92] In addition, by the late 1840s, if not earlier, they would have been less expensive than masonry, particularly if ornament was required. Cast iron, rather than wrought iron, would have been used because it was the less expensive of the two; was easier to shape; required fewer connections and/or the connections required less fabrication; was easier to ornament; felt and sounded more substantial; and could be cast with non-slip treads. Despite cast iron's relatively low tensile strength, the only wrought iron required might be a minimal stringer bar. Alternately, as will be seen below, there could be through-bolts joining adjacent tread units, thus pre-loading the cast iron into compression, as was first done on the outer ends of circular stair treads and later on some straight run iron staircases, creating de facto stringers.

***Early cast iron stairs in Europe***

Although the British use of cast iron columns and beams, especially in mills and warehouses, was greatly in advance of U.S. practice, that was generally less true of cast iron staircases. Even in British buildings with advanced iron internal frames, the staircases remained stone until later in the century. Many of the less than two-dozen pre-1848 cast iron staircases readily identified in Europe (primarily in the U.K.) appear to have been for exceptional buildings.[93] The iron stairs in Sir John Nash's 1815-23 Royal Pavilion at Brighton are the earliest, most gaudily conspicuous, and best-known. There seem to be no readily identified pre-1848 examples in France. That is not surprising, given the relatively limited development of French architectural cast iron then. Early French iron stairs, if any, might more likely have been of wrought iron. In Germany, the 1817 exhibition hall of the Prussian Royal Foundry, K.F. Schinkel's 1830 Albrect Palais, and the 1832 Villa Ravené, built for an iron founder, had cast iron staircases. None of them survive. The only extant pre-1848 German examples may be in the 1845-47 Bethanien Hospital, a project of the King of Prussia, designed by protégés of Schinkel.[94] All four German projects were in Berlin, the Prussian capital. Three had royal connections. Two were in iron founders' own buildings. Thus they all were privileged exceptions in a way that their more ordinarily employed U.S. counterparts were not. In Russia there is at least one extant cast iron staircase in an 1838-45 fortress that guarded the sea approaches to St. Petersburg where U.S. and British engineers and metal founders were active.[95]

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A cast iron rail iron railing with cylindrical wrought iron balusters survives in the gatehouse. It is quite similar to those on Brookline staircases but perhaps not identical and not recorded on the 1849 drawings. Also surviving are the 1848 and 1859 dedicatory marble plaques.

[92] For representative arguments from the period for "fireproof" iron stairs see: Thomas S, Kirkbride, *On the Construction, Organization and General Arrangements of Hospitals for the Insane* [*etc.*], (Philadelphia, 1854), 77; and William Fairbairn, *On the Application of Cast and Wrought Iron to Building Purposes*, (New York: John Wiley, 1854), 117-20.

[93] With respect to Scotland at this early date and later, this is confirmed by communications from David Mitchell and from Thomas Swailes, whose encyclopedic *Scottish Iron Structures*, (Edinburgh: Historic Scotland, 2006), includes no reference to cast iron stairs. (It does refer to the stone stairs that were typical in iron-framed British mills). Nor are any shown on the extensive "Scottish Ironwork" website, devoted to Scottish iron architectural components, ranging from rain leaders to bandstands to *pissoirs* to tombstones, with hundreds of illustrated examples. http://www.scottishironwork.org (Accessed 6 Jan., 2009)

With respect to England, it is confirmed by English Heritage personnel and by Malcolm Tucker. He has communicated that the only un-published pre-1850s iron staircase he is aware of lead to the roof of a now-demolished 1828 warehouse by Philip Hardwick in the St. Katherine Docks, London.

[94] Other than the well-known Albrect Palais, Miron Mislin, knows of no others from that early period.

[95] Fort Alexander, a greatly oversized Martello tower, rising startlingly from the waters of the Gulf of Finland has a tough-looking, wide, multi-story cast iron staircase. http://www.fsgfort.com/DB/C077/28/Text.html (Accessed 22 March 2009).

Among those engineers was General George Washington Whistler, E. S. Chesbrough's mentor, who was recruited to Russia to build the St. Petersburg to Moscow railway and who was reported to have designed an iron roof for a huge indoor riding hall.[96]

***Early cast iron stairs in the US***

Given that the U.S. production of cast iron urban facades (as distinct from entire pre-fabricated, free-standing iron buildings) rapidly exceeded that of Britain, much less of continental Europe, by the late 1840s, it is not surprising that the development of iron staircases might also have been approaching parity at that same time. Efforts to identify all known 1848 or earlier U.S. cast iron staircases have found surviving examples in one or two penitentiaries by John Haviland, and in four lighthouses, as well as no longer extant staircases in one other lighthouse, two hotels, and three hospitals. A few early U.S. lighthouses have later, retrofitted cast iron staircases of a distinctive standard Lighthouse Service design post-dating the present period of interest.[97]

The earliest known U.S. cast iron staircases are in the ca. 1834, Cell Block 7 of John Haviland's Eastern State Penitentiary in Philadelphia.[98] They are a single symmetrical pair of straight-run stairs, each with one side supported by a wall, and with elaborate, widely spaced balusters and wooden rails. They seem to be an almost direct translation into iron of the type of masonry "flying" staircase in which each tread-block is supported along its front edge by the rear edge of the tread-block below and which depends on having the wall-end of each tread-block tightly socketed in the wall masonry for complete resistance against rotation about the tread-block's long axis. Each riser-tread unit of Haviland's stairs is a single casting projecting from the masonry wall, with no stringer, and with its front edge resting on the unit below. The outer end of each unit is fastened to those above and below only by small iron clips that perhaps serve a role like the rebated joints that typically key together adjacent treads of a masonry flying-staircase. Haviland's treads (later crudely roughened to prevent slipage) were originally smooth-surfaced, like masonry, and did not take advantage of cast iron's ability to provide a slip-resistant patterned surface. The stairs were cast from patterns made for and owned by Haviland.[99]

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[96] "Obituary, George W. Whistler," *The American Journal of Science and Arts*, Second Series, VIII, No. 23 (New Haven: 1849), 298. George L. Vose, *A Sketch of the Life and Works of George W. Whistler Civil Engineer* (Boston: Lee and Shepard, 1887), 39. Robert W Tolf, *The Russian Rockefellers* [*etc.*] (Stanford: Hover Institute, 1976), 10. Tolf describes it as a "new roof," suggesting it was on an existing building. A comparative reference to the "timber" span in Moscow suggests that Whistler's roof structure, rather than just its covering, was of iron. Russian non-structural sheet iron roofing was widely exported beginning in the eighteenth century. Descriptions of the Moscow building's span range upwards from 150 feet. The terms exercise house or riding house, riding school or academy, and *manège* were used somewhat interchangeably. In addition to other lesser ones, there were at least three major buildings of this type in St. Petersburg at the time. All three survive, the two older ones as exhibit halls. The alluded span of Whistler's roof better suggests Vincenzo Brenna's, 1798-1800, *Mikhailovsky Manège* (refaced in 1824 by Carlo Rossi), which is 36 meters wide. A text of 1842, a year before Whistler's arrival, describes a *Manège* "within the Michailhoff quarter," presumably the *Mikhailovsky Manège*, as having an apparently trussed, timber roof with iron tie rods, spanning "150 feet" [sic] and covered by iron plates. Giacomo Quarenghi's, 1804-07, Horse Guard *Manège* spans only 86 feet. And the Neo-Gothic *Peterhof Manège*, begun in 1847, two years before Whistler's death, has a timber hammer-beam roof. Correspondence with sources in St. Petersburg have yet to resolve the nature and/or present status of Whistler's purported "iron roof."

[97] In addition to specific citations below, general sources on early U.S. lighthouses include: Sara Wermiel *Lighthouses*, (New York: W.W. Norton, 2006), and J. Candice Clifford & Mary Louise Clifford, *Nineteenth Century Lights* [*etc.*], (Alexandria, Va.: Cypress Communications, 2000).

[98] In correspondence D.G. Cornelius, together with Jeff Cohen of Bryn Mawr College, provided valuable information on Haviland's Eastern State Penitentiary (ESP).

[99] Correspondence from D.G. Cornelius.

***Lighthouse stairs***

Boston's, no longer extant, cast iron Long Island Head lighthouse, built in 1844 by Cyrus Alger & Co.'s South Boston Iron Company, had a cast-iron spiral staircase, with a central post that apparently served as a stove chimney.[100]

That same year the venerable Boston Light, the oldest in the U.S., was fitted with its present center-post cast-iron stairs, also made by South Boston Iron.[101]

The 1846 Juniper Island lighthouse on Lake Champlain in Vermont, made by the same company, is the oldest surviving U.S. cast-iron lighthouse. It has the same spiral staircase as Boston Light, in which the outer end of each tread is bolted to those above and below. This structure is derelict, as is the taller but otherwise identical, including identical stairs, Monomoy Point lighthouse, of 1849, on Cape Cod. While some sources say that the Monomoy and Juniper lighthouses are identical to the earlier Long Island Head light, surviving images of the latter clearly show a different more tapered form consistent with its contract drawing, which also shows the stairs as being different.

The three above staircases, with their treads cantilevered from a centerpost, again represent a direct adaptation into iron of a form that, while rare, had previously existed in wood.

In 1847 Alexander Parris designed the stone lighthouse on the remote Mt. Desert Rock in Maine. His original specifications called for stone steps but were changed to cast iron.[102] These are not the typical centerpost spiral stairs of most U.S. lighthouses but rather a helical staircase attached to the masonry wall. It appears that the bolted-together tread-riser units are cantilevered from the wall, like Haviland's stairs. They have no separate stringer bar but undoubtedly some structural continuity at the projecting ends of the treads. The lighthouse also has an "1847" cast iron date plaque on its otherwise all masonry exterior.

An 1847-48 cast-iron lighthouse in Biloxi, Mississippi, has a spiral staircase with perforated treads (the earliest known U.S. example) bolted to the central post, and a surprisingly modern-looking stepped wrought-iron stringer. The lighthouse was made in Baltimore by Murray & Hazelhurst.[103]

***Stairs in two hotels and three hospitals***

There were also iron, or partially iron, pre-1848 staircases in two luxurious southern hotels and three hospitals. The hotels' stairs would have been intended for the general public, less so or perhaps not at all those of the hospitals. None survive. It is not evident that heretofore the existence, or at least the technological significance, of any of these stairs has been known.

Probably the earliest were in what was known as the "United States" or "Government St." Hotel in Mobile Alabama, designed by James H. Dakin and constructed in 1836-37, but burned in 1839 before completion. (Work stopped before completion because Mobile was devastated by the great depression of 1837 and then

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[100] "Cast-Iron Light-House, Long Island Head, Boston Harbor by the South Boston Iron Company, May 1844" contract drawing. http://gallery.pictopia.com/archives/gallery/S968917/photo/8611073/?o=77 (the National Archives website, accessed 24 March 2009)

[101] Fitz-Henry Smith, Jr., *The Story of Boston Light* [*etc.*], (Boston: 1911), 46.

[102] Parris' specifications, with the tipped-in addition, all in his hand, is in the Massachusetts State Library (cataloged as SLN210). Roger Reed brought this to our attention.

[103] The most complete source on the Biloxi Lighthouse is a letter-form memorandum historic structure report by Deborah Slaton & David S. Patterson (Princeton Junction, N.J.: Wiss, Janney, Elstner Associates, 2008). It treats the stairs as entirely original. Bill Raymond, Historical Administrator of the City of Biloxi, who provided a copy of the report, agrees that the stairs appear original, despite the appearance of the stringer.

much of the city burned in 1839.) It had "eight cast iron stairs weighing 1,280 pounds."[104] "Stairs" must mean flights and that weight would be consistent with that of 20 to 26 eight-inch riser treads of a range of presently produced ornamental cast iron spiral staircases.[105] Nothing else is known of the stairs in this hotel.

Of almost the same date were stairs in New Orleans' "City Exchange" or "St. Louis Exchange" Hotel (later St. Louis Hotel and Hotel Royal), 1835-38 (partially burned 1841 and restored, eventually demolished 1916), designed by J.N.B. De Pouilly. It is recorded that "The floors of the gallery which engird[ed] [its] rotunda and the winding stairs leading to them [were] of iron."[106] The hotel had a famous, much photographed, multistory main spiral staircase that appears to have been of wood and was not in the described location. The seemingly inconsistent description "floors of the gallery . . . and the winding stairs leading to them" could indicate one or more gallery levels around the space. The rotunda space arose from the second floor of a double walled drum whose inner wall, supporting the dome, was separated by corridor space from its outer wall. This seems, most likely, the "gallery." Notably, the building's dome was constructed of clay pots in a framework of wrought iron (possibly discernable in the demolition photographs) that would have been consistent with De Pouilly's French technical training. Again, nothing else is known of these stairs.[107]

The "Island Retreat" or "Pauper Lunatic Asylum" on Blackwell's Island (now Roosevelt Island) in New York harbor was designed and begun, but not completed, by Dakin's former partner Alexander Jackson Davis in the mid-1830s. Originally there were to be three large octagonal stair pavilions. The first phase of construction ended in 1839 with only one completed. "The Octagon," as it was called, contained a dramatic, sweeping, freestanding, five-story helical staircase, encircled by colonnades. In 1842 Charles Dickens was impressed enough by the "spacious and elegant staircase" to mention it in his often critical travel journal, *American Notes for General Circulation.*[108] In 1852 another traveling English writer Mary Grey Lundie Duncan described "a remarkably beautiful iron staircase, which combines beauty and strength at a high degree."[109]
The staircase had an exposed, largely wrought iron, substructure consisting of three sets of curving stringers below each run as well as tread support brackets.[110] All appear to have been wrought iron. Only the ornamental portion of the outer tread supports and the cantilevered stair-landing supports appear to have been partially cast iron. The treads, risers, balusters, and handrails all appear to have been of wood, as were the Ionic columns supporting the surrounding balcony corridors. The wood treads and risers could have provided some lateral diaphragm stiffness to the helically curved iron sub-structure, which was also attached to the wood Ionic columns at the third-points of the runs between landings for lateral stability but not, it would appear, for support. Only partly of iron, and that apparently primarily wrought iron, the staircase probably dated from the

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[104] Arthur Scully, Jr**.** *James Dakin, Architect* [*etc.*], (Baton Rouge: Louisiana State University Press, 1973), 76 & 82.

[105] (http://www.dincast.com/cast-iron-spiral-staircases.html, accessed 29 October, 2012.)

[106] *Hunt's* Magazine *and Commercial Review V 19*, Freeman Hunt, ed. (New York: 1848), 509-10.

[107]The building experienced several cycles of decay and reconstruction prior to demolition in 1916 — which is documented in the George Francois Mugnier Photograph Collection, New Orleans Public Library (http://nutrias.org/photos/mugnier/hotels/gfmh.htm, accessed 18 October, 2012), and by photographs in the Vieux Carre Digital Survey of the Historic New Orleans Collection.(http://www.hnoc.org/vcs/property_info.php?lot=18461, accessed 17 January, 2013). See also [WPA] *Louisiana: A guide to the State*, (Baton Rouge: Louisiana Library Commission, 1941), 155. Eleven contract drawings are also appended to two contracts in the city's Notorial Archives (F Grima v7 act 500, 1835, and Ducatel v7 act 71, 1838). The earlier set clearly varies from the hotel as built with respect to aspects of the principal staircase's setting and the dome's structure, which is shown as wood. They do show a helical staircase, of no specific structure, adjacent to the drum. The latter set does not show relevant aspects of the building.

[108] Even the book's title is a sarcastic pun on the often dubious banknotes issued by banks linked to speculative developments, such as the one associated with the New Orleans Gas Works.

[109] Charles Dickens, *American Notes for General Circulation*, (New York: Harper & Brothers, 1842), 37. Mary Grey Lundie Duncan, *America as I Found It*, (New York: Carter & Brothers, 1852), 325.

[110] Three, very crisp, Historic American Buildings Survey (HABS) photos, taken after the building was abandoned, provides the only detailed information about the staircase. HABS NY,31-WELF,6-4, 6-5, 6-6.

late 1830s, but may have been introduced in 1847-48 when the building was enlarged by the addition of a second wing.

Although less dramatic, the most important by far of these three early hospitals' staircases were in the Pennsylvania Hospital for the Insane, in Philadelphia, begun 1836, completed 1841.[111] The building was designed and begun by Isaac Holden, who surprisingly won the commission in a competition against John Haviland, for whom Holden had once worked, and against William Strickland, even though both men were better known and more advanced in their careers.

In 1838 the British-born, American trained-Holden returned to England "for a time." He never returned and subsequently had a successful career in Manchester. Just prior to his departure a contract was let to the firm of Morris, Tasker & Morris for "iron castings for the stairs at 5 cents per pound" based on "the plan submitted to us" by Holden. (Originally the stairs were to have been of wood.) Morris, Tasker & Morris undertook "to furnish . . . all of the cast iron work, wrought iron work, and sheet iron work of any description for the whole of the iron stairs with their respective accompaniments, also for the furnaces for heating with heated air . . . " The contract explicitly required them to "furnish to [the hospital] all the requisite patterns for the castings for the stairs . . ." but not so those for the furnaces etc., clearly indicating that the furnaces were a proprietary item but the stairs were not, and that the patterns for producing the stair castings belonged to the hospital and not to Morris, Tasker & Morris — who, in any case, seem not to have produced many architectural iron components at that time, although they were a very large firm.[112] Morris, Tasker & Morris, a.k.a. the Pascal Iron Works, was founded in 1821, specialized making equipment for gasworks, as well and wrought iron pipe and heating systems, for which they were major suppliers to the hospital. The firm's name was changed to Morris, Tasker & Co. in 1856. Although by 1860 Morris, Tasker was advertising iron spiral stairs, there is no known indication that it made any other iron stairs before the 1850s. The firm continued in business to the end of nineteenth century.

As was already the practice in insane asylums, the hospital's window sash and frames were also of iron — made to patterns drawn by Holden — but they were produced by a different firm, which underbid Morris, Tasker & Morris.

After Holden's departure, the hospital was completed by the building committee. The then 23-year old Samuel Sloane, at that time still a carpenter, was involved, although he is sometimes misidentified as its architect. However, the building committee's minute books refer to Sloane, beginning about a year after construction commenced, only in connection with "carpentry work," although he was paid regularly in the last year or so. When it was decided to extend the almost-completed hospital in 1841 by the addition of one-story outlying pavilions for the most uncontrollable patients, Sloan applied for the commission, as architect, but it went to a Mr. Cairnes.

The profile of the hospital stairs' tread end supports is reminiscent of the Eastern State Penitentiary stairs' flat faced supports, which would have been known to Holden. However, their structural design is entirely different. They are made more like conventionally framed, wood staircases, with multiple wrought iron stringer bars, even though these are not expressed in profile. That is reminiscent of the Blackwell's Island hospital's wrought iron and wood staircase with its multiple stringers, which probably was known to Holden. However, the thick cross-bracing below the treads, as well as a change of the tread-edge profile where it abuts the next riser up, and the

[111] Again, a single, very crisp, HABS photograph provides the only detailed information about the staircases. HABS PA,51-PHILA,511-9.

[112] Virginia Jacobs researched the history of the construction of the Hospital for the Insane in the building committee's minute books in the archives of the Pennsylvania Hospital.

fact that the fronts of the treads are of a dark color, all indicate the treads were stone slabs over the evident cast iron supports. There were five iron staircases connecting the hospital's first and second floors. The stairs below them to the basement level apparently were not iron.

As noted above, Isaiah Roger's "fire-proof" Boston Merchant's Exchange, completed in 1842, one year after the Philadelphia hospital, was advertised as having "iron and stone" staircases, but no more detailed description is available. Rogers' work/expense-diary for 1846, mentions in connection with his now demolished Howard Athenaeum theater in Boston: "sketch of iron stairs for side entrance to gallery."[113] The theater's filigreed balcony fronts were cast iron, as undoubtedly were its thin balcony columns. No other identified source mentions iron stairs in this storied theater.

After Holden returned to Britain, he built, in 1845, the Palatine Hotel, Manchester, with an iron staircase. It attracted the following comments from the architectural press, which speaks to its rarity in Britain at that time:

> "A novelty in this edifice is the main staircase opposite the entrance; the whole of the stairs and landings (with the exception of the mahogany handrail) is of iron, each step (riser and tread included) is of one piece of cast iron, which is attached to a wall-plate and depends therefrom; the whole has a remarkably light and elegant appearance, and is an instance of the grand effect which may be gained by a judicious use of this material. In the case of fire, a staircase of this construction would be invaluable, as it would afford a means of escape to the inmates which would not be liable to destruction."

And:

> "Near the station is the Palatine Hotel . . . in which there is a staircase wholly of iron. It was executed by Bellhouse & Co. and while demonstrably conducive to its object of providing a means of escape from fire, it is not inelegant, and may be given as an example of the successful treatment of ironwork. The strengthening ribs beneath each tread are arranged so as to intersect with one another, with good effect when seen from below."[114]

Last of the three hospitals' iron staircases was a spiral staircase inserted into the old main building of the Society of the Hospital of New York, for internal circulation within an academic library occupying part of the building's second and third floors.[115] Three bids were received early in 1845, presumably for this staircase. One suggests stairs of wrought iron. No conclusion can be drawn as to the others. There are no meaningful illustrations. Nothing suggests whether any were standard items. Within a few years, two firms with lineages going back to one of these bidders, Cornell & Jackson, would be advertising iron staircases.[116]

**The Brookline Gatehouse staircases**

The paired cast iron staircases in the Brookline Principal Gatehouse are the oldest known surviving examples in the US intended to be publicly accessible, and therefore provided broad public exposure in the use of structural cast iron.

One of the 1859 "as built" drawings of the gatehouse is a cross-section through the staircases. One variance from the actual as-built condition is that the stairs are shown as having no architecturally expressed stringer. That would be consistent with the earlier examples discussed above and might have reflected the architect's

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[113] Information from Roger Reed.

[114] Respectively, "Architecture and the Building Arts in Manchester and its Neighbours" *Civil Engineer and Architects Journal,* (April 1845): 129, and "Architecture and Art in Manchester" *The Builder,* (November 8, 1845): 548.

[115] "Library of the New York Hospital; an Error Corrected" *The New York Medical Journal LII*, (Dec. 6, 1890): 636.

[116] "Estimates for iron staircase (one with drawing), 1845." in the "Sundry papers of the records of the Secretary/Treasurer of the Society of the New York Hospital," Weill Medical College of Cornell University Archives, Box 1, f.9: 1846. It consists of three single-sheet proposals plus one drawing, all from New York vendors. None explicitly specifies whether the material would be cast iron or wrought iron. The last reads more as if it was wrought iron. The first is for a pair; the latter two for single staircases.

original intent. As actually built, these stairs differ from all adequately documented earlier U.S. iron staircases in having expressed stringers. What the drawing does correctly show is the stairs' perforated risers and tread-end supports — as well as a scalloped lower edge of the end supports (discussed below). The perforations of the risers and tread-end supports have no identified U.S. precedents. (The essentially contemporaneous Biloxi lighthouse stairs have perforated treads.) Such perforations, which became common, saved material and permitted the penetration of light from above, as would have been desirable here.

As built, the staircases have conspicuous expressed stringers, although these are actually separate, non-structural panels, integral with the tread-end supports above them, behind which is a continuous wrought iron bar. The risers, treads, and end-supports/stringers of each step are three separate castings bolted together. The stringers are only on one side of each run because the other end of each tread has cast pins set into the wall. The stairs' upper and lower runs are joined by two 90° winder sections. Based upon the drawings, the rails, balusters, and winder-posts appear to have matched the now-lost railing that encircled the gate chambers in the upper level of the Brookline gatehouse. The balusters are round wrought iron bars. The treads have a checked non-slip pattern.

While the Brookline Principal Gatehouse stairs bear no foundry marks, certain aspects of their design clearly relates them to an almost contemporaneous spiral staircase at the Boston Athenaeum, fabricated by Smith & Lovett, who specialized in architectural iron. There is a Boston Water Works payment voucher for "iron work" to "D. Stafford & Co.," an older name for Smith & Lovett who made the Athenaeum stairs. Although possibly it could have been for one of the gatehouse roofs, most likely it was for the Brookline gatehouse staircases or the matching handrail around the stone staircase well in the Lake Cochituate Gatehouse. The firm was established in 1813 by Daniel "Deacon" Safford. Although its names, as found in various sources, are not always consistent, about 1827 it became for a time Safford & Low (sometimes "Lowe") and then D. Safford & Co. In 1845 or 1849 (accounts vary), it began to be listed both as Smith & Lovett and as Smith, Lovett & Co. The use of "D. Stafford" in both the Boston Water Works and Athenaeum records suggests 1849 as the correct date for the name change. A Boston 1848 Athenaeum reference to "Safford & Smith" noted below seems unrecorded elsewhere.[117]

**The Boston Athenaeum and Brookline Gatehouse staircases**

Two types of iron stairs were used in the Boston Athenaeum and are closest to those of the gatehouse in time, place, and, at least for the one surviving Athenaeum staircase, in certain aspects of design.[118] The exterior of the Athenaeum, a private membership library, was completed in the spring of 1847, but it was so over-budget that completion of the interior stretched out over five years. The building first opened with a temporary iron entry-hall staircase, which existed for approximately the two years prior to February 1851. There appear to be no surviving images or descriptions of it. It speaks to the rapidly emerging relative cost competitiveness of iron that it was chosen for this temporary staircase, in use for only two years, rather than a conventional staircase of wood.

As originally drawn, the Athenaeum's second floor plans were sprinkled with conspicuously placed spiral staircases leading to balcony bookshelves. As built, the reading room had five spiral staircases tucked into alcoves. Considerably more is known of them. Surviving contract specifications for the building's ironwork

[117] This chronology is compiled primarily from: *Commerce, Manufactures & Resources of Boston*, (Boston: National Publishing Co., 1883), 61-2, and; Richard Herndon (edited by Edwin Monroe Bacon), *Boston of To-Day: a Glance at its History and Characteristics*, (Boston: 1892), 299.

[118] Catharina Slautterback, Curator of Prints and Photographs at the Boston Athenaeum and author of *Designing the Boston Athenaeum*, (Boston: the Boston Athenaeum, 1999), was immensely helpful concerning the known history of the Athenaeum's iron stairs.

include the spiral staircases, one of which survives. The specifications are dated July 1848 and reference both "Safford & Smith" and D. Safford & Co., "iron smiths." An 1852 Smith & Lovett advertisement mentioned "iron stairs" among other products. It is their sole advertisement for iron stairs thus far identified.

Aside from the 1848 Cornell advertisement noted above, other identified earlier or contemporaneous advertisements for iron stairs were placed by: Wood's Ornamental Iron Works of Philadelphia in 1851; Heins & Adamson of Philadelphia in 1851-52; and Hudson River Iron Works of New York in 1851.[119]

After a 1913-15 gutting and reconstruction of the second floor, the one surviving Athenaeum staircase now provides access to the balcony of a typical, glass-floored, iron book-stack system of that later period. Given the July 1848 date of the Safford & Smith / D. Safford & Co. Athenaeum contract and the Athenaeum's July 1849 opening date, its various iron staircases post-dated the gatehouse stairs by less than a year.

The similarities between the Athenaeum and Brookline stairs would suggest that they were produced by the same firm and, at least in part, designed by the same hand. There are, however, many differences between them: the Athenaeum balusters are ornamental castings of attenuated floral forms, the Brookline balusters are round wrought iron rods; the Athenaeum's treads have an elegant intaglio floral decoration, the Brookline treads have simple checkering. Also unlike the gatehouse stairs, the Athenaeum staircase has open risers, as spiral stairs usually do because of reduced tread width near the center-post. However, the Athenaeum's tread end supports are strikingly similar to those of the gatehouse staircases, except they do not sit atop as wide, nor as conventional-appearing, a stringer. Both staircases' end-tread supports incorporate an identical Rundbogenstil-like open silhouetted arcade above a reversed spiral within an open triangle.

The Brookline stringers look very substantial. The Athenaeum stringer has a running bas relief laurel garland, which seems deliberately architectonic and reflects a very different sensibility from the shared motifs above it. Both staircases' visible stringers are backed by a "hidden" structural wrought iron-bar. Both share the same unusual, convexly-scalloped lower edge, probably intended to mask joints between sections. On the gatehouse stairs the scallops are, by alignment, an extension of the parallelogram panels above them, although those two elements are not otherwise particularly well integrated. The Athenaeum stairs' scallops, in contrast, do not visually relate at all to other staircase element. But, unlike the gatehouse's stiff, constant-radius scallops, their curvature is subtly inflected, as if responding to gravity — all of which heightens their architectonic appearance. However, the narrower Athenaeum stringer seems better proportioned to the delicacy of the openwork end-supports — especially as part of a spiral stair, where visible stringer length is inherently limited. Being part of a spiral staircase, the Athenaeum's end supports lie in a curved plane. Thus they were made using an entirely separate casting pattern, which is significant in considering the genesis and common design motifs of both stairs.

The Boston community of architects and engineers was not large, and there are social and professional connections that support interaction between Edward Clarke Cabot, the novice architect who won the Athenaeum design competition, and Charles Edward Parker, architect of the Brookline Gatehouse. Cabot, a lifelong Brookline resident, would like have had an interest in the aqueduct, and particularly the highly visible Brookline Principal Gatehouse. In the execution of the Athenaeum he was paired with the architect and civil engineer George Minot Dexter, who also had Brookline family connections. More important, Dexter was the

[119] See respectively: *The Massachusetts Register and United States calendar for the year 1852* [*etc.*], (Boston: George Adams, 1852, "Boston advertisements"), 18; *Hunt's Merchants' Magazine and Commercial Review*, November 1851, ["Philadelphia Business"] 3; *Thompson's Mercantile and Professional Directory 1851-52 edition*, (Baltimore: Wm. Thompson, 1852), 274; and E. Porter Belden, *New York Past, Present and Future* [*etc.*], (New York, 1851), 273.

founding vice-president of the Boston Society of Civil Engineers — which put him in direct contact with Chesbrough and probably his staff. The first regular meeting of the Society was held on July 3, 1848, in the offices of the Boston Water Commissioners. The founding president was James F. Baldwin a member of the Commission and brother of Loammi Baldwin Jr., who trained Dexter. Chesbrough and Whitwell were both present.[120] The Athenaeum stair contract was signed that same month. Conversely, ca. 1848, neither Parker nor any of the three principal Cochituate engineers, nor the gatehouse contractor were Athenaeum members.[121]

**The Wider Adoption of Iron in Architecture:**
**Ammi B. Young and the Middlesex County Courthouse staircases**

Isaiah Rogers and Richard Bond, the architects of Boston's Merchant's Exchange and Harvard's Gore Hall respectively were partners, briefly, in 1834-35.[122] In December 1836 both of them, along with Alexander Jackson Davis and Thomas Thomas of New York, as well as Thomas U. Walter, William Strickland, and John Haviland of Philadelphia, had attended the founding meeting, at Rogers' Astor House hotel in New York, of the American Institution of Architects — a short lived precursor to the American Institute of Architects. Ammi B. Young, then practicing in Vermont was not present but was in correspondence with the group, as was James H. Dakin of New Orleans.[123] Dakin was then in a brief partnership with James Gallier and previously had been in partnership in New York with Ithiel Town and Alexander Jackson Davis.[124] The second edition of Gallier's *The American Builder's General Price Book and Estimator* [*etc.*], published that same year, included a testimonial that it had been "examined and approved" by Alexander Parris, Isaiah Rogers, and Gridley J.F. Bryant.[125] Taken together, this thoroughly networked group of architects — all of whom, except Young and Thomas, have already been encountered above and many of whom were often equally identifiable as civil engineers — is connected directly or at one remove to a majority of the U.S. iron roofs and staircases touched upon in this study. While Thomas Thomas, an important designer of New York's commercial "palaces" who often used iron, does not figure elsewhere in this narrative, his Moffat Building, of 1847-48, is described in contemporary accounts as having had an "iron roof [that] utilized a new technique of iron plates in ridges" a description that sounds like what is known about the Boston Merchants Exchange and Savannah roofs. Other contemporary accounts describe the Moffat roof as "wholly of iron and cement," which suggests something different, if still worthy of comment at the time.[126] Mid-century Boston architects did not eventually play as large a role in the development and utilization of iron for facades and framing as their counterparts in New York and Chicago would as the century progressed beyond its mid-point. Nonetheless, Boston architects had been the first in the U.S. to use iron roofs on non-industrial buildings and had used iron stairs in publicly accessible places. Boston also had a highly developed building technology tradition — albeit of finely executed trabeated granite — beginning with Alexander Parris and continuing through his trainees, including George M Dexter, Ammi B. Young, and Gridley J.F. Bryant, to the generation of Bryant's (and Bond's) trainee Charles E. Parker. Bryant and Dexter were also trained by the engineer Loammi Baldwin Jr.

Through much of the first half of the nineteenth-century, New England was the most industrialized region of the country due to its water-power resources and the manufacturing of precision machinery used in its massive mill complexes. When needed, that technology was available to be passed from industrial manufacturers such as the Lowell Machine Shop or the South Boston Iron Works to Boston's architectural/engineering community. It is

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[120] *Journal of the Association of Engineering Societies 1,* (1881-1882): 7.
[121] Communication from Catharina Slautterback.
[122] O'Gorman, *On the Boards,* 36.
[123] Cecil D. Elliot, *The American Architect from the Colonial Era to the Present,* (Jefferson, N.C.: McFarland & Co., 2003), 44.
[124] Julia M. Truettner, *Aspirations for Excellence: Alexander Jackson Davis and the First Campus plan for the University of Michigan, 1838,* (Ann Arbor: University of Michigan Press, 2002), 38-41.
[125] James Gallier, *The American Builder's General Price Book and Estimator* [*etc.*], (Boston: M. Burnes, second ed. 1836), [n.p.].
[127] David R. Meyer, *The roots of American Industrialization,* (Baltimore: Johns Hopkins University Press, 2003), 196.

not commonly appreciated that the pattern of urbanization and industrialization in New England, ca. 1840, was quite different from the other two principal U.S. manufacturing regions, centered on New York and Philadelphia. While each region had a similar percentage of the national industrial work force, in Philadelphia and New York a majority of industrial employment was in the city itself and more inherently dependent on steam power. In the case of Boston and New England, over 85% of the manufacturing population was disbursed, primarily to water-power locations, including to such remarkable planned industrial mill cities as Lawrence, Lowell, Manchester, and Holyoke. In this industrial sense Boston truly was the "hub" city. It was also "the Athens of America," not only for its academic traditions but because, like Athens, rather than growing, it spawned colony-like (if industrial) daughter cities.[127]

In 1852 one of those Boston architects, Ammi B. Young, would take on a role that came to be formalized as Supervising Architect of the U.S. Treasury Department.[128] With it came the first consolidated responsibility for the construction of most civil Federal buildings. Previously, Federal buildings were commissioned somewhat haphazardly and typically overseen locally, as was true of Norris's two Custom Houses. As noted above, over the next decade Young (followed briefly in 1863-65 by Isaiah Rogers), would produce a series of Federal buildings across the country, together with a series of some fifty folios of detail drawings of them and their iron construction details.[129] (See "Drawing; Iron stairs details, Custom House, Wheeling Va." below.) Due to these buildings and their widespread publication Young has been long recognized as having pioneered various U.S. architectural uses of iron, or at least as having fostered its wider adoption.

However, prior to that Young spent a decade building the Custom House in Boston. Consistent with the Boston tradition, it is notable for its huge monolithic granite columns and fireproof masonry construction, including a stone roof, but not for any significant use of iron.[130]

In 1848-49, as his work on the Custom House was concluding — almost exactly coinciding with the installation of the Athenaeum stairs and just slightly later than the Brookline gatehouse — Young extensively reworked and added wings to Charles Bullfinch's 1814 Middlesex Courthouse in Cambridge. Although Young was a "proprietor" of the Boston Athenaeum (holding share #233), there is no record of his involvement with its staircases.[131] Young employed cast iron for non-structural trim on his Courthouse project, in part to embellish the original fabric and unify the design. He also used it for portico columns, as well as internal columns supporting masonry groin vaults, and for doors and shutters. In addition, Young's new wings had two-story semi-elliptical cast-iron staircases around an open D-shaped well.[132] These stairs are different in conception, ornamentation, and structural design from the gatehouse staircases and the surviving Athenaeum stairs. They are more spatially sophisticated than the Brookline stairs and have an exposed, elegantly executed and expressed, square wrought iron structural stringer bar, separate from the cast iron components above it. The

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[127] David R. Meyer, *The roots of American Industrialization*, (Baltimore: Johns Hopkins University Press, 2003), 196.

[128] Lawrence Wodehouse, "Ammi Burnham Young, 1798-1874," *The Journal of the Society of Architectural Historians 25, No. 4*, (Dec., 1966): 269ff.

[129] *Plans of Public Buildings in the Course of Construction Under the Direction of the Secretary of the Treasury* [*etc.*], Washington, 1855

[130] Margaret Henderson Floyd et al, *The Custom House and Tower*: Boston Vol. I, (unpublished t.s. Historic Structure Report, 1988), 28.

[131] Catharina Slautterback knows of no active role that Young played in the project or institution.

[132] Jean Innamorati, preservation planner in Brookline MA, who has researched Young's Vermont work, made us aware the Middlesex Courthouse stairs. Wodehouse, "Ammi Burnham Young, 1798-1874," does not mention them. "Middlesex County Superior court Building," *HABS report MA-1028*, mentions the internal iron columns supporting groin vaulting, and the iron staircases. Graham Gund, architect and owner of the building, has communicated that iron was not used to span the large courtrooms occupying the largest portion of Young's wings.

ironwork contractor was G.W. Adams & Co. (subsequently Denio & Roberts, then Denio, Ham & Co., and then L.M. Ham & Co.).[133]

Clearly, time was becoming ripe for the widespread adoption of structural iron. Young undoubtedly knew the earlier "iron and stone" stairs and not-visible iron roof in the Boston Merchant's Exchange. However, his Courthouse expansion, with its iron stairs (with iron treads) and other visible iron components, suggests a more immediate possible link with the conspicuous uses of iron in the Athenaeum and Brookline Principal Gatehouse.

Lastly, while the Athenaeum viewed its temporary iron entrance hall staircase as expedient, that was not true of the Brookline gatehouse whose conspicuous use of iron was emblematic of the project's massive investment in iron technology involving thousands of tons iron piping. And certainly there was nothing merely expedient about Young's staircases.

Young's subsequent use of iron surely reflected its increasing availability. But the rapid incorporation of iron onto American architectural construction, beginning in the 1850s, was certainly encouraged by his use of it in Federal buildings throughout the country — just as the conspicuous uses of iron in a small but significant, publicly owned and accessible building in Brookline had perhaps provided to the Athenaeum and then to Young an immediate example.

**Significance of the Brookline Gatehouse Staircases**

It might seem that the largely cast iron Brookline Principal Gatehouse stairs are not an advance in architectural technology comparable to the building's wrought iron roof system. However they do represent a significant revolution, given that the alternatives were combustible wood or expensive heavy masonry. They are a counterpart to the then increasing use of iron as an acceptable architectural façade material, not only because it was fireproof (a stated concern in the case of the gatehouse) but also because, as in the case of the gatehouse, iron was clearly becoming acceptable in an architecturally, technologically, and civically significant setting.

As discussed above, iron stairs had previously been used in at least two U.S. hotels, but there is good reason to believe based upon plans that in both they were secondary stairs (and one of those hotels burned before opening). Admittedly, six years before the Brookline Gatehouse Isaiah Rogers had used "iron and stone" stairs in his fireproof Boston Merchants exchange, a building marked by several technical achievements, not least its wrought iron roof system (which was not visible), but also for its façade's much commented upon gigantic monolithic granite pilasters. Rogers' stairs' presumed-stone treads would, like the building's granite façade hiding its iron roof, have made the stairs more conventionally acceptable. In 1845, only three years prior to the Brookline gatehouse, the American trained Isaac Holden's cast iron main staircases (with stone treads) in a Manchester England hotel had been deemed worthy of note as a "novelty" and of praise in two leading British architectural journals. Conversely, a ca. 1850 cast iron circular staircase in the Savannah Custom House led only to the attic. Despite the structural iron used throughout the building, its principal stairs remained of stone.

It was Ammi B. Young who, after having used iron stirs with iron treads in his Cambridge courthouse extension, beginning in the mid-1850s first systematically used, published, and thus proselytized iron principal staircases throughout the country — almost a decade after the Brookline examples.[134]

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[133] The 1849 *Boston Directory* lists "Denio, Cheney & Co. (Late of George W. Adams & Co.)" at the Adams location.

[134] It's not entirely clear how much Young's Cambridge courthouse stairs were intended for public use, given their location at the back of the wings behind the courtrooms. The building's principal staircase remained Bullfinch's in the center of the building.

**Significance of the Brookline Principal Gatehouse Iron Roof**

Compared to most iron roof trusses of that time or even of a decade or more later, the Brookline gatehouse trusses are notable because they are entirely wrought iron. No earlier U.S. building with wrought iron roof trusses survives. The two earlier non-industrial U.S. examples were both in Boston and one certainly was known to the Brookline gatehouse's architect. (Arguably the gatehouse's function might be considered industrial but, unlike a retort house or train shed, its function did not call for an iron roof and the gatehouse was a notable public building as well.) Of the two types of surviving British wrought iron trusses (there being several examples of each type), one type had several notable failures while the other was a sophisticated and undoubtedly more expensive adjustable kit-of-parts design. Both were clearly intended for field assembly.

More typically at the time cast iron was used, whenever possible, for the compression members of iron trusses. Even if heavier, it was cheaper. But cast iron, being brittle, is preferably bolted not riveted. Bolting also facilitated field assembly. It was also probably easier — as well as less risky — to transport such trusses disassembled. Mishandled, the more brittle cast iron components of a preassembled truss were at greater risk of breaking. And assembled, such heavy trusses presented a handling disadvantage. A wrought iron truss was substantially lighter. Wrought iron components could be almost a quarter the weight of cast iron members, with no concern about brittleness. Wrought iron trusses could be riveted and transported pre-assembled. Thus the gatehouse trusses could have been efficiently factory produced a few miles away in Boston. Hot rivets, more efficiently used in a factory setting, were stronger and cheaper than screws with nuts. So too, rivet holes could be more efficiently punched or drilled. The three trusses in the gatehouse roof whose end verticals are identically misplaced further suggests the trusses may have been factory made; otherwise the error might have been discovered with the first one.

Thus the Brookline Principal Gatehouse roof trusses represent a confident design for its time, produced in an efficient modern manner. Compared to the complex roof trusses of Boston Merchants Exchange six years earlier or of the Savannah Custom house two years later — neither of which would seem readily subject to structural evaluation with the analytical tools then known — the simple elegance of the Brookline roof trusses is self-evident.

The gatehouse's self-supporting roof of flat, stitch riveted, iron plates eliminated the need for any other subsidiary roof structure such as purlins or rafters and for any sort of additional water shedding material. It is technically elegant but in this form has no evident immediate progeny. Its closest surviving European counterparts are the iron plate roofs of Jesse Hartley's well-known Albert Dock warehouses of 1846 in Liverpool. The Brookline plate roof and the Savannah Custom House roof of 1850 likely derive from the tightly stitch-riveted plate construction to Roger's Boston Merchants Exchange roof. Like its trusses, the gatehouse's roof may have been assembled in a workshop where the riveting would have been more efficient and then moved in parts or complete to the construction site. At the time in New England, moving buildings of comparable dimensions was commonplace, as was moving and raising granite blocks of vastly greater weight.

When a couple of professionally trained architectural historians first entered the long shuttered Brookline Gatehouse in 2005, their initial erroneous reaction was disappointment that the original roof apparently had been replaced by light modern trusses. Conceptually, today's closely spaced, light open-web steel joists directly supporting a steel roof deck system (now topped with insulation and a roofing membrane) are almost direct descendants of the Brookline Gatehouse's simple, efficiently produced, wrought iron trusses.

The Brookline Reservoir and its Principal and Influent granite gatehouses is an exceptional surviving component of an extensive mid-nineteenth century water-supply system for a major American city. The

Renaissance Revival style granite exterior of the Principal Gatehouse contains the major components of the system's most advanced engineering technology, all of which was open to the public. In addition to the reservoir with its great granite retaining walls and iron doors, the Principal Gatehouse itself contains cast iron staircases and a wrought iron trusses supporting a wrought iron plate roof representing the most advanced thinking in the use of iron technology for building construction. In the Brookline Reservoir the public can still enjoy its architectural splendor and park-like setting, while the interior of the Principal Gatehouse affords students and scholars an opportunity to understand one of the great accomplishments of nineteenth century American technology. A greater appreciation of this site gained through NHL listing will assist the town's efforts in preservation and adaptive reuse.

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Previous documentation on file (NPS):

__ Preliminary Determination of Individual Listing (36 CFR 67) has been requested.
_x Previously Listed in the National Register.
__ Previously Determined Eligible by the National Register.
__ Designated a National Historic Landmark.
__ Recorded by Historic American Buildings Survey:
_x Recorded by Historic American Engineering Record: # HAER MASS,11-BROK,4-

Primary Location of Additional Data:

__ State Historic Preservation Office
_x Other State Agency: Massachusetts Water Resources Authority
__ Federal Agency
_x Local Government: Brookline and Boston
__ University
__ Other (Specify Repository):

## 10. GEOGRAPHICAL DATA

Acreage of Property: 32.12 acres

| UTM References: | **Zone** | **Easting** | **Northing** |
|---|---|---|---|
| A | 19 | 324220 | 4688260 |
| B | | 324170 | 4687960 |
| C | | 323790 | 4687820 |
| D | | 323580 | 4688030 |

Verbal Boundary Description: Bounded on the east by Warren St., on the north by Boylston St. (State Route 9, originally the Worcester Turnpike), on the west by Lee St., on the south by Dudley Way and Dudley St., and on the south-east by 469 Walnut St., a short tangent section of Walnut St., 433 Walnut St., 37 and 45 Warren St., thence returning to the starting place at Warren St.

Boundary Justification: The site is the Brookline Reservoir Park. Its boundaries have remained substantially unchanged (other than minor street line adjustments) since the time of the completion of the reservoir in 1848. The property was listed in the National Register as part of three separate nominations. In 1980 the Brookline Reservoir was part of the Town Green Historic District, designated primarily for its residential resources. In 1985 Reservoir Park was listed as part of the Town of Brookline Multiple Resource nomination. The entire boundary of the park was included in both of those nominations. Finally, the Brookline Reservoir was included as part of the Water Supply System of Metropolitan Boston multiple property nomination listed in 1989.

## 11. FORM PREPARED BY

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NATIONAL HISTORIC LANDMARKS PROGRAM
September 24, 2014

## Appendix A. Approximate Course of the Cochituate Aqueduct

The following is a description of the approximate course of the Aqueduct from the inlet gatehouse in Wayland to the Brookline Reservoir:

***Wayland*** — The inlet gatehouse is on the east shore of Lake Cochituate, in the Cochituate State Park, just a few hundred yards north of Commonwealth Avenue (Route 30). From the inlet gatehouse, it runs east paralleling the entrance drive to that part of the park, then passes under Commonwealth Avenue, soon intersecting the Wayland/Natick town line at Snake Brook.

***Natick*** —It follows the Wayland/Natick town line east-southeast (passing under the Massachusetts Turnpike) after which it passes through an excavated defile in a hill, surrounded by a sub-division, to the bottomlands of Mudpond Stream, where the town line abruptly turns north. The aqueduct continues straight along the bottomlands, crosses under Oak Street and turns south paralleling Peterson Road, before turning back east and crossing the Natick/Wellesley town line. Over half its length in Natick is on public land, much of which is low and wet. Until recently there was no town acknowledgement of its presence.

***Wellesley***—Here, a portion of the aqueduct now is a "utility corridor" and a portion conveys sewage to the MWRA system in Newton. Above ground its right of way is used for recreation. The "Wellesley Cochituate Aqueduct Corridor" is maintained as part of the Wellesley Trails network. The Aqueduct enters Wellesley just before crossing Bogle Brook, just south of Reed Street Pond. It then turns southeast and passes under Route 9 to the northern end of Morses Pond where there is the stone roofed Morses Waste Weir Gatehouse, where the "waste" (excess) water from Lake Cochituate is fed back into the Charles River system. The bermed aqueduct then follows the northeast shore of the pond, parallels Halsey Avenue, passes through the Wellesley College "North 40" campus, and through Wellesley Square, to the north of Town Hall. It then crosses under and then parallels Washington Street (Route 16), crossing Hunnewell Field as a low straight embankment, before swinging north, approximately paralleling the change of direction of the MBTA tracks, almost to Wellesley Farms. There, paralleling Squirrel Road, it turns east in a defile in which there is a granite-roofed gatehouse and continues east paralleling Hillside Road and Prospect Street until it originally emerged on a, section of high embankment where, just south of Walnut Street, there was an underpass through the embankment for Cedar Street. Most of that embankment has been removed except for a short section near the Charles River, where the inverted siphon begins. A lintel from the underpass, inscribed "1848," remains by the side of the Cedar Street where the embankment was. The site of a missing granite-roofed gatehouse, formerly at the Needham (now Wellesley) end of the Charles River inverted siphon, is occupied by a concrete slab and vent pipe. (The original gatehouse was carried away in a breach of the aqueduct in 1859). At the bottom of the inverted siphon's steep descent to the river, the berm-topped three-arched granite bridge carrying it across the Charles remains in place, with its eastern abutment buried under the western embankment of Route 128.

***Newton*** — The Aqueduct was acquired by the city for sewer lines. Its right-of-way is preserved for much of its length as a walking path (with a few detours) from the Charles to Newton Center. The path begins from Quinobequin Road on the east bank of the Charles, where the inverted siphon and east end of the bridge carrying it over the Charles River are buried under Route 128. Then, still in a pipe, the aqueduct climbs the hill to the former location of a missing granite-roofed gatehouse at Waban Avenue, which marked the east end of the inverted siphon. The aqueduct follows the median of the divided Waban Avenue to Waban. Then it parallels Pine Ridge Avenue and Chatham Road to Cold Spring Park, whose eastern edge it follows north before turning northeast towards Newton center. The path ends at Tyler Terrace and Pleasant Street (where there is a granite-roofed gatehouse of the 1878 Sudbury Aqueduct, which closely parallels the Cochituate Aqueduct that point). From Newton Center, the Cochituate Aqueduct continues northeast along the northwest

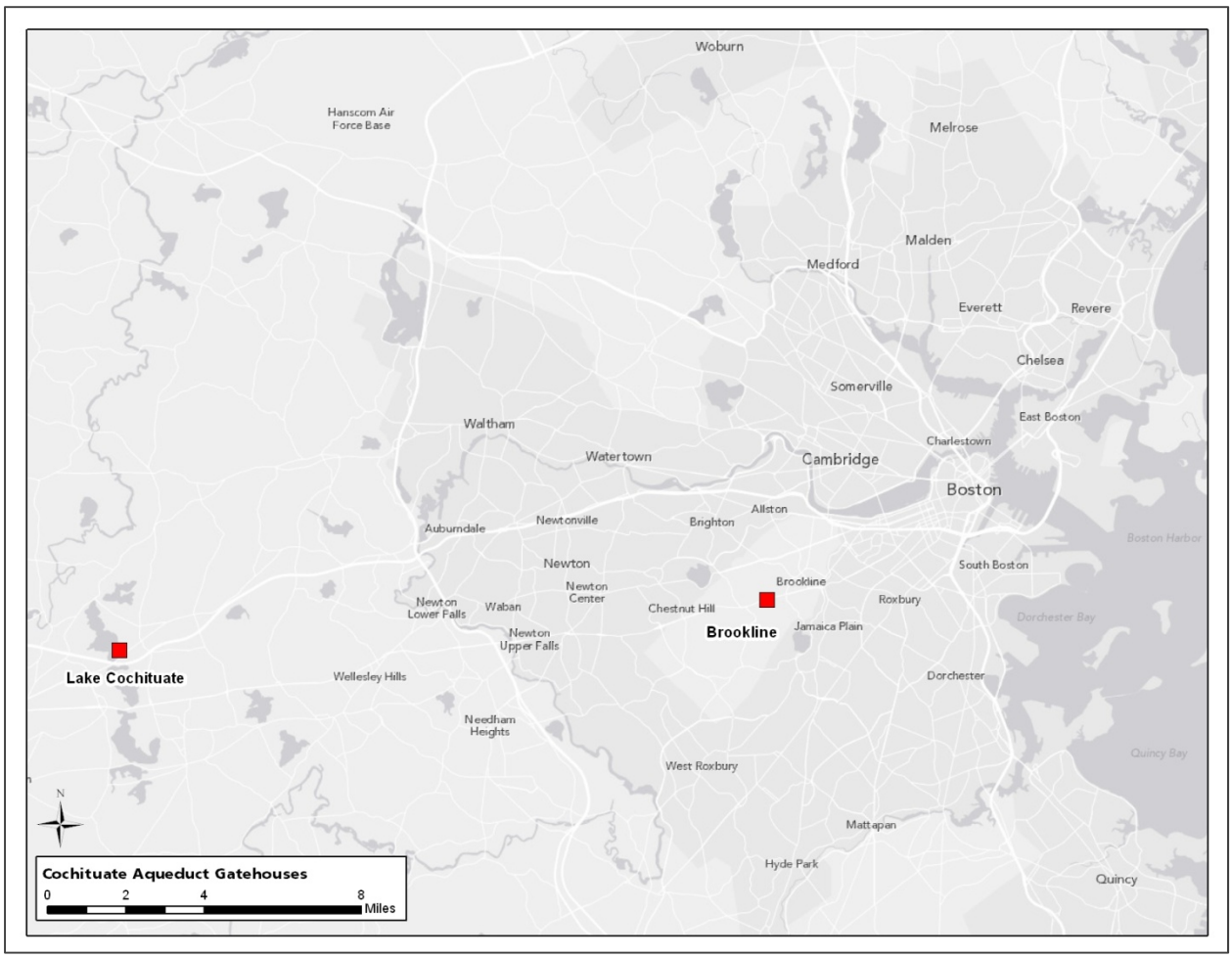
side of Newton Center Playground (with the Sudbury Aqueduct along the south side) to Commonwealth Avenue and then loops around the north side of Prospect Hill to the north of the Boston College Campus. Part of that section, marked by a 14-foot high tapered granite ventilator, is in a rock tunnel. It then follows St. Thomas More Road between the surviving basin of the Chestnut Hill Reservoir and the Reservoir's filled-in original second basin (now part of the Boston College campus.) It then follows Beacon Street east along the southwestern shore of the Reservoir before turning south passing just to the west of the Chestnut Hill High Service Pumping Station (now Metropolitan Waterworks Museum). Two gatehouses were built atop the aqueduct in connection with the reservoir and near the pumping station the original masonry was replaced with cast iron. It then passes under the D-Line trolley tracks into Brookline Station.

***Brookline*** — It first briefly runs in its own bermed right of way, where there is the granite roofed Webber's Waste Weir Gatehouse, paralleling Reservoir Road to Crafts Road, then follows Crafts Road and Eliot Street southeast, before tunneling to a depth of up to 60 ft. through ledge, under Boylston Street to emerge from a stone-roofed gatehouse at the head of the reservoir.

Note: A map locating the upper and lower gatehouses follows; the aqueduct runs between them, and through the municipalities, as noted above.

## Appendix B. Cochituate Aqueduct

Map Noting the Location of the Upper and Lower Gatehouses of the Cochituate Aqueduct, courtesy of Matthew Stutts, CRGIS, National Park Service, 2013.



Appendix C

***Early wrought iron roof trusses in Europe***

France pioneered the structural use of wrought iron in roof structures in the eighteenth century, and in the nineteenth century contributed substantially to the development of structural theory and analysis. The first three sets of all-wrought iron roof trusses in Europe are typically identified as having been in:
• The two 1833-34 greenhouses in the *Jardin des Plantes*, in Paris. (Although some sources seem unaware the originals were destroyed, the Jardin des Plants greenhouses were reconstructed in 1874, in a modified, more substantial appearing form, after Franco Prussian War damage.)
• The 1835-37 Euston Station train shed, in London.
• The 1835-38 *Marche de la Madeleine* in Paris. (The original roof structure of this market shed was poorly braced and fell victim to an 1845 windstorm. Both its failed wrought iron roof trusses and those of the failed post-1840 abattoirs in Bourges were vertical-kingpost trusses, known in France as "English trusses," whose round bar-stock compression members, too small in diameter in relation to their length, failed by deflection.).[135]

Of these three, often cited structures, only the Euston station roof lasted into the mid-twentieth century. Perhaps in part for that reason, it is better known than its shorter-lived French (and, as noted below, American) contemporaries. Notwithstanding the general recognition of the Jardin des Plantes trusses and/or Euston trusses as the earliest of their kind in Europe, some other earlier "iron roofs" and "iron trusses" are cited in various sources. While detailed information is sometimes minimal, it appears likely that none are entirely wrought iron and/or they are not trusses. A few are iron tied-rafter systems.

There appear to be no surviving, pre-1848, all-wrought iron French roof trusses, as defined herein.[136] Despite the two early Parisian examples cited above, the use of true wrought-iron roof trusses developed in France somewhat later than in the U.K. All other pre-1848 French wrought iron roof structures sometimes identified as "trusses" tend to incorporate arched or domed spans, sometimes combined with forms of diagonal bracing, and often suggest earlier timber framing traditions — seeming intuitive and, in part or whole, structurally indeterminate. The most significant of these problematic early wrought iron roof structures, made of forged barstock and redolent of the blacksmith and pre-industrial technology, supports the 1823-26 roof of the Paris Bourse — not to be confused with the better known, iron framed, glazed dome added to the Halle aux Ble (subsequently the Bourse du Commerce) in 1806-11.

The Polonceau (a.k.a. Wiegmann-Polonceau) truss was developed in France in the late 1830s. It has its "verticals" perpendicular to its upper chords, rather than to the ground, so that each half of its most typical embodiment looks and functions like a separate inverted-king-post truss, with the halves then joined by a tie-rod.[137] However, in part because iron was relatively expensive and timber relatively cheap then in France, such

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[135] Frances H. Steiner, *French Iron Architecture*, (Ann Arbor: UMI Research Press, 1984) is the best source in English concerning the French use of iron in buildings in the eighteenth and nineteenth centuries. Two other useful sources are Bernard Marrey, *Le Fer a Paris Architectures*, (Paris: Picard Editeur et Pavillon de l'Arsenal, 1989) and Bernard Marrey & Paul Chemetov, *familierement inconnues. . . Architectures, Paris 1848-1914*, (Paris: Secretariat d'Etat a la Culture, 1972). Almost all built French examples from before 1848 appear to have been in and around Paris. The fact that the principal period covered by the latter two books post-dates the political, cultural, and economic revolution of 1848, speaks to the relatively late widespread adoption of iron structural members in France, as compared to Britain.

[136] This conclusion is based on the absence of contrary evidence, including in three comprehensive sources: Steiner, *French Iron Architecture*; Marrey, *Le Fer a Paris Architectures*; and Marrey & Chemetov, *familierement inconnues. . . .*

[137] The question of roof truss type nomenclature in the nineteenth century is largely beyond the scope of this study. The name Polonceau for this type of truss was, and still is, commonly used in Europe. In the U.S. by 1906 the widely published Frank E. Kidder called Polonceau trusses "braced rafters." [Frank E. Kidder, *Building Construction and Superintendence V 3*, (New York: William T. Comstock, 2nd Ed. 1906), 36]. By 1921 his successors were calling them "French trusses" [The Late Frank E. Kidder, *The Architect's*

trusses prior to 1848 were typically of composite construction, often incorporating timber in addition to wrought iron and/or cast iron.[138]

The two earliest surviving, wrought iron roof trusses anywhere may be in the 1837-38 Engine House and former Boiler House in the Kew Bridge Pumping Station (now Kew Bridge Steam Museum), in London. These little known trusses are made of flat wrought iron bars connected by cast iron gusset plates. They are generally identified with Richard Tomlinson, who held the 1815 patent for the gussets, and James Wellington, who initially built such trusses, including those at Kew Bridge. Six other surviving Tomlinson/Wellington type truss roofs pre-dating 1848 are known. Typically they are in obscure, often "at risk," industrial settings. Much of what is known about these trusses derives from the notorious trial following the collapse of the Brunswick Theater roof in 1828 noted above. These trusses, whose design seems to reflect at best an intuitive understanding of their structural dynamics, could be quite unstable at longer spans. Typically they did not have purlins but the upper chords were supported against buckling under compressive load by the closely-spaced iron "battens" between them, to which the roofing slates were attached. With one exception, the surviving examples tend to span smaller spaces, which often were boiler rooms and retort houses where there would have been a concern about fire. At the time of writing two of the few remaining examples are under permission for demolition and two are derelict.[139]

The much better-known, more sophisticated kit-of-parts "Euston type" trusses used in that London station's train shed were widely replicated by their builders, Fox, Henderson & Co. during the 1840s British railway boom and beyond. At least eight train sheds predating 1849 with Euston type trusses survive. Unlike the Tomlinson/Wellington trusses, they had stiffer T-shaped compression members, adjustable tension members, and pin connections. None of those refinements were in either Cochituate roof, nor in the Philadelphia Gas Works roof, although fabricated T-sections were used in the Boston Merchants Exchange (all discussed below).

Even in the U.K., during the 1840s "composite" all-iron roof trusses, combining wrought and cast iron, often following the Polonceau model, were more typical than entirely-wrought iron trusses. Arched forms, often entirely of cast iron, were preferred for the increasing spans of larger train sheds and market halls — and for the less well known but spectacular iron roofs which spanned the Royal Navy's ship-building "slips" beginning in the mid-1840s. Most of the survivors of the approximately sixteen iron roofs (enumerations vary slightly) built over the Royal Navy's shipbuilding "slips" are of cast iron and/or wrought iron arched construction.[140]

Outside Britain there may be only a few extant wrought-iron roof trusses of this period. As early as 1825, Leo von Klenze, who trained under Napoleon's court architects Percier & Fontaine, may have used a wrought iron roof structure in rebuilding Munich's fire-gutted National Theater (destroyed 1943). Ca. 1838, he also used wrought-iron trusses, whose details appear consistent with his French training, on his Greek-temple-form *Walhalla*, a pan-German pantheon project of the King of Bavaria, near Regensburg.[141]

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*and Builder's Handbook*, (New York: John Wiley & Sons, 17th Ed. 1921), 1026.] Current U.S. sources often identify them as one of many configurations of Fink roof trusses, sometimes as "cambered Fink trusses" [Michael R. Lindeburg, *Civil Engineering Reference for the PE Exam*, (Belmont Calif.: Professional publications, 2012), 41-13.]

[138] Stefan M Holzer, "The Polonceau Roof and its Analysis," *International Journal for the History of Engineering & Technology*, 80, No. 1, (January, 2010), particularly 27-37.

[139] Malcolm Tucker, of the Greater London Industrial Archaeology Society, generously shared unpublished research and firsthand knowledge of Tomlinson/Wellington roof trusses and other early shorter span iron roof structures.

[140] David Evans, *Building the Steam Navy* [etc.], (London: Conway Maritime Press, 2004), 44ff; Adam Mornement and Simon Holloway, *Corrugated iron: building on the frontier*, (New York: W.W. Norton, 2007), 16ff.

[141] Werner Lorenz & Annegret Rohde, "Building with Iron in Nineteenth Century Bavaria: The Valhalla Roof Truss and its Architect Leo von Klenze," *Construction History 17*, 55-74.

In 1838 the Winter Palace in St. Petersburg, Russia, was destroyed by fire. Its roofs were rebuilt by 1842 with wrought-iron trusses, using the new, rather complex Emy truss that preceded the more rational Polonceau truss, together with parallel-chord trusses designed by the Anglo-Russian engineer, Matthew Clark. The New Hermitage Palace, begun shortly thereafter, has Polonceau-like trusses, erected 1844-45, based on designs by von Klenze.[142] It should be noted that the history of iron production in Russia was quite different than that of Britain. Russia had a long established iron industry but it was based more on wrought iron, not just cast iron. Wrought iron bar and roofing plates were major Russian export products in the eighteenth century. There was also an unusual tradition of using iron floor tiles in churches, suggesting that the material was relatively abundant while also prestigious.

Except for the Munich theater, these continental imperial and royal projects all survive.

In 1844 and 1847, wrought-iron truss roofs were erected over the locomotive assembly hall and foundry respectively of the *Borsig Werk* in Berlin-Mobat. Their use that early in an industrial setting seems exceptional on the continent. Borsig was a technically advanced firm in the Germany of that time. Neither Borsig roof survives.[143]

[142] Bernhard Heres, "The Iron Roof Trusses of the New Hermitage in St. Petersburg —Structural Survey, Analysis and Assessment of a Masterpiece of Structural Steelwork [sic] from the 1840s," *Second International Congress on Construction History Conference Proceedings* http://www.arct.cam.ac.uk/Downloads/ichs/vol-2-1555-1568-heres.pdf/view, accessed July 24, 2011). Von Klenze's designs were reportedly reworked by Russian engineers.

[143] Miron Mislin "Iron constructions [sic] for factory buildings in the nineteenth and early twentieth century," *Proceedings of the First International Congress on Construction History*, (Madrid: 2003), and written communication with Mislin. The ca. 1900 photograph in his paper (his figure 3) purporting to show the 1844 wrought iron truss roof in the Borsig Werk locomotive assembly hall appears more consistent with the ca. 1900 column construction technology also described in the article.

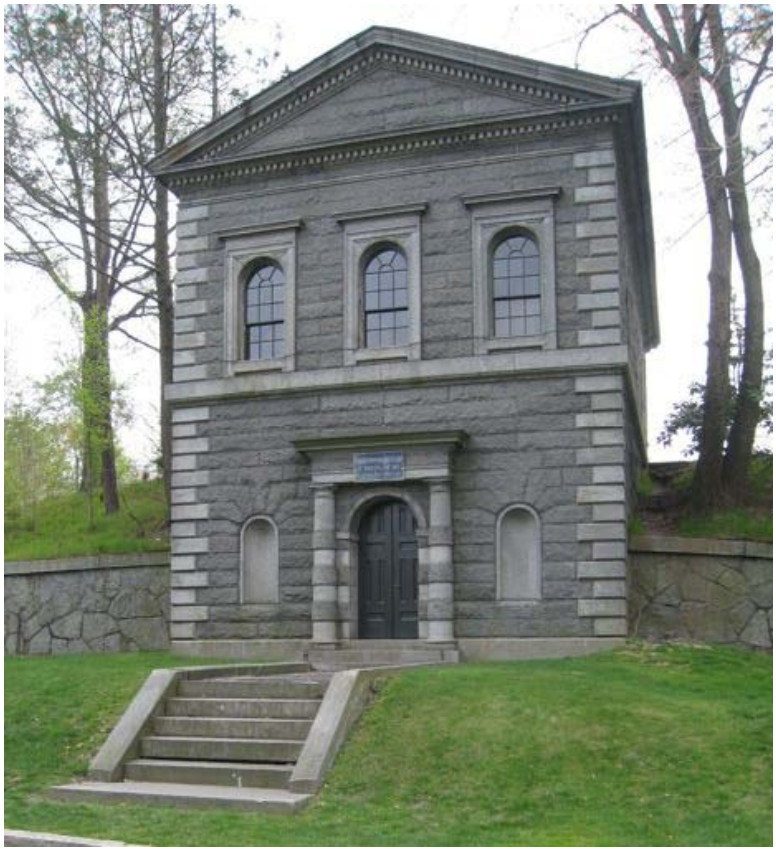

Fig. 1 Principal Gatehouse, view to south.
Dennis J. DeWitt Photographer 2012.

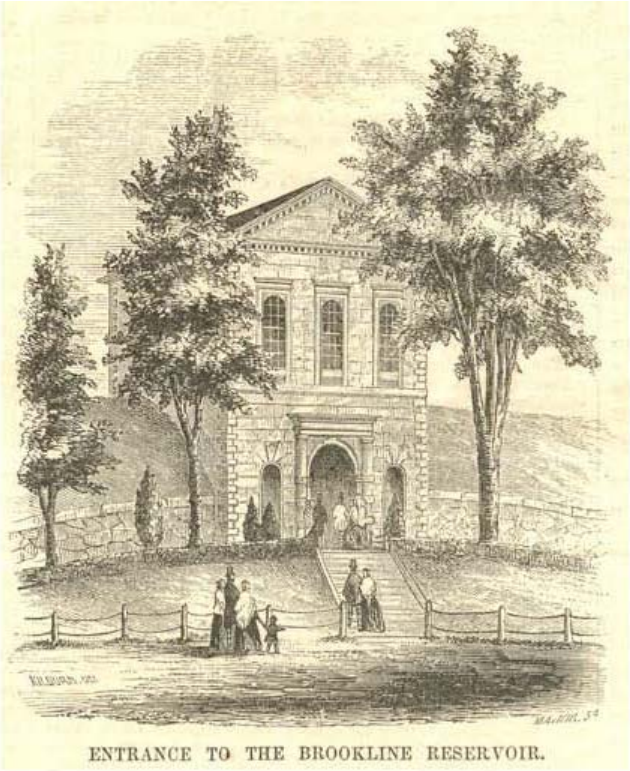


Fig. 2 Historic view of the Principal Gatehouse.
*Gleason's Pictorial*, July 16, 1853 (Courtesy Brookline Public Library)

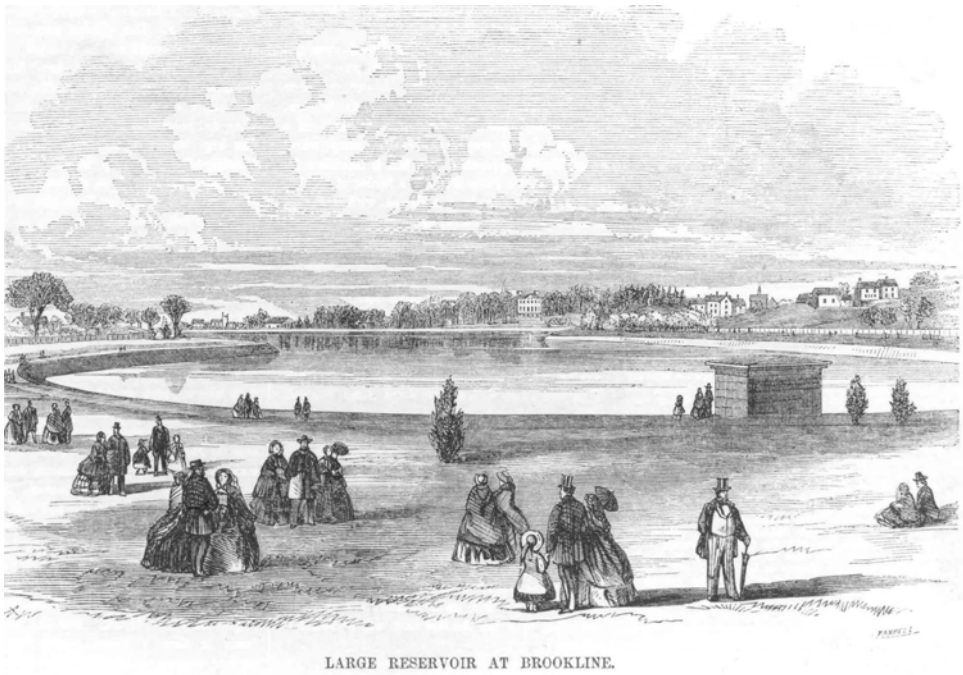


Fig. 3 View of Reservoir from Influent Gatehouse.
*Gleason's Pictorial*, July 16, 1853 (Courtesy Brookline Public Library)

Fig. 4 View of Reservoir looking northeast toward Principal Gatehouse (arrow).
John Phelan Photographer 2010.

Fig. 5 View of rear of Principal Gatehouse with Reservoir drained, c.1926.
(Courtesy Brookline Preservation Commission)

Fig. 6 Principal Gatehouse, view of double staircase.
Dennis J. DeWitt Photographer 2010.

Fig. 7 Principal Gatehouse wash rendered cross-section drawing through gate chambers.
(Courtesy of Archives, Massachusetts Water Resource Authority)

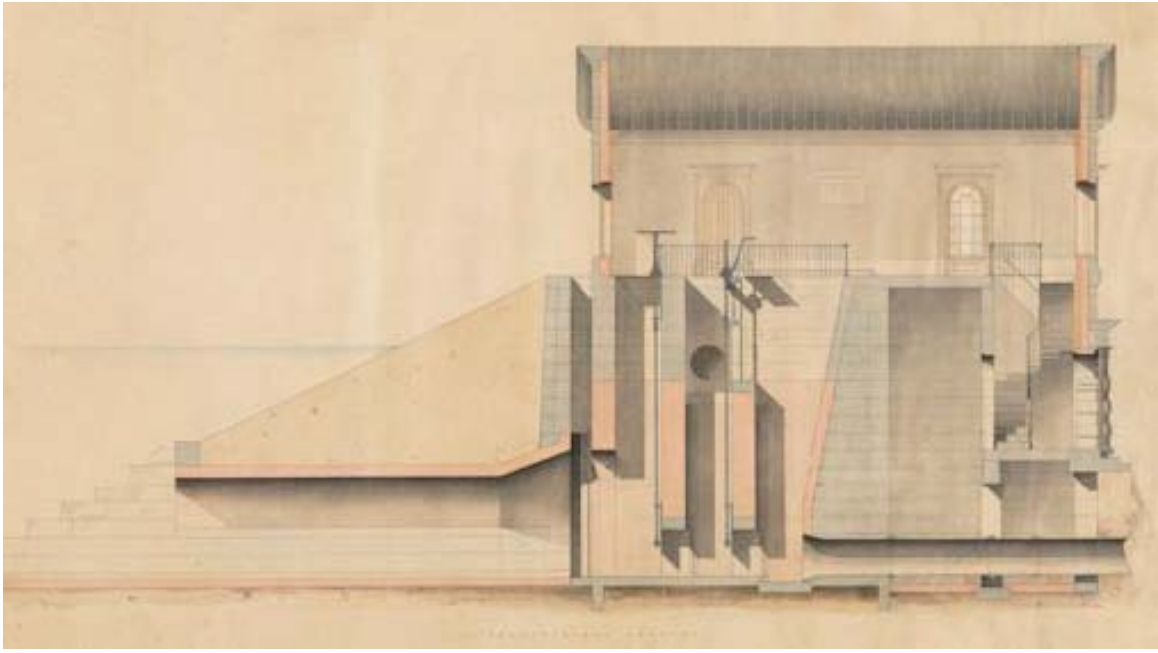

Fig. 8 Principal Gatehouse wash rendered longitudinal section along centerline of building.
(Courtesy of Archives, Massachusetts Water Resource Authority)

Fig. 9 Principal Gatehouse, wash rendered longitudinal-section along centerline of building.
(Courtesy of Archives, Massachusetts Water Resource Authority)

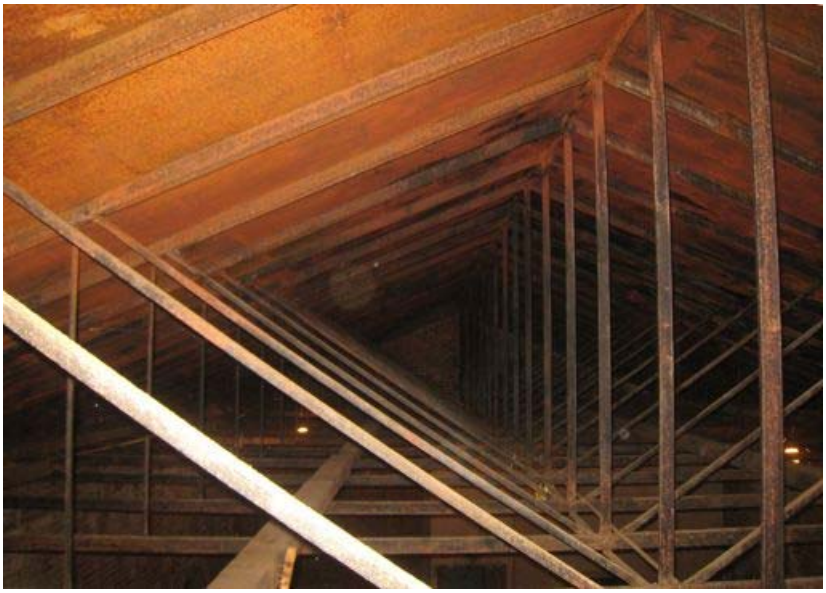

Fig. 14 Detail, iron trusses supporting roof deck.
Structures North Photograph 2009

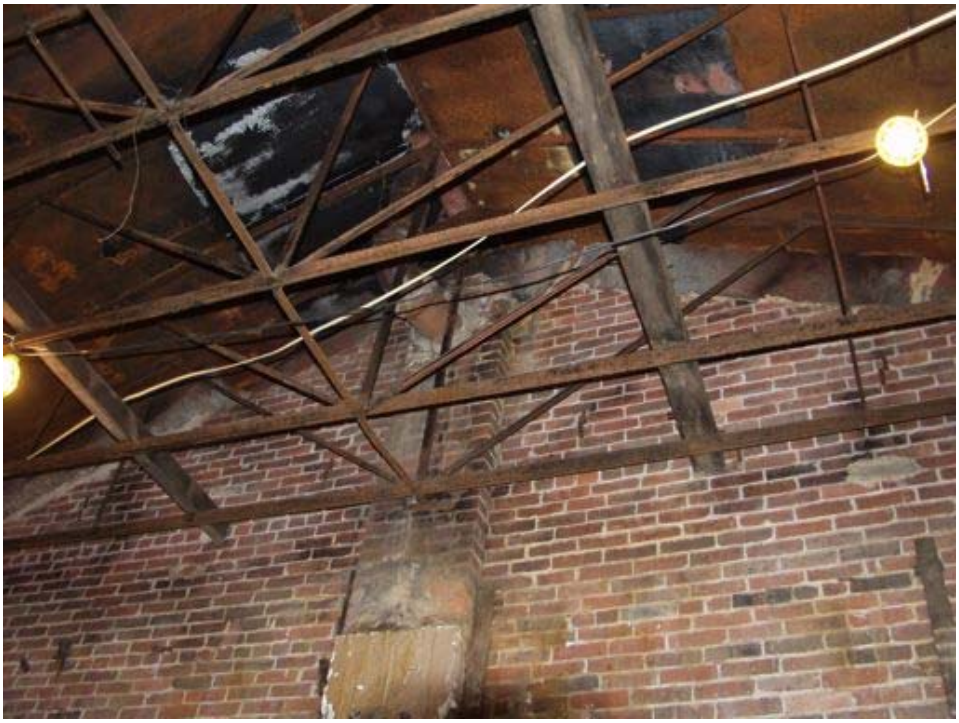

Fig. 10 Iron trusses and roof deck with two areas of repaired deck damage; nonstructural wood members on bottom truss chords.
Photograph by Structures North, 2009

Fig. 11 Principal Gatehouse, detail of end of typical roof truss with leveling bricks showing corrosion form gutter leakage.
Photograph by Structures North 2009.

Fig. 12 Interior of Principal Gatehouse looking north showing exposed trusses and brick walls with opening around center guard gate lead screw, 1926 toilet room partitions over staircases. In foreground is temporary boarding around opening in floor with center gate screw. Dennis J. DeWitt, Photographer 2010

Fig. 13 Detail, original window sash and grain-painted trim in north window.
Dennis J. DeWitt Photographer 2010

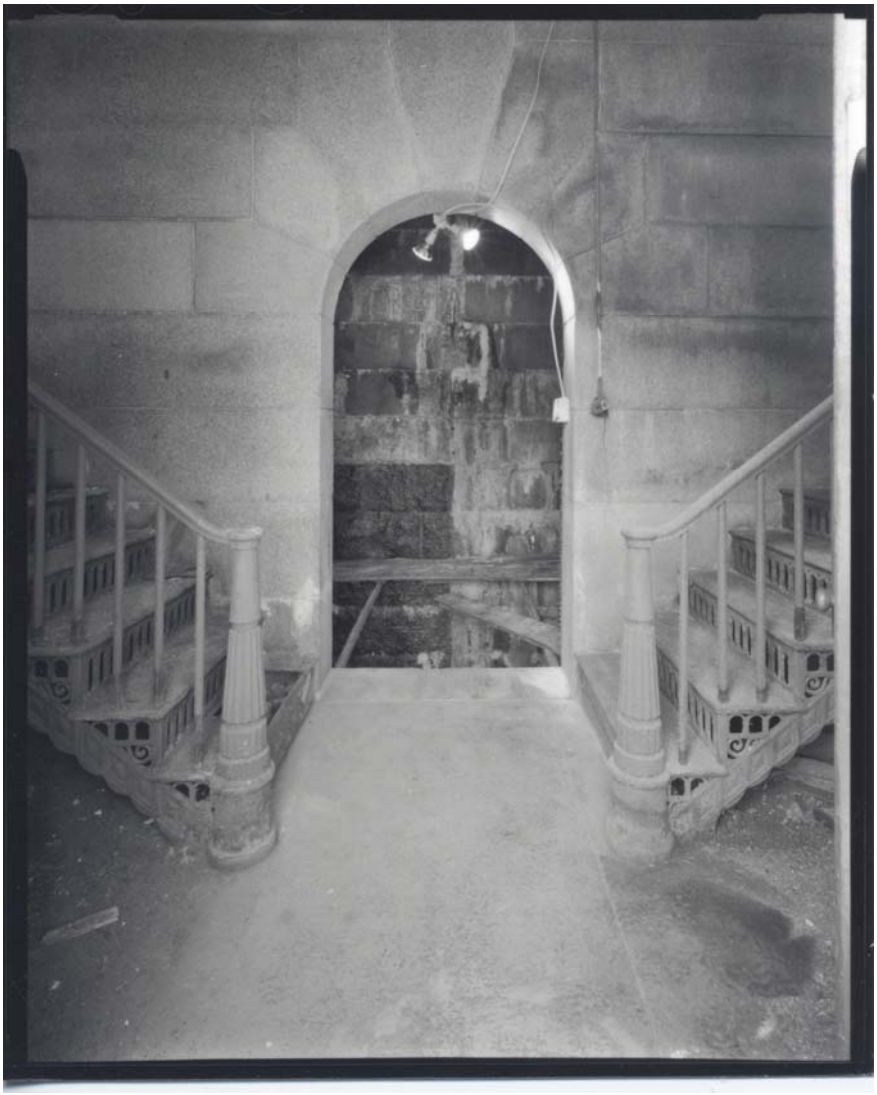

Fig. 14 View from main entrance with twin staircases flanking opening to bulkhead chambers.
(Historic American Buildings Survey 2013)

Fig. 15 Detail, Principal Gatehouse staircase.
Dennis J. DeWitt Photographer 2008

Fig. 16 Detail, Boston Athenaeum staircase.
Dennis J. DeWitt Photographer

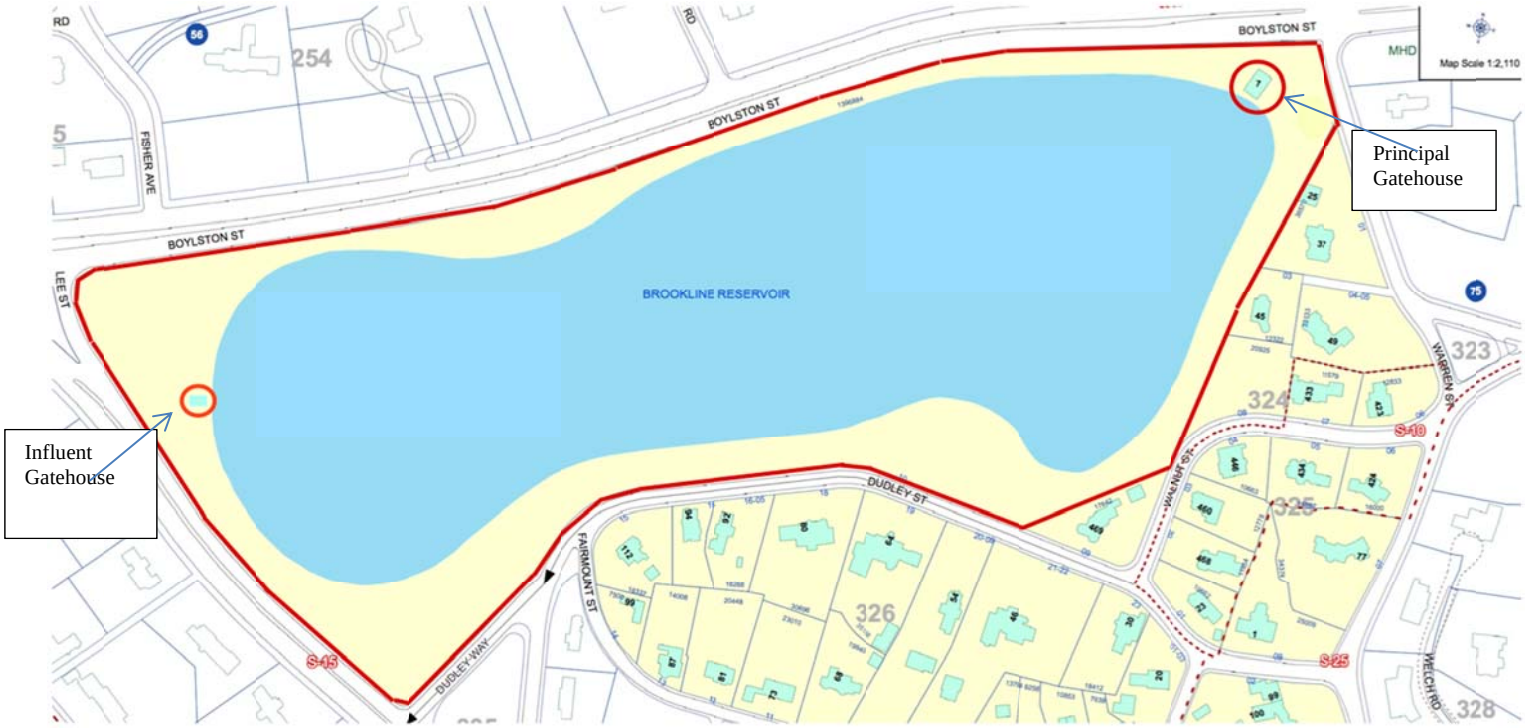


Fig. 17 Map showing nominated property with the entire Reservoir Park.

Brookline Reservoir
Brookline, Massachusetts
A: 19/324220 4688260
B: 19/324170 4687960
C: 19/323790 4687870
D: 19/323580 4688030