Society for Industrial Archeology · New England Chapters

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This Newsletter is mailed as a membership benefit to Northern and Southern NE Chapters, SIA, members. For information on the Web go to: http://nec-sia.org/membership.htm

SNEC President's Report
Spring 2016

As of early April, the Southern New England Chapter has two events planned for the Spring; one on May 14 in the Salisbury Iron District of Northwest Connecticut and the second, a bicycle tour on June 11 along the path of the Sudbury Aqueduct in Wellesley and Needham, Massachusetts (full reports will be posted in the fall newsletter). We also have tentatively scheduled a tour in Amesbury, Massachusetts, in September, as well as a return to Pawtucket, Rhode Island, in October to mark the 40th anniversary of the SNEC-SIA. Details of these events will be posted on the website as they become available.

Reminder: Please make sure we have your current e-mail address, so that you are included in the monthly e-news blast, so that you do not miss important news and events (this includes NNEC-SIA members too). If you have not been receiving notices, there is a good chance that we do not have your current e-mail address. Make sure so that you can be kept informed!

I am also pleased to introduce a new logo for the SNEC-SIA (see below). The design was chosen over several dozen options and will be used for marketing purposes. The final design features a 1968 HABS drawing by Dennis W. Jacobs of Durfee Mill No. 1 in Fall River. I've also had a banner made for use as part of our planned "road show" so that we can get the word out to the general public.

Southern New England Chapter
Society for Industrial Archeology

As mentioned elsewhere in this issue, NNEC President David Dunning and I are hoping to arrange a meeting of the officers of two New England Chapters this summer, in order to discuss important matters facing us in the near future. A lot of good suggestions have been made over the years, but if we are to survive, we really need to establish a "Plan of Action," with a specific message and a specific list of tasks delegated to those members who are willing to help. If you have enjoyed the SIA over the years, or if you have any advice on marketing, please think about contributing suggestions and/or time to help us carry on for years to come!

Marc N. Belanger
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NNEC President's Report
Spring 2016

State of the Chapter:
At the spring conference, Dennis Howe led an open discussion about how we might adjust to our decreasing membership. It is noted that associations of all types are experiencing this problem; it seems to be generational. Much discussion ensued at the meeting, but many other observations were noted by board members after the meeting, and they were e-mailed around. Here are some of the thoughts that were expressed. (Please e-mail your own to David Dunning at dunmark@tds.net):

- We are getting new members regularly but not enough to keep up with attrition.
- Most groups have a shortage of members willing to take on the leadership roles.
- Many people stayed long after the conference was over to network and chat. That indicates a need/opportunity to arrange for that to happen more often.
- A Chapter picnic has been suggested by several of us over the years.
- Some students attend our conferences and a few may join but not keep it up.

The two Chapter boards are planning to meet in a few months to discuss the need for changes. Please e-mail us your input. Thank you.

Our Treasurer, Rick Coughlin, reports that we now have $5,053 in our savings account. Last year, at this time, we had $5,461. This reflects a continual annual drop. Each year we gain a few new members, but we also lose a few. Hence the need for a leadership summit.

David Dunning
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NNEC 2015 Fall Tour in Nashua, NH

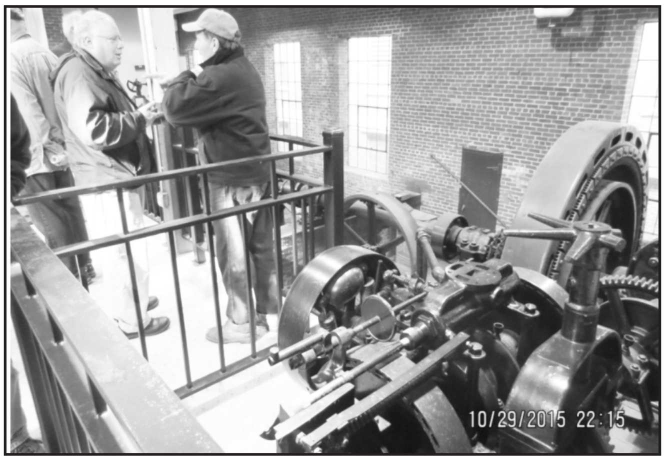
Our tour began at the Mine Falls Park Gatehouse. The name stems from the 18th century when low quality lead was mined from the island below the falls. In the 19th century, the potential of the Nashua River to drive the wheels of industrial mills was recognized. Workers used shovels and mules to dig a 3-mile-long canal, which provides a vertical drop of 36 feet at the mills. The first gates were built in 1826, and the gatehouse near the falls was built in 1886. By the late 1900's the gatehouse had fallen into disrepair and was an eyesore as well as a safety hazard. It has recently been restored as a walk-in museum and we really enjoyed walking in and seeing and hearing all about it. From the gatehouse, we walked a short distance to the modern hydropower station.

From there we drove the 3-mile canal distance to the Nashua Manufacturing Company's brick mill building with its identifiable clock towers. Down in the basement we examined the old power generating turbines. They were state-of- the-art in their day but are now replaced by the newer hydro-station back at the falls, which serves the whole area. Up in a clock-tower we saw the actual workings of one of the clocks. It was built in 1901 by E. Howard and Company.

"In December 1824, the Nashua Manufacturing Company obtained a charter to build a canal with the necessary locks and dams to connect the Nashua River with the Merrimack. The effort included construction of a second dam on the Nashua River, to create an intermediate river level that still exists, and a canal with 4 locks. Begun in 1825, ... the canal opened in 1826. Its purpose was to support the village, the several mills along Canal Street, and the Nashua Manufacturing Company." Credit to Bill Gerber for the above information. At one time, the Nashua Manufacturing Company was the largest producer of blankets in the world, employing one-fifth of the city's workers. Like some other mill towns we have studied, they laid out the city's streets, built its church and fostered other business enterprises.

Inside the Mine Falls Gatehouse

Sluiceway to the Powerhouse



Much discussion about the generators

Nashua Manufacturing Co.'s Main Building

Inside the Clock Tower

The railroad had put Nashua on the line between Concord to the north and Boston. In the twentieth century, however, the advent of synthetics and competition from southern mills combined to bring the New England textile mills to their knees. In 1948, just four years after receiving a government award for service to the military during World War II, the mill shut its doors. A few years before that, it had been acquired by Textron.

We had lunch at the Portland Pie Company along the canal. Upstream we could see The Peddler's Daughter restaurant (which wouldn't seat us as conveniently). It was at the second of two landings that served the Nashua community. The Peddler's Daughter was built above flood stage of the Nashua River. Boats accessed through the water-level portal and were loaded and unloaded from the floor above, probably using a 'wheeled windlass'.

The Nashua Wastewater Treatment Plant visit, just after lunch, was a really interesting education on a modern day complex system that we don't often think about. All of the waste is purified; some its byproducts are used and the clean water flows right into the Merrimack River. The flaunt seeps down through a digester which extracts methane gas. Some of the methane is used to power an internal combustion engine which spins a generator to produce electricity, and some is just burned off. In a junk pile at the treatment plant, Ray Breslin showed us the old rusty remnants of a steam engine that was built locally by the Rollins Engine Company. There we also explored a newer skeleton of an Ingersoll Rand air compressor. It had a single cylinder with a connecting rod and a flywheel.

Finally, we traveled across the Merrimack River into Hudson to Vaupell Rapid Solutions. This was a real travel in time from exploring industrial history to one of the most modern processes used today. Vaupell is in the rapid prototyping business. They make single unit or short run plastic parts for other companies to verify their new product designs and try them out. Their primary process is called stereo lithography (SLA). It is a photo-electronic sintering process that uses a computer-controlled light beam to solidify a plastic fluid along electronic blueprint lines. The result is a very accurate plastic model of the part. Overnight, they can produce a model that would have taken much longer and been greatly more expensive than to machine it from metal. Another benefit is that once customers have their SLA parts in hand and see needed changes, they are also quick and less expensive to redo. Vaupell is a global company, owned by Japanese investors, but the local Hudson plant started out as Brookfield Rapid Solutions and later was acquired by Vaupell.

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29th Annual Winter Conference

The winter conference took place on Saturday, March 5th in Plymouth, N.H. We had a large turnout for the day to listen to many interesting and varied topics. The first speaker was Bill Gerber who spoke about the canal side landings used on both the Merrimack River and Middlesex Canal. These landings were illustrated in a few drawings and sketches from the early 1800's and gives us an idea of how they were utilized. In some landings the goods were loaded and unloaded by a wheeled winch from above the canal boat. In other landings the boat was docked along the shore and unloaded there. The only remaining canal side landing is found in Nashua under the Peddler's Daughter restaurant.

Peter Stott gave a presentation on the disappearance of the Engineering Index from research library open shelves. He told us how to obtain these past issues online until circa 1924 from various website sources. This led to a discussion on how many SIA-related publications are no longer available at libraries and have to be requested from remote library storage locations.

Chip Taylor, a new NNEC member, gave a stimulating talk on how not to do an investigative dig. He related the story of a 220-year-old dig still taking place on Oak Island, Nova Scotia, which started in the late 1700's looking for buried treasure.
From picks and shovels it's progressed to steam-powered drills, pumps, and dynamite. Today backhoes, bulldozers, and SCUBA gear are used and six people have died over the years in this continuous digging into the earth.

Marc Belanger provided us with new information on the M.M. Rhodes Company from Taunton, Mass. The company closed in 2014 after being in business for more than 150 years. This company produced a variety of items over the decades with their most successful product being paper-mache shoe buttons made between 1875 and 1915.

To wrap up the day, David Starbuck spoke about industrial sites he had visited during a recent trip to Ireland, featuring Waterford Crystal in the city of Waterford and the Guinness Storehouse in Dublin.

Dave Coughlin

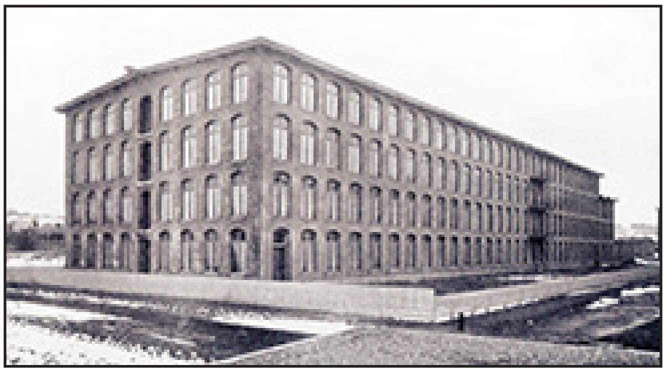
A Tale of Three Bristol County Mills (the Good, the Bad and the Maybe)

The Good
On January 11, 2016, the Taunton Daily Gazette reported that the historic 14-acre Reed & Bardon Complex in Taunton had been sold to Acuity Management Inc. of Duxbury for $100,000. The new owners have promised a "responsible redevelopment". Reed & Barton, the famous silverware maker, filed for bankruptcy in early 2015. No production had occurred in Taunton since 2009. In March 2012, the history of Reed & Barton was featured in an SNEC-SIA talk & tour of the Old Colony Historical Society (see article in Spring 2012 New England Chapters Newsletter). The site covers both sides of the Mill River, and features an impressive complex of brick structures primarily built between 1830 and 1881. It has been expanded a number of times over the years, including several large additions during the mid-20th century. In 1984, the site was added to the National Register of Historic Places. The listing also included two brick Cape Cod-style worker houses built by the company (c. 1855).

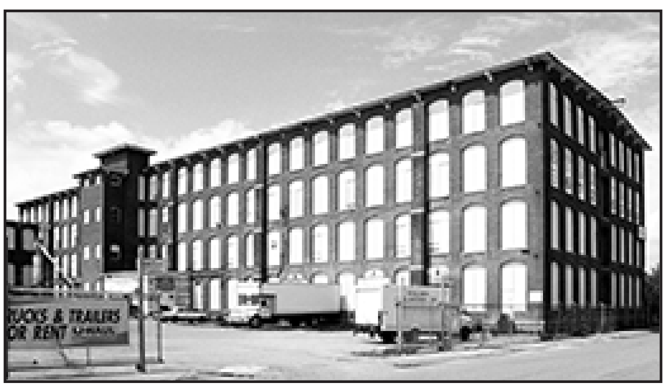
The Bad
Border City Mill No. 3 in Fall River, Massachusetts, was destroyed in a massive inferno during the early morning hours of February 20, 2016. Built in 1888, the mill was part of the northernmost group of mills in the city, near the shores of the Taunton River. In recent years the lost mill was used for storage. Thanks to favorable wind conditions and the efforts of fire fighters, no other nearby structures were damaged. This includes Border City Mill No. 1, and Mill No. 2, as well as the nearby Sagamore Mills. The Border City Mills company was established in 1872, during a period of incredible mill expansion in Fall River. By 1917, the Border City Mills had 118,896 spindles and 2,935 looms. The company survived the great depression and operated into the 1940s. The site was determined to be eligible for the National Register of Historic Places in 1983, but omitted due to the owner's objection. The fire was deemed to be suspicious and has sparked fears in south end residents regarding the vacant King Philip Mills.

The Maybe
The future of King Philip Mills in Fall River, Massachusetts, has been uncertain ever since a portion of the complex was destroyed by an arsonist in January 2012. Faced with an absentee owner who was delinquent on taxes, the city soon evicted all tenants of Mills No. 1 and No. 2, and fenced off the site, due to safety concerns because of a non-working fire sprinkler system. The four mill complex was built between 1871 and 1892. It is located in the city's South End, along the shores of Cook Pond. In 1930, it was purchased by Berkshire Fine Spinning Associates of Adams, Mass. The mills were later part of Berkshire-Hathaway after the 1955 merger with Hathaway Mills of New Bedford, but were closed in 1964, just prior to Warren Buffet's takeover of that company. Mill No. 3 (1888) is still occupied by Korber Hats, and is not

Reed & Barton Complex (2008) Taunton, MA - Marc N Belanger photo.



Border City Mill No 3 (1901) - photographer unknown



Border City Mill No 3 (2006) - Marc N Belanger photo

KIng Philip Mills (2011) - Fall River - Marc N Belanger Photo.

part of the city's acquisition. Mill No. 4 (1892) was occupied by Crown Uniform & Linen Services until mid-2014 when that company moved to Brockton. In recent months, a local neighborhood group (whose homes were mostly built by the King Philip Mills) has demanded that the city demolish the three unoccupied mills. However, as of March 2015, a glimmer of hope remains that the mill complex can be saved and redeveloped in a responsible way. The Fall River Historic Commission is currently awaiting a feasibility report for the property.

Marc N. Belanger
Taunton, MA

Bartlett Roundhouse Named to National Register of Historic Places

The New Hampshire Division of Historical Resources is proud to announce that the Bartlett Roundhouse has been honored by the United States Secretary of the Interior with placement on the National Register of Historic Places. In addition to being a surviving example of a rare type of 19th century railroad architecture, it is significant for the role it played in the history of rail transportation in northern New England.

Once a critical part of a bustling railyard in Bartlett Village, the Roundhouse was built in 1887 for the storage and repair of locomotives on the Portland & Odgenberg line. Its footprint is arch-shaped and was designed so that a 56-foot turntable in front of it could guide trains into the six separate repair stalls, where crews could perform maintenance 24 hours a day, seven days a week.

Locomotives kept at Bartlett assisted trains over the steep grade to Crawford Notch. In addition to carrying tourists to hotels and boardinghouses in the White Mountains, they also transported a wide variety of freight, including lumber,

The Bartlett, New Hampshire, Roundhouse

pulpwood, cedar ties, telephone poles, limestone, ice, sulfur, coal, paper and manufactured goods.

After playing a critical transportation role during World War II, rail transportation in New Hampshire scaled back as highways were built and roads improved. The Maine Central Railroad Company, the final owner of the Bartlett Railyard, ran its last passenger trains in 1958 and the Roundhouse then ceased being used as a service facility.

The Bartlett Roundhouse was one of 35 on the Boston and Maine Railroad, a handful of which still exist in vari ous forms in New Hampshire. It proved highly adaptable throughout the years: two stalls were lengthened in 1913 to accommodate larger steam locomotives and two other stalls were removed around 1950 as train transportation declined. Windows were added after each of these renovations to provide additional natural light. Each stall has double doors that open inward to avoid getting stuck in ice and snow. Segments of rail survive in each of the stalls, and train track with sidings and switches is still located north of the building.

The Bartlett Roundhouse was listed to the New Hampshire State Register of Historic Places in 2008. Administered by the National Park Service, which is part of the U.S. Department of the Interior, the National Register of Historic Places is the nation's official list of cultural resources worthy of preservation and is part of a national program to coordinate and support public and private efforts to identify, evaluate and protect our historic and archeological resources.

For more information about the National Register program in New Hampshire, please visit nh.gov/nhdhr or contact Peter Michaud at the New Hampshire Division of Historical Resources at 603-271-3483.

Peter Michaud
NH Division of Historical Resources
peter.michaud@dcr.nh.gov

The First Winchester Brass Mill

For over a hundred years from 1817, when Daniel Hayden built a shop for making brass in Waterbury, western Connecticut was the center of the U.S. brass industry. This had nothing to do with availability of natural resources -- copper, zinc, and coal fuel had to be brought in from other parts of the country -- and everything to do with a community of specialist artisans. Brass making was an art entirely dependent on artisans' skills until the introduction of electric furnaces and chemical analyses in the 1920s. When HAER recorded Waterbury's Scoville brass works, only modernized manufacturing space remained. No other Connecticut brass mill has been recorded. Thus the opportunity to study the 1883 brass mill at the Winchester Repeating Arms Company's factory complex in New Haven was the last chance to record features of the industry that until the early twentieth century supplied nearly all of the brass made in the U.S. Raber Associates conducted documentary, photographic, architectural, and subsurface archeological research at the mill between 1987 and 1992, including investigations after the mill was razed.

Makers of firearms encountered rapid technological change after the Civil War as they replaced the muzzle-loading and early breech-loading arms with rifles and pistols that used metallic cartridges. When the Winchester began making its repeating rifles in 1866, it also had to undertake production of metallic cartridges. Despite mechanization rifle production remained dependent on hand fitting of parts well into the twentieth century, but cartridges had to be both perfectly interchangeable and suitable for large-scale, automated production. Makers soon found that an alloy of copper with 30 percent zinc was the ideal material for cartridge cases. Its strength and work-hardening properties were a good match to the deep drawing processes that formed the cases while, when properly heat treated, its elasticity assured a good gas seal and easy extraction of the spent cartridge.

Winchester needed a supply of high quality brass. This was conveniently at hand because of the concentration of brass makers in nearby Waterbury and neighboring Naugatuck Valley towns. Although Connecticut brass makers had competed with each other fiercely, in 1853 they formed the American Brass Association to control production and prices. By 1869, as Winchester moved into large scale cartridge production, mills were routinely circumventing the quotas set by the association. However, a new agreement between the firms that produced more than 90 percent of the rolled brass in the U.S. was set up in 1884. Winchester managers did not want to be at the mercy of a sole-source supplier of an essential raw material, and in 1883 decided to establish their

Figure 1. *1992 View Northeast of the Winchester Brass Mill after the Adjoining Cartridge Shop was Razed. Photo by William Sacco*

own brass mill to assure a supply of brass for its ammunition production.

An opportunity to find out how Winchester met this challenge arose when its first brass mill building was to be razed. The company had removed the furnaces, roll stands and other machinery when it built a new mill in 1916, but it retained the 1883 building for storage space with many of its structural features intact. Removal of a post-1916 concrete floor exposed the below-ground features of the original mill. Only limited salvage archeology was possible, with no opportunity for excavation of deep exposed features. Fortunately Winchester's drafting department made drawings of virtually every piece of equipment the company used. Drawings of the brass mill and its equipment found in the company's abandoned office vault facilitated the interpretation of the physical features of the building.

Mill Building Structure, History and Significance

The mill erected by Winchester in 1883 was a one-story 130-by-101-foot structure facing Newhall Street near the corner of Argyle Street in New Haven. The company designated it F5, and added a 90-by-101-foot extension, F6, in 1886. With a few minor additions this structure accommodated the melting and casting shop, rolling mills, and annealing furnaces needed to make brass sheet from primary metals (Figures 1-2).

All mill sections were one-story brick-pier spaces. The brick piers reinforced the side walls at bay intervals, adding strength for the additional vertical loads at these points where beams, rafters, or trusses were supported. There were also brick piers on the original exterior end walls of the 1883 and 1886 sections, with arched brick doors which in some instances were altered or bricked in before World War I. Arched brick windows with stone sills and wood sash lit the two spaces between the piers or pilasters. Ornamental cornices with dentils decorated all mill sections.

The 1883 and 1886 sections were three-bay spaces with varied structural arrangements. Stone foundations supported the walls and columns. The earliest and tallest section had 18-foot-high side walls, two rows of columns on 10-foot centers, and an asymmetrical, inclined roof truss of 8-by-12-inch timbers. The truss ran from the western, taller column row of 12x12-inch timbers to the lower, eastern column row of steel lattice girders; the latter, similar to those found in the 1886 section, were probably replacements. The truss, of 8-by-12-inch timber beams, made minimal use of triangular forms, and appeared to be a kind of king post truss with additional posts. This strange but fascinating structural system may reflect a need for extra clearance or carrying machinery loads over part of the floor. There were also metal tie rods and other trussing elements, some with turnbuckles, which may have been later additions. A wooden monitor with ventilating flaps crowned the composition, wood-decked roof. Obvious alterations to this section included a concrete floor, a steel craneway attached to the columns, and a central transite-and-wood wall dividing the space longitudinally.

The 1886 section had 16-foot-high side walls, and two rows of lattice girders on 10-foot centers which supported triangular, riveted plate-girder roof beams. This unusual structural system was erected by the Berlin Iron Bridge Company. The wood-decked symmetrically-pitched composition roof lacked a monitor, but had a 12-foot-high, 20-by-50-foot raised section of unidentified function at the southwest corner. A concrete floor and a narrow craneway in the westmost bay were later additions.

At the north end of the mill, a small two-bay section was added in 1915 section, defined by a central row of riveted-steel-girder columns on 9-foot centers, with 21-inch I-beams carried on the columns to support 15-inch I-beam or steel truss rafters. A stepped brick parapet on the end wall hid the low, gabled, composition roof.

As noted above, the 1883 and 1886 sections gave Winchester independent brass rolling capability for cartridge manufacture. Under-documented early laboratory work by the company also probably included important use of this mill for cartridge development. Use of the structure during World

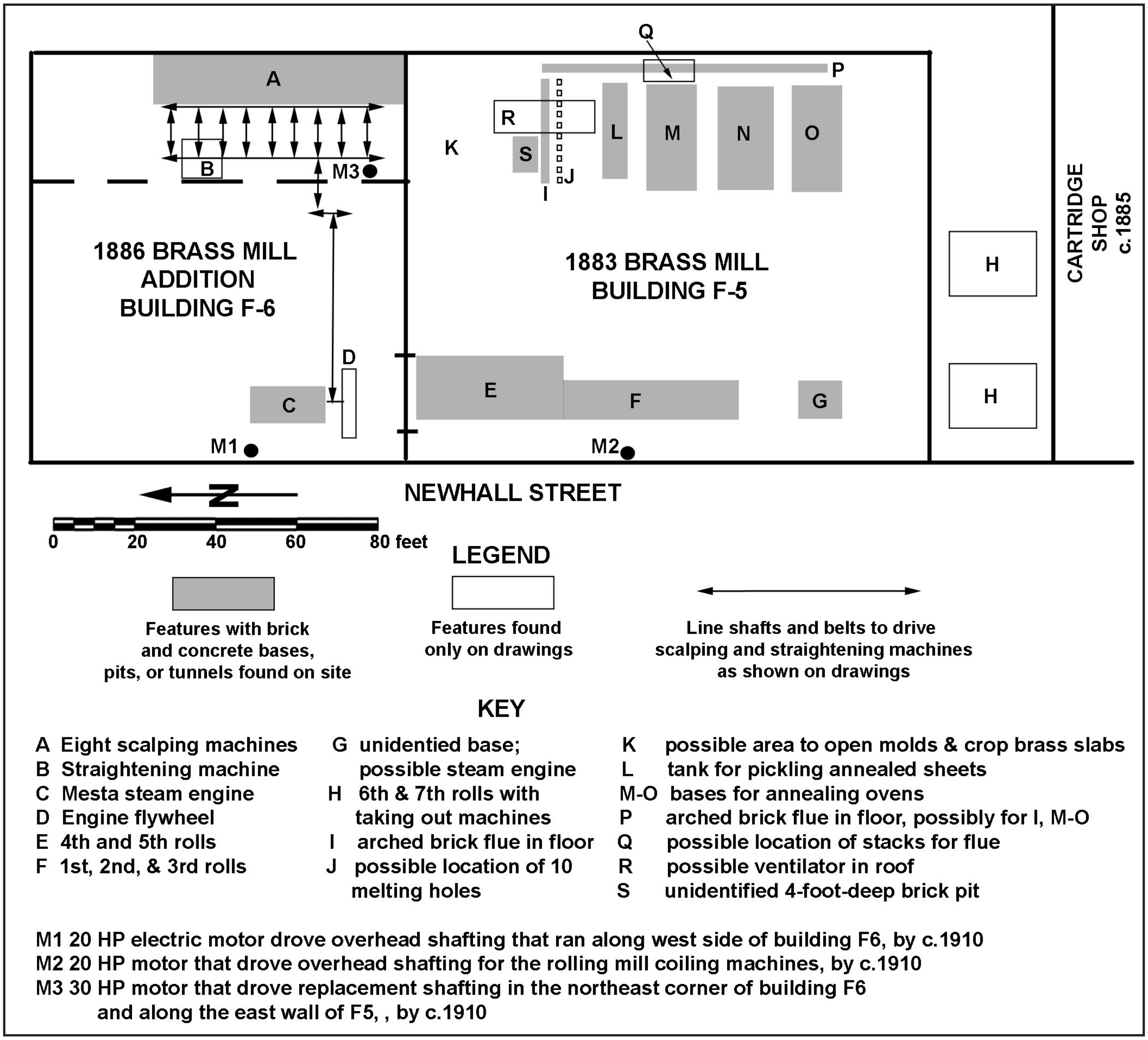


Figure 2. *Winchester Repeating Arms Co. Principal Brass Mill Features c.1883-1913*
Identified in Historic Drawings and Archeological Excavations

War I, when the third section was built and the much larger brass mill to the north also appeared, remains unclear. By the 1930s, this building housed brass casting and re-rolling facilities, which evidently continued until sometime in the 1940s; by the early 1950s, it was used for storage of various materials including lumber, rolled brass, and paper.

In the 1980s, this was the oldest remaining structure at the Winchester plant, and probably the only surviving one with any wood framing. The monitor-roofed 1883 section represented a late-nineteenth form once typical of Connecticut foundries and rolling mills, of which very few now remain.

Evidence of Brass Mill Operations

The surviving features we found in the two main mill building sections (Figure 2), together with the drawings retrieved from the company's vault show that Winchester made its brass by melting copper in graphite crucibles, adding zinc, and casting the alloy into slabs. Figure 3 shows how coal-fired melting furnaces were set up along an in-ground flue in a typical brass mill. We found this flue with its brick-arch roof still in place (Figure 2: I; Figure 4). This flue vented to a longer flue that ran along the east wall of the building (Figure 2: P) and probably connected with a stack outside the building (Figure 2: Q). The space along the shorter flue could accommodate ten melting furnaces.

South of the likely melting furnace locations, three nearly identical structures consisted of common brick walls filled with sand, coal, and debris (Figure 2: M-O). These were bases of annealing furnaces that were also vented through flue P. A nearby pit 63 inches deep with a stone bottom and common brick walls was the tank in which annealed brass was “pickled,” cleaned by immersion in dilute sulfuric acid (Figure 2: L).

The features found in the southwest quadrant of Building F-5 show that this area was used for rolling the brass made on the other side of the building into sheet. Concrete foundations with numerous hold-down bolts still in place were machinery bases (Figure 2: E-G). The dimensions of foundation E show that it accommodated two of the roll stands illustrated in an 1886 drawing, (Figure 5), designated as the fourth and fifth rolls. Foundations at F held the first, second, and third roll stands. A concrete foundation in building F-6 (Figure 2: C) is a close match to a drawing of the foundation of the 30-by-48-inch vertical Corliss engine that was in use in 1913. Placed at location C, this engine could drive the line of rolling mills along E and F with a shaft in the pit beneath the foundations, as shown in Figure 5. There was no boiler in the mill building so steam for the engine would have come from the adjacent cartridge shop building to the south (F-37).

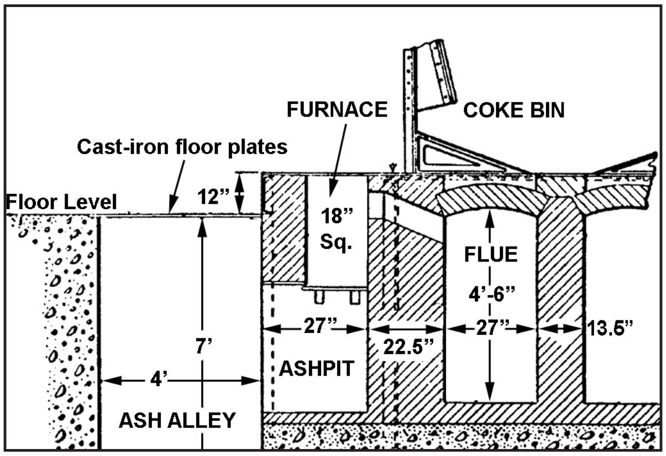


Figure 3. *Cross Section of Typical Brass Mill Melting Furnace, Ash Pit, & Flue. Base image: Alford et al. 1917*

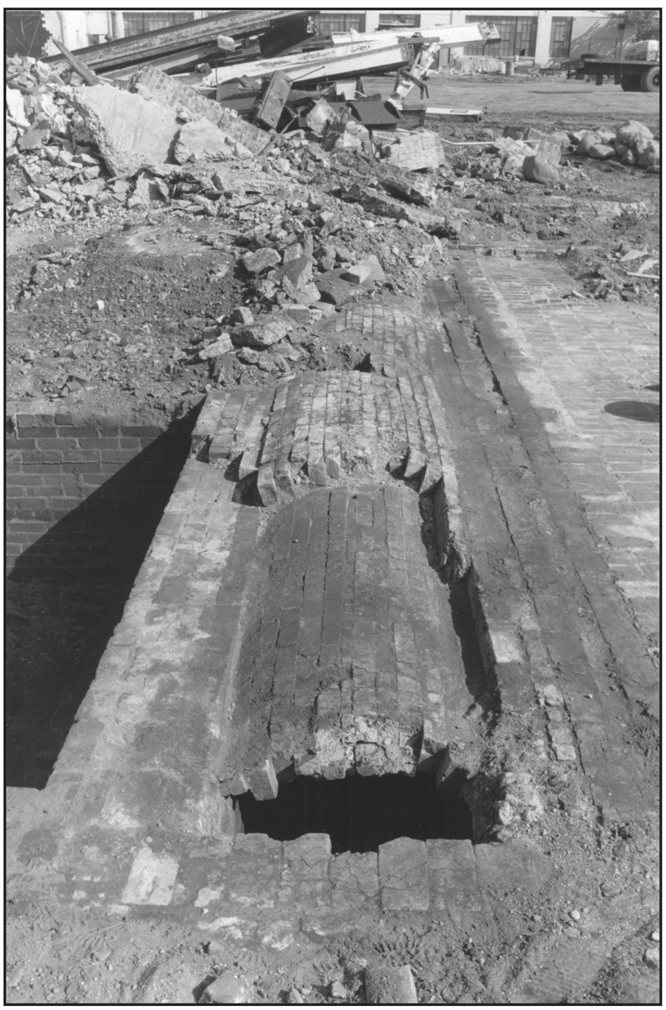


Figure 4. *1992 View East of In-Floor Flue that Served the Brass Melting Furnaces. Photo by William Sacco*

In the northwest quadrant of Building F6 there was a foundation with hold down bolts in place (Figure 2: A). A 1899 drawing shows a line of scalping machines was located here. They were used to remove casting defects from the bass slabs. The drawing shows they were driven with belts from overhead line shafting that was itself driven by a set of belts run to the engine at C.

Reconstruction of Brass Mill Operation

The features found within the mill building and under the concrete floor show how brass was made at the 1883 Winchester mill. A melter, two helpers, and a laborer worked a line of ten melting furnaces (Figure 2: J). A row of “book” molds, each made of two cast iron plates that fitted together to make a slab-shaped cavity, would have stood on end in a shallow pit in the space adjacent to the furnaces.

The melter and a helper charged a graphite crucible of about 200 pound capacity with copper and placed it in one of the melting holes on top of burning coal that rested on grate bars. More coal, probably anthracite, was packed around the crucible. Once the copper was liquid the melter used tongs to thrust in enough pieces of zinc to get the desired brass composition. Bubbles of zinc vapor began to form once the zinc was dissolved in the copper. The melter detected this through vibration of his iron stirring rod. It was a signal to pull the crucible. A helper used a block and tackle suspended from a jib crane to lift the crucible filled with molten brass and place it on the floor so that the melter could skim the dross from the metal. Next the helper held the crucible over a mold while the melter carefully poured the brass so that the mold filled from bottom to top without splashes on the mold walls. After a mold was opened, the cast slabs of brass were cropped down to clean, sound metal with power-driven shears, probably just to the north (Figure 2: K), and then passed to the rollers on the opposite side of the building to be reduced to sheet.

Brass mills used two-high roll stands fed and adjusted by hand, and relied on the rollers’ skill to make sheet of uniform thickness. Figure 5 shows a mill stand typical of those used

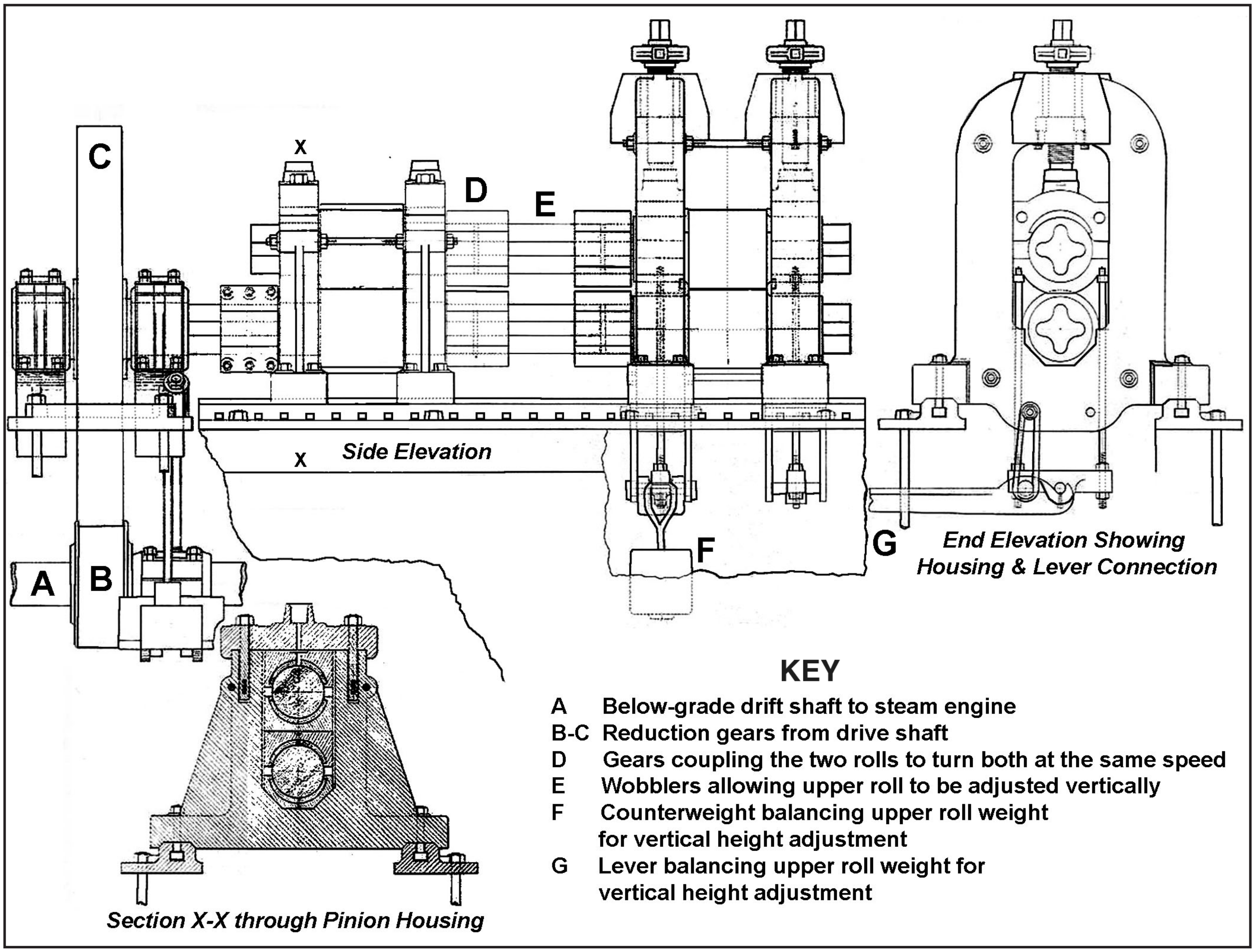


Figure 5. *Brass Rolling Mill. Base Image: Winchester Repeating Arms Co. Drawing Dated Feb. 9, 1886*

in the brass industry until the 1920s. The rolls were driven from a shaft (A) that ran in a pit beneath the mill floor to the steam engine that provided the required power. Since all the rolls were directly geared to a common shaft they could neither be reversed to do successive passes of brass through the rolls nor stopped in an emergency. Reduction gears (B and C) transferred power to the mill. Gears (D) coupled the two rolls so that they both turned at the same speed. Power was then transmitted to the rolls with wobblers (E) that allowed the upper roll to be adjusted vertically. The rolls turned in heavy brass bushings. Counterweights and levers beneath the mill (F and G) balanced the weight of the upper roll so that its height could be adjusted easily. In the initial passes through the rolls a catcher stood opposite the roller and passed the slab back over the top roll for the next pass while the roller reduced the gap between the rolls. When the slab became too long for a catcher to handle the strip emerging from the rolls it was fed into a power-driven coiler.

After each reduction in thickness of about 50 percent, the brass had to be annealed so that it would not split on emerging from the rolls. Workers placed the metal in iron pans in open-fired flat-hearth furnaces located across from the rolls (Figure 2: M-O), where it was heated to 600 - 650oC for about half an hour. After each anneal the brass was cleaned by immersion in 10 percent sulfuric acid solution (Figure 2: L) followed by washing in clean water. The cast slabs had surface defects that made blemishes on the rolled strip. These were removed after the initial passes through the rolls. First the rolled slab was run through a straightening machine (Figure 2: B) consisting of three rolls above four. A machinist then clamped the straightened slab in a scalping machine (Figure 2: A), essentially a high-speed shaper (also known as an overhauling machine) where a reciprocating tool cut down to sound metal. At least five, and for the thinner gauges, more successive roll passes with intermediate anneals were needed to reduce the cast slabs to the thickness required for drawing intro cartridge cases. Winchester engineers designed an inspection bench for examining the rolled strip. It had a power-driven spindle at one end and a bracket for the coil of brass at the other. The inspector would have watched the strip pass and used an overhead clutch to stop it at defects.

Evolution of Mill Equipment c1883-1915

Winchester's cartridge production grew so rapidly that within three years it had to expand its brass mill. When built in 1883 there were ten melting fires and three stands of rolls. Roll stands 4 and 5 were added in 1886 (Figure 2: E), when the extension Building F-6 was added to the original building. The engine that drove the rolls 1-2 in 1883 was probably located to the south (Figure 2: G). Either in 1886 or at a later date the engine was moved to Building F-6 (Figure 2: C).

The next major addition was made in 1899, when two more sets of rolls were installed in the space between Building F-5 and the cartridge shop, F1, just to the south (Figure 2: H). This formerly open space was roofed over to make room for the new rolls and the line shafting that drove their coilers. The company also added three additional scalping machines on the east side of Building F-6 (Figure 2: A)

The 18-inch-diameter rolls Winchester used ran at a peripheral speed of 9 feet per minute. The driving gear diameters, 32 and 92 inches (Figure 5), then show that the engine had to run at 54 rpm. If the steam pressure were 100 psi and mechanical efficiency 80 percent, the mill engine with its 30-inch bore and 48-inch strike would have developed 720 horsepower, just about enough to drive seven roll stands. Because of the variable loads applied to the engine as individual brass strips were passed though the rolls, a very large flywheel was needed to stabilized the power train. It was about 18 feet in diameter (Figure 2: D). With the successive additions of roll stands Winchester had much more rolling capacity by 1903 than the original set of melting fires in Building F-5 could supply with brass slabs. To increase the melting capacity it set up a separate brass casting shop nearby, in building F-28.

Starting in 1907, Winchester began using electric motors to drive the overhead shafting in the brass mill. By 1911 three electric motors drove a system of line shafting that provided mechanical power throughout buildings F-5 and F-6. A 20-HP motor (Figure 2: M1) provided power in the northwest quadrant of Building F-6, for a use not yet identified. A 20-HP motor (Figure 2: M2) was coupled to shafting over the rolling mills where it could drive the coilers that collected the rolled-out brass sheet. The 30-HP motor (Figure 2: M3) drove the scalping machines, no longer powered by the steam engine, and the straightening machine in the northeast quadrant of Building F-6 as well any machinery in the southeast quadrant of Building F-5.

With the addition of electric motors the original brass mill reached its final development. Brass consumption continued to increase, and to meet the demand from European wartime orders Winchester engineers considered adding more mill stands in the space north of the steam engine in Building F-6 (Figure 2: C). These mills would have been driven by electric motors, probably because the existing mill stands fully used the steam power available. Since no mill foundations were found in this location, it appears that the additional mill stands were not added. Instead, Winchester built and entirely new, much larger brass mill at the northern extremity of its plant, on Division Street.

Brass casting and rolling was done without chemical, instrumental, or quantitative control when Winchester entered the industry in the 1880s. Brass making by the long-established technique of melting in crucible with coal fires remained a small-scale, batch process because of the limited strength of the crucibles. It was unhealthful work for the melters and helpers. In addition to the heavy lifting involved, these men were exposed to inhaled zinc fumes released from the molten brass which caused a form of palsy known as the spelter shakes. No temperature measuring equipment was used; deciding on the right time to pour was entirely a matter of the melter's judgment. By 1916, when Winchester was building a new mill, brass makers were replacing the crucible system by electric furnaces that produced molten brass in larger batches with substantially less labor. The electric furnaces improved working conditions in the mill, and allowed instrumental control of the temperature of the melt.

Management, Engineering, and Innovation at Winchester

The incremental alterations and enlargements to the brass mill illustrate the piecemeal way that Winchester managers enlarged their complex of factories through World War I. It made subsequent rationalization of ammunition and rifle production difficult, and was one factor that led the company into financial difficulties after the war.

While Winchester could buy its rolling mills, its engineers designed and the company built auxiliary equipment such as coilers and inspection benches. Additionally, the engineering staff designed experimental equipment. A drawing dated 19 Oct 1908 shows parts for a power testing apparatus for electric motors intended to drive rolls in place of the steam engine. The operator was to move an arm to line up with the pointer of an ammeter (range 1,000 amperes) thereby making a pen record the current drawn on a slowly rotating drum driven off of an overhead line shaft. Another drawing probably from about this time shows a plan for a six-pot, round furnace for melting brass. It had a central grate and a heat exchanger at the side for preheating forced-draft air. It was probably intended for anthracite fuel. This represented a substantial departure from standard brass mill practice of the time. There is no evidence that Winchester built this round melting furnace.

More radical was Winchester engineers' design of a steam turbine to drive the rolling mills. They planned to put the turbine in the area north of the engine in Building F-6 at (Figure 2: C). The intermediate shaft of the turbine, turning at 500 rpm, would have driven a pinion mating with a 14-foot-diameter spur gear to turn the existing drive shaft to the roll stands at 75 rpm. In 1911 one English steelworks drove a plate mill with a turbine running on exhaust steam. The 2,000-rpm turbine shaft speed was reduced with two stages of gearing and turned a 23-foot diameter flywheel. While steam turbines achieved high efficiency turning steady loads, they were unsatisfactory for the alternating loads common in brass mills, and were rarely, if ever, used in American rolling mills. The Winchester engineers evidently thought better of their idea and continued to use the Mesta reciprocating engine until electric motors of the requisite power were available.

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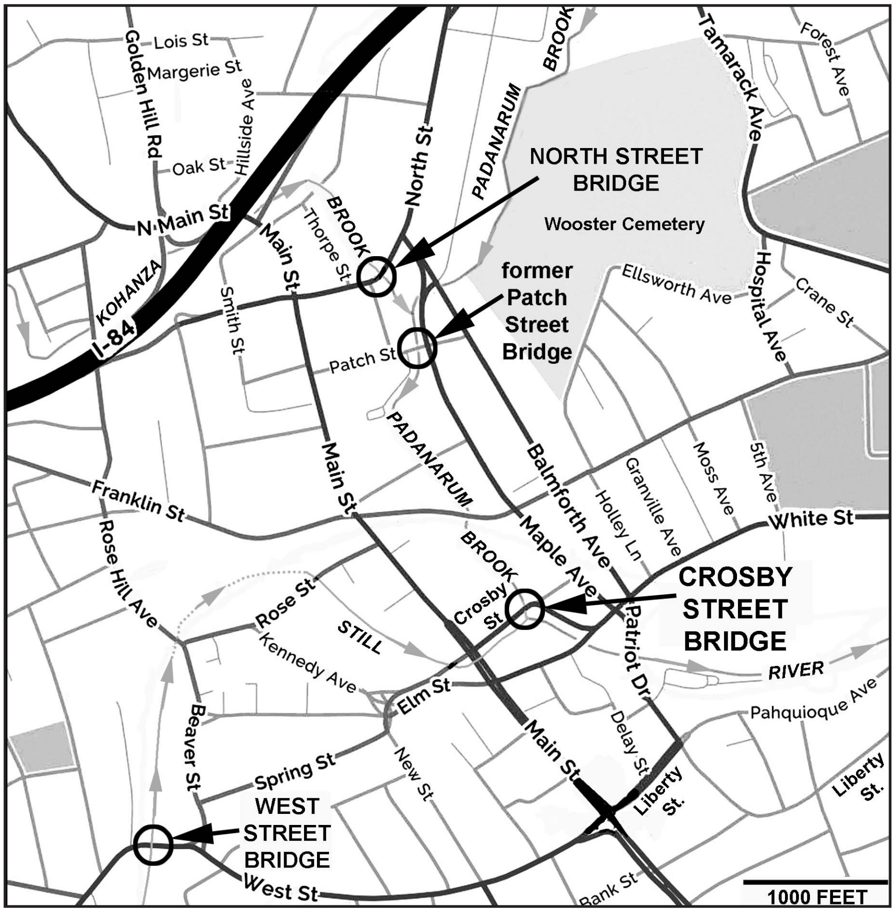
The Crosby Street Bridge in Danbury, Connecticut

The City of Danbury rehabilitated the Crosby Street Bridge over Padanaram Brook in 2015, replacing the roadway surface, concrete parapet and existing railing system, and replacing the stone masonry wingwalls in concrete. This is the last, largest and perhaps the best preserved of five to eight stone arch crossings built in Danbury following a disastrous 1869 flood, an important episode in local public works history seen elsewhere in Connecticut in response to the same period of floods. The bridge is also among the largest surviving double-arch stone bridges in the state. The bridge appears eligible for listing on the State Register of Historic Places, and The Connecticut State Historic Preservation Office requested documentation of the structure. Documentation included photographs taken prior to, and during, the rehabilitation project.

Local Development and the Opening of Crosby Street
Danbury began in the 1680s as an agricultural community with a trade outlet to Long Island Sound at Norwalk, via the Norwalk River valley. The town's emergence as a hatting center began shortly after the Revolution, but while local growth led to creation of a borough centered on south Main Street in 1822, industrial and commercial development remained extremely uneven unti1 the 1852 arrival of the Danbury and Norwalk Railroad. The new rail connection stimulated expanded hat manufacture at steam-powered factories, with local population increases by 1860 of some 75%. With its depot near the junction of Main and White streets, the railroad also generated a new local commercial center immediately south and west of the later Crosby Street Bridge. Population and industry were further enhanced in 1874 and 1881 by the respective completion into Danbury of branches of the Housatonic and the New York and New England railroads. In the 1880s, the borough's population nearly doubled, from about 11,000 to over 19,000, including the arrival of many German and Italian immigrants. In 1889, the borough became a city within the larger town, which continued to retain responsibility for road maintenance, bridges, schools and care of the poor. Separate town and city governments operated until the 1965 consolidation into a single city.

Prior to 1850 the area east of Main Street and north of Liberty Street was sparsely developed along stretches of meadow in the floodplain of the Still River and its tributaries. Still River, Danbury's major stream flowing east and north through the city, is a Housatonic River tributary with broad floodplain areas. Known by a variety of names, Kohanza and Padanarum brooks are tributaries of the Still River which converge a half mile north of later Crosby Street, and flow into Still River as Padanarum Brook just south of Crosby Street. Kohanza and Padanarum brooks run most of their courses through somewhat steep and narrow areas, once dotted with upland meadows or swamps. Soon after 1850, construction of the Danbury and Norwalk Railroad depot,



Location of Crosby Street Bridge and Other Danbury Stone Arch Bridges

and of the parklike Wooster Cemetery east of the tributaries' confluence, increased local demand for housing along side streets east of Main Street's growing commercial district. The area immediately north of White Street and the Still River, east of Main Street, became a dense cluster of commercial and industrial sites, including a livery stable owned by Phineas D. Crosby (1817-1891), a blacksmith shop, a carriage shop, a hat factory, and a marble yard making funerary monuments. A lane between Main Street and Padanarum Brook provided access to many of these industries by 1875, and by the early 1880s was named after Crosby, an astute entrepreneur and real estate developer who was among the first to take advantage of the rail depot's effects on commercial property values.

Beginning in the late 1880s, Crosby Street landowners sought recognition of the lane as an official town highway. Private ownership of the lane was an issue. The proposal was defeated at town meeting in 1888, but by 1892 additional development on both sides of the brook and undocumented private wood bridge construction led to town consideration of a new street running from Main Street to Maple Avenue. The town voted to build an iron or stone bridge in 1893, but only after all legal obstacles to opening the street by the city were removed. An 1895 proposal to purchase an iron bridge was amended to allow the town selectmen to build a stone bridge if it were cheaper, but this appears to pre-date the acceptance of the public road. In late 1896, 28 property owners donated or sold the land to the city needed to create the road, and a contemporary map of the city showing the road convinced the town counsel to accept the street as a lawful public way. The town began detailed consideration of bridge design in 1897, in the context of three decades of local bridge construction.

Stone Arch Bridge Construction in Danbury and the Crosby Street Bridge

Masonry arch bridge construction is an ancient design, but was not widespread in Connecticut until the mid-19th century due to a prevailing preference for cheaper timber crossings. The growth of urban centers and railroads, and some severe weather events, increased preferences for the more flood-resistant stone arches throughout the state c1865-1880, after which metal truss structures became competitive with masonry construction. By the early 20th century, few new stone arch bridges were built, and the form became more valued for its picturesque quality and, in less urbanized locations, its closer resemblance to a natural feature than an unfinished concrete structure.

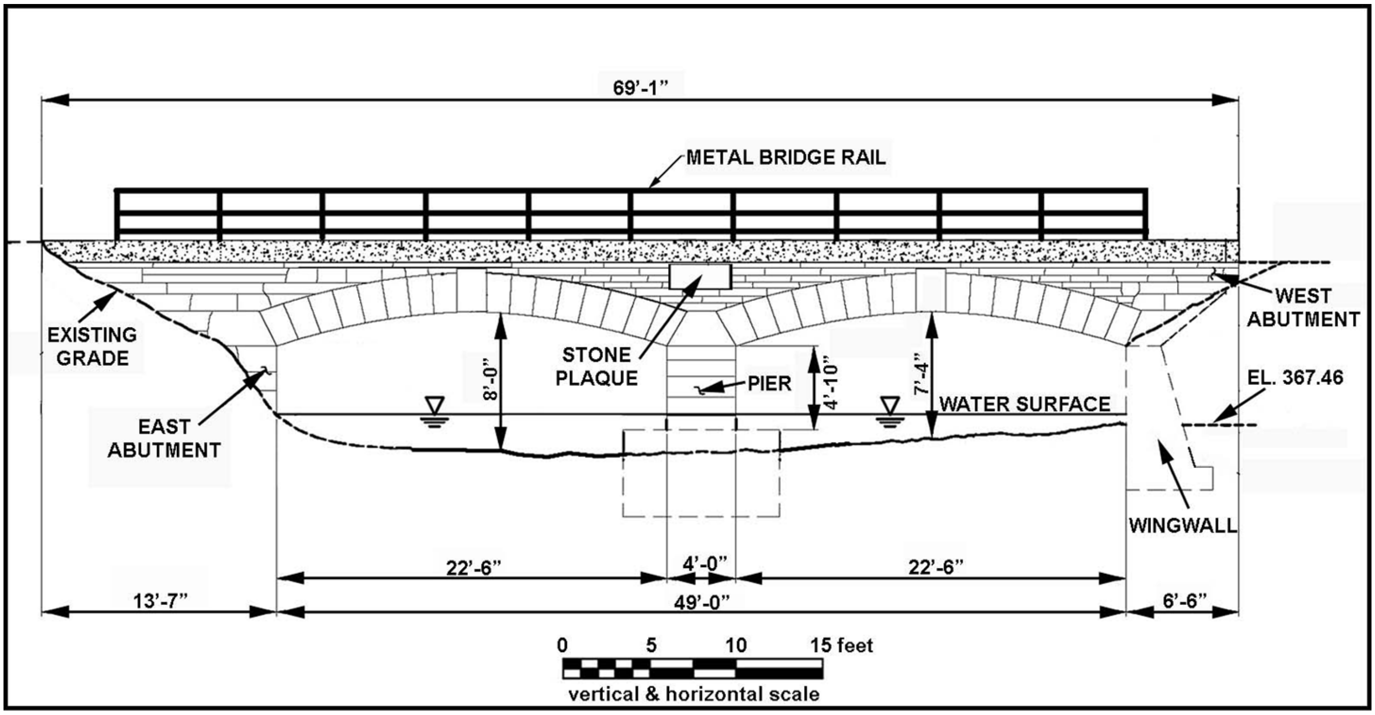
By 1865, Danbury's town and borough expansion led to the construction of hundreds of stream crossings of various sizes, all but a handful of which were wood decks, usually on stone abutments and sometimes supported by wood trusses. The few exceptions were on important roads such as Main Street, along which the town built at least one double-arched stone bridge over the Still River c1867. In January 1869, a flood caused by the failure of two recent water supply reservoir dams on upper Kohanza Brook destroyed much property on upper Main, North, and White streets, killed five people, and destroyed or damaged five bridges. While the relative merits of stone or iron bridges were a topic of public discourse before the flood, as a practical matter of public finance the less expensive but less durable wood bridges prevailed. The complete or partial loss of five bridges in the Kohanza flood changed the tone and outcome of later discussions, and for some four decades afterwards stone bridges were the preferred type of crossing over the larger streams in the town's more densely settled areas, although wood structures continued as the dominant type generally.

Surviving records on Danbury bridge construction are incomplete, but the town completed at least five, and possibly as many as eight, stone bridges between 1869 and 1907, with most constructed c1885-1899 during a period of rapid population growth and urban expansion. There was a preference in this period for replacing one bridge a year in stone, to diminish the frequency of bridge repairs, but in practice only larger or more flood-prone crossings received such treatment. Town voters and officials considered metal bridge alternatives throughout this period, but despite lower metal bridge costs the perceived greater durability and lower maintenance costs of stone proved to be the deciding factor at all larger crossings. Iron or steel bridges began appearing at smaller crossings c1893, replacing wood structures, but were rarely used at larger crossings before concrete bridges or metal culverts became widespread locally after 1910. In what is apparently the only surviving detailed comparison of alternatives, an 1897 report to the town by consulting engineer William C. Smith on the proposed Crosby Street Bridge noted stone as the most durable material, but recommended a less expensive steel bridge because of the greater water area open under the span in the event of a flood. Voters authorized a stone arch bridge for Crosby Street after submission of Smith's report.

Most stone arch crossings for local roads were built by local stonemasons adapting to local conditions of terrain, bedrock or soil conditions, and availability of building materials. Few plans of such structures survive, even when built by town highway departments as was evidently the case at Crosby Street. During the 1895 consideration of alternative Crosby Street crossings, however, a plan for a double-arch masonry bridge was prepared by the Berlin Iron Bridge Company. This firm did not build stone bridges and probably submitted a companion plan for an iron bridge which has not survived, but the 1895 plan resembles the double-arch alternative described in Smith's 1897 report, and was likely very similar to the design presented in 1897 but modified in 1899 just prior to construction. The 1895 plan was for a 50-foot-long, 48.5-foot-wide structure with a 34-foot-wide roadway, and a 39-foot-span including a 4-foot-wide central pier. The pier and abutments were to be supported on timber platforms resting on timber piles, reflecting the clay riverbed as tested by Smith, whose recommended footings were piles under concrete platforms. The segmental arches in the 1895 design were 3 feet above the arch springlines and approximately 5.5 feet above the pier base. Arch voussoir, intrados, and spandrel components were shown as ashlar masonry. Smith recommended a 45-foot span for his three 50-foot-wide alternatives, with the lowest estimated cost of $6490 for a through steel plate girder bridge with a creosoted timber roadway. He acknowledged the iron bridge would need paint every five years. His estimated costs for single- and double-arch masonry bridges, respectively $8842 and $7612, may reflect the fact that even with a mid-river stone pier the double-arch structure required less timber falsework than the single-arch alternative. Both masonry designs included mortared ashlar or rock-faced cut stone.

Town selectmen, probably in consultation with street department superintendent Frederick G. Olmstead and an unidentified engineer, selected a double-arch design, which had the smallest waterway area but cost far less than a single-arched stone bridge. This case of somewhat mixed signals on maximization of strength and flood prevention is of general local interest, since all but perhaps two of the completed stone bridges in Danbury were double arched. Double-arch stone bridges may have been better adapted to broad channels closer to the mouths of rivers or streams, where high-energy flows were less frequent. For Crosby Street, however, riverside landfilling and nearby building construction c1880-1896 led to a final design with spans which were wider and higher than recommended in 1895 or 1897, with the stated intent of providing a larger waterway and avoiding potential lawsuits over flood damages. Built with arches 5 feet longer than those recommended in 1897, the bridge as completed by the town street department in the summer of 1899 cost $10,489 – considerably more than William C. Smith's estimate.

The Crosby Street Bridge is approximately 69 feet long, with a 49-foot-span over Padanarum Brook consisting of two 22.5-foot-long segmental arches and a 4-foot-wide, approximately 4.8-foot-high pier. Each arch is approximately 6.3 to 8 feet above the brook. The 47.2-foot-wide upper surfaces include a 31.8-foot-wide, 1.8-foot-thick macadam-surfaced roadway approximately 2.8 feet above the keystone bottoms, concrete sidewalks of unequal widths, and approximately 1-by-1.5-foot concrete curbs supporting steel pipe railings. Four vertical scuppers through the intrados provided roadway drainage. There are no available images of the original railings, spandrel top or parapet, but it is possible the present curb and railings were installed after 1955 floods noted below. Abutment and pier footings remain undocumented, but may include timber piles. Except at the replacement concrete curbs on the spandrel tops, all exterior masonry is mortared ashlar granite or granite-gneiss. The pier and the abutments have partially-coursed blocks. The upper course at the downstream pier face projects south of the bridge face, and the lower courses of the upstream pier face project approximately 5 feet upstream in a wedge-shaped fin



Crosby Street Bridge North Elevation Prior to 2015 Reconstruction
(Base Image: Tectonic Engineering and Surveying Consultants, P.C.)

to protect against river scour, flood debris, and ice. The abutments are of unknown height below the arch springlines, but are very wide to support the long segmental arches. Above the abutments and the 18 lines of voussoir stones in the two arches, the spandrels are coursed ashlar blocks typically 0.7 feet high. Most voussoirs are 2.1 feet high, 1.25 feet wide, and approximately 5.5 feet long. The slightly wedge-shaped keystones are at least 2.25 feet high, approximately 2 feet wide at the top and 1.7 feet wide at the bottom, and typically 5.5 feet long with the downstream keystone blocks 3 feet long. The upper voussoir surfaces beneath the roadway are unfinished, and as exposed in 2015 the keystone blocks project up to 4 inches above adjacent voussoirs. There are two approximately 30-foot-long mortared rubble masonry walls at the downstream abutments, most likely built during c1965 reconstruction of the stream channel.

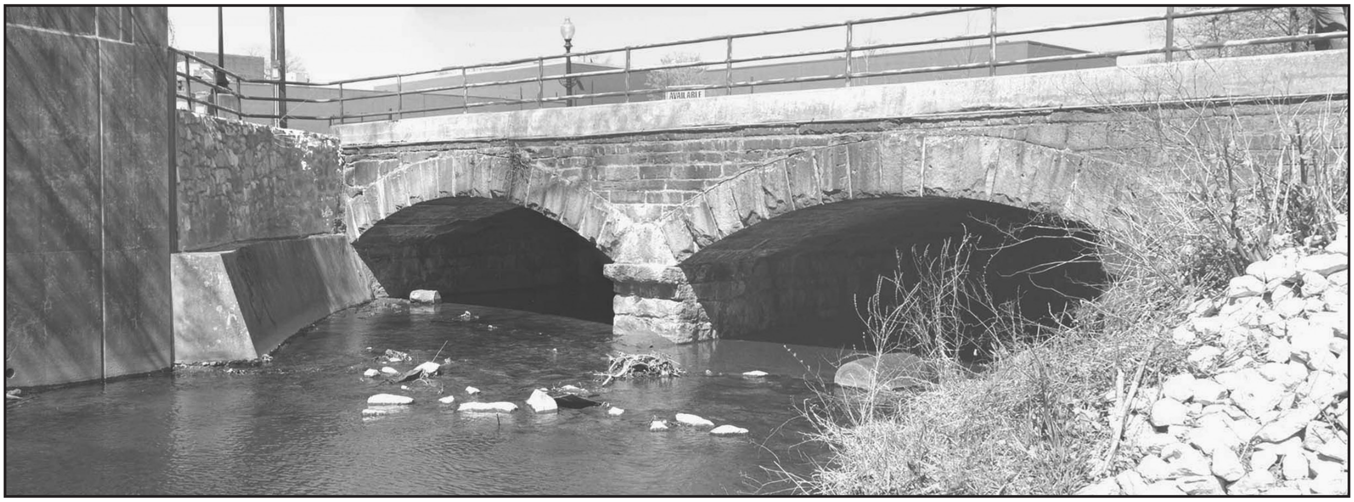
There is a polished stone plaque set into the north spandrel between the arches, one course below the curb. The approximately 3.5-by-1.5 foot panel commemorates the bridge's construction with the year, names of town selectmen, and name of the street department superintendent:

ALEX. TURNER
18 T.T. ALEXANDER 99
LEWIS REED
SELECTMEN
F.G. OMSTEAD, SUPT.

After 1899, all new Danbury bridges were built with metal or concrete. The strength of the Crosby Street Bridge, now 116 years old, is reflected in its survival and retention following the severe floods of August and October 1955. Town records indicate the bridge was quickly repaired, probably with the concrete parapet and pipe railing system replaced in 2015. Immediately downstream of the bridge, a federally-supported flood control and urban renewal project completed by 1965 included re-alignment and widening of Padanarum Brook with concrete channel walls, and a dramatic re-location of the Still River which moved the confluence of the two streams approximately 280 feet north to a point only 75 feet downstream of the bridge. Current rehabilitation, which leaves all of the original arch masonry in place, attests to the strength of this design form, here in one of the largest examples of its kind in Connecticut.

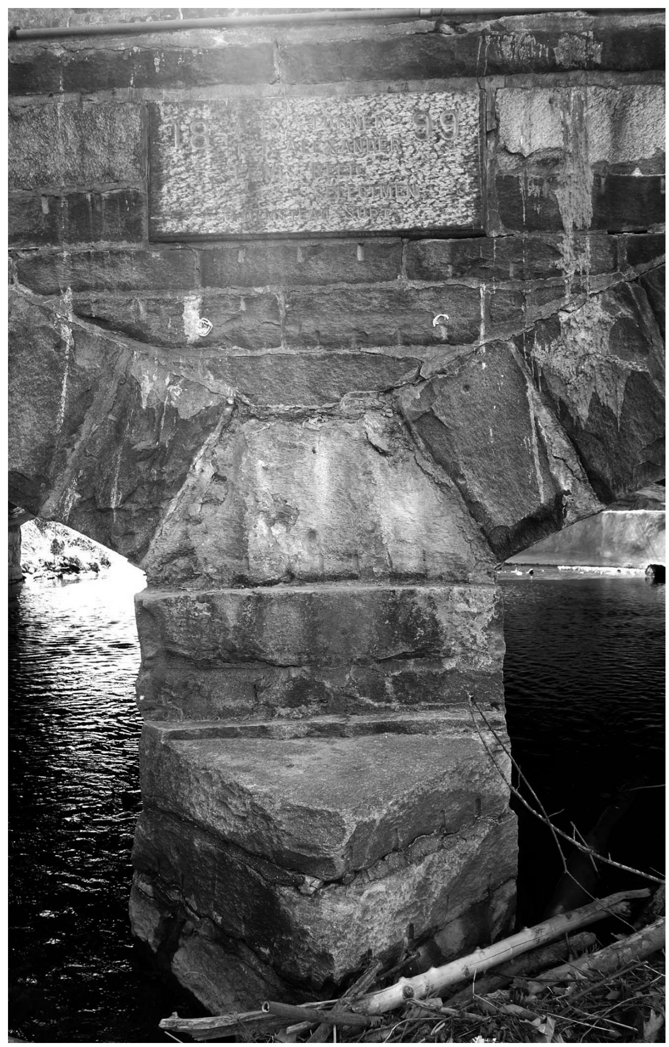
Significance of the Crosby Street Bridge

Masonry arch construction is based on placement of wedge-shaped stones, or voussoirs, in a ring which compresses under vertical loads which must be countered by equal reactions at the abutments. Timber falsework is needed for arch construction. The principal skills needed for falsework and masonry tasks were usually available within the local labor pool. As discussed below, the compressive strength in natural rock allowed for a variety of masonry forms in construction of Connecticut stone arch bridges. The most stable arch shape is semicircular. Longer spans with lower rise-to-span ratios than a semicircular arch are possible with segmental (defined as a circular arc of less than 180 degrees) or elliptical arch forms, but the flatter forms develop more tension in the arch ring and require heavier abutments, as stone has relatively low tensile strength. The arch ring sup-



Crosby Street Bridge South Elevation with Rubble ans Concrete Channel Walls at Left

ports spandrel walls and parapets that hold back fill placed between the arch ring and the roadway. The parapets in most cases are extensions of the spandrel walls. Crosby Street Bridge is an example of a segmental arch structure.



Crosby Street Bridge Upstream Central Pier End, and Commemorative Plaque

Although there has been no comprehensive photographic review of all surviving or former stone-arch crossings in the state, preliminary comparisons suggest some regional variations in building materials and masonry techniques, based on local stone resources and, sometimes, the local aesthetic significance of a structure. Spandrels built in the central and western parts of the state often had coursed or semi-coursed rubble or ashlar blocks, especially in areas with ready access to arkose deposits or granite quarries. In eastern Connecticut, large uncoursed rubble often formed the spandrels, a treatment found on some bridges in western Connecticut including the Patch Street Bridge built a half mile upriver of Crosby Street in 1885 on Kohanza Brook. A wide variety of voussoir treatments suggests the basic strength of these structures accommodated almost any well-fitting stone masonry, including unmortared, largely uncut flat stones, carefully-cut blocks, and the irregular rubble seen at the c1880 Old Town Hall Bridge in North Stonington. Regardless of masonry treatment, the lower surface of a typical arch ring (the intrados) was kept in a uniform plane, but the upper surface beneath the fill (the extrados) was often more irregular. In the context of available state-wide information, the Crosby Street Bridge has unusually fine masonry, consisting entirely of mortared, cut blocks of granite or granite-gneiss, with coursed spandrels, partially-coursed abutment and pier blocks, and relatively uniform-sized voussoirs with rock-faced end blocks. Rubble masonry channel walls at the downstream abutments appear to have been added during the c1965 reconstruction of the stream channel. The contrast with the now-demolished nearby Patch Street Bridge, built of similar material but with large uncoursed rubble spandrels and mixed-size voussoirs, was dramatic. The masonry treatments at Crosby Street may reflect the bridge's location close to Danbury's central commercial district centered along nearby Main Street, in an era when public and private construction in this area often used monumental Victorian styles. Although not identical to the bridge as built, the 1895 plans prepared for a Crosby Street Bridge showed similar masonry.

The regional and local variations in masonry treatments reflect the design solutions possible with firm arch foundations. Stone-arch bridge footings, abutments or foundations reflecting vernacular practice and knowledge are rarely documented, although archeological opportunities have arisen through cultural resource management studies of bridge replacements. Few of the state's stone-arch bridges were founded on bedrock, and the limited documentations of arch footings suggest a narrow range of adaptations to local streambank and stream channel conditions. The use of stone slabs on beds of gravel, seen at the Old Town Hall Bridge in North Stonington and c1831-1835 Depot Road Bridge in Coventry, was probably the most common footing design in stream channels of glacial outwash or till. Different solutions were required in stream beds with much finer materials. At the Patch Street Bridge in Danbury, the Kohanza River has a clay bed on which the builder, local stonemason Peter Rowan, placed a double layer of perpendicular 10-foot-long, 2.5-by-10-inch boards, with the lower layer oriented perpendicular to the footings. A half inch of mortar on the uppermost boards bonded the simple spread footings to very large flat pieces of rubble on which the large single arch was founded. While there is no confirmed information on actual Crosby Street Bridge footings, three sets of plans or specifications for this crossing -- including those for a proposed 1968 replacement – show timber piles supporting timber or concrete footings. Pile supports appear to be very unusual among Connecticut stone-arch bridges, and if actually installed at Crosby Street may reflect a combination of very soft streambed conditions and the heavy abutments needed to support the segmental arches which are among the longest built in the state during the 19th century.

Incomplete listings in a 2011 Connecticut Department of Transportation database suggest that most of the state's stone-arch road bridges had single spans, usually ranging from 10 to 30 feet with a small number built with single spans of 40 to 74 feet. At least 34 single-span structures survived in 2011, compared to at least 13 twin-arch bridges with typical spans of 10 to 26 feet. As suggested by the 1897 comparison of costs prepared for Crosby Street, a double-arch stone bridge cost far less than a single-arch structure; as suggested above, timber falsework costs likely contributed to this difference. Despite the costs, the preference for single-span stone arches probably derived from the much smaller water area below the decks of twin-arch structures in riparian environments prone to flooding. Virtually all the single-arch structures with spans over 40 feet were built c1899-1912, perhaps reflecting increased sensitivity to flood events. Connecticut towns including Danbury and Stamford continued to select two- or even three-arch stone bridges on some streams into the very late 19th century, but on streams such as flood-prone Harbor Brook in Meriden five single-arch structures were built c1864-1892.

The three stone arch bridges in Danbury extant in 2015 at North, West and Crosby streets, built respectively in 1887, 1888-89, and 1899, are all double-arch structures, with arches 5-7 feet high each spanning approximately 13-23 feet. Low concrete parapets set several courses above the voussoirs modify all three structures, but all appear to have substantial original structural integrity. Additional post-1955 modifications at North Street include a concrete wall extending some 15 feet downstream from the bridge center, and upstream concrete channel walls abutting the north face and supporting a commercial building, giving this bridge the least visual integrity of Danbury's remaining stone road crossings. As a group they continue to represent an important episode in local public works history following a disastrous flood. Crosby Street Bridge is the last, largest and perhaps the best preserved, and is among the largest surviving double-arch stone bridges in the state.

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Michael S. Raber
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