1. NAME OF PROPERTY

Historic Name: **BOLLMAN TRUSS RAILROAD BRIDGE**

Other Name/Site Number: Bollman Suspension Truss Bridge

2. LOCATION

Street & Number: Spanning Little Patuxent River
near the junction of Gorman Road and Foundry Street Not for publication:__

City/Town: Savage Vicinity:__

State: MD County: Howard Code: 27 Zip Code: 20763

3. CLASSIFICATION

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

Number of Resources within Property

Contributing	Noncontributing	
___	___	buildings
___	___	sites
1	3	structures
___	___	objects
1	3	Total

Number of Contributing Resources Previously Listed in the National Register: 1

Name of Related Multiple Property Listing:

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: Transportation Sub: rail-related

Current: Transportation Sub: pedestrian-related

7. DESCRIPTION

ARCHITECTURAL CLASSIFICATION: Other: Bridge

MATERIALS:
Foundation: Abutments and pier: Stone
Walls: N/A
Roof: N/A
Other: Trusses: Cast Iron--Wrought Iron

Describe Present and Historic Physical Appearance.

The Bollman truss railroad bridge crosses the Little Patuxent River in the town of Savage, Maryland.[1] Fabricated in 1869, most likely by the Baltimore and Ohio (B&O) Railroad's bridge shop at Mount Clare in Baltimore, this bridge was used in main line service at an unknown location until the increasing weight of locomotives and rolling stock on the main line forced its removal.[2] Ever vigilant for cost savings, the B&O disassembled the bridge superstructure and re-erected it at Savage in 1888. Thereafter it carried a light-use, single-track industrial spur (extending from the B&O's Washington Branch) which served the nearby Savage textile factory until its closure in 1915. The bridge sat derelict until its "rediscovery" in the early 1960s, when it was made the focal point of local preservation efforts.[3] Today it is owned and preserved by the Howard County Commission as a historic centerpiece to a public park and carries a pedestrian walkway.

The bridge is a two-span, cast- and wrought-iron through truss, resting on two granite abutments and a single granite mid-river pier (figure 1, photos 1 and 7). The superstructure incorporates the *Bollman suspension truss* configuration patented by Wendel A. Bollman in 1852. Each truss is 79'-6" long, 25'-6" wide, and approximately 21' tall from the lower to upper chords.[4] The overall length of the combined superstructures is 160', considering that the two identical spans are separated by 1' on the center pier. It is aligned on an exact north-south axis, crossing the river at a 90-degree angle.

To discuss bridge trusses, some basic terminology is used to identify the various parts (top chord, bottom chord, panel, diagonal, vertical, etc.). Figure 7 names the major components of a Bollman truss. One should understand that a trussed bridge usually consists of two lines of identical parallel trusses (connected by cross pieces) exhibiting a repeating pattern along the "web" of each truss, thus only representative portions of a truss need be described in detail. Generally speaking, trusses are structural forms based on the inherent strength of rigid triangles. By tying together multiple triangles, clear spans of hundreds of feet are possible. Scores of configurations can be created by rearranging the members into different patterns, but over time only a few of the most practical designs ever found wide use, and of those only two variations (either Pratt or Warren layouts) are commonly used today.

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[1] Savage is located midway between Baltimore, Maryland, and Washington, D.C.

[2] Robert Vogel, "Speculations on the History and Original Appearance of the Last Bollman Truss," *IA-The Journal of the Society for Industrial Archeology* (Volume 7, 1970): 427. The possibility exists that the bridge was fabricated by Bollman's own company, The Patapsco Bridge and Iron Works, in west Baltimore, but this does not deter from its nationally significant aspects. Most records in the Baltimore and Ohio's engineering department were lost in the disastrous 1904 Baltimore fire, which destroyed the B&O's main offices. As a result, many details of the B&O's early engineering history are sketchy, at best.

[3] This effort was aided by Robert Vogel (then curator of civil and mechanical engineering at the Smithsonian Institution Museum of American History), the foremost historian on Wendel Bollman and his bridges. The American Society of Civil Engineers designated this bridge a Historic Civil Engineering Landmark in 1966. This was the first designation of any structure under the ASCE's History and Heritage Program. It was placed on the National Register of Historic Places in 1972. The bridge underwent moderate restoration in 1983-84.

[4] Historic American Engineering Record (HAER), HAER No. MD-1, measured drawings 1 through 7. The HAER documentation includes large format photographs and a short narrative history.

On any truss, the various structural members fall into two basic categories--compression members which resist crushing forces, and tension members which resist pulling forces. By using a combination of compression and tension members, the loading on a bridge deck (and the weight of the bridge itself) is transferred along the truss until reaching the abutments where it dissipates into the ground. The numerous cross pieces (also called lateral, or transverse, connections) connecting the two truss lines add rigidity, preventing the chords from buckling sideways and, along the bottom chord, supporting the deck as well, but they do not directly aid in carrying the load back to the abutments. Differentiating the two types of member is simple on an early cast- and wrought-iron bridge like the Bollman truss: thicker, heavier parts are cast-iron compression members; thin, lighter parts (usually in the form of rods or eyebars) are wrought-iron tension members.

Functionally, a Bollman truss is a cross between a rigid truss and suspension bridge. A pure suspension bridge relies solely on tension members, usually wire cables (although some suspension bridges used ropes, chains, or eyebars) draped over end towers. The extreme ends of the wire, etc., are anchored in stone or concrete monoliths which resist the pull on the wires, while a deck is supported by vertical tension members hung from the main suspension cables. On the Bollman truss, long wrought-iron suspension bars extending out from end towers crisscross as they pass along the length of a simple underlying rigid truss, giving the Bollman layout a distinctly complex appearance. These suspension bars--working in combination with the verticals and top chord--are the essential load carrying members of the bridge and are analogous to the cables of a suspension bridge. But, unlike a pure suspension bridge, the top chord of a Bollman truss resists the inward thrust of the end towers, negating the need for the heavy abutment anchorages required on a normal suspension bridge. Therefore, the Bollman truss is a hybrid structure, the suspension truss, which incorporates elements of a standard rigid truss and a suspension bridge.

The Bollman truss at Savage has six panels[5] in each span--within each panel two bracing rods form an "X". Each span's top chord is created by six hollow, octagonal cast-iron "pipes" cast in panel-length sections and connected by mortise-and-tenon joints. It stretches between the vertical cast-iron end towers, and interconnects by shallow mortise-and-tenon joints with five hollow, octagonal, cast-iron verticals. The verticals are accentuated with squared Doric capitals and bases (figure 4). The bottom chord (photo 4) along the four central panels consists of cast-iron I-beams with circular piercing, while on the outermost panels these are rolled iron I-beams.[6] The lower chord only prevents sway between the floor beams and was often omitted altogether in deck truss versions. However, the upper chord (or stretcher, as Bollman called it), verticals, and diagonal panel bracing are indispensable. The upper chord resists the inward thrust exerted by the pull of the suspension bars on the end towers, while the verticals and panel bracing work together to prevent buckling of the top chord.

The primary load-bearing elements of each truss (and the most visually striking aspect of the spans) are the web-like array of wrought-iron suspension bars radiating diagonally out from the top of each cast-

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[5]The outermost two panels are approximately 15' wide, and the innermost four panels approximately 12'-3" wide.

[6]The lower chord sections are set into cast-iron plates riveted to either side of the transverse floor box-beams. The outermost beams of the lower chord are bolted to iron castings--the same fixtures on the end tower pedestal that secure the secondary diagonal bracing bars in the outermost panels. The castings are in-turn bolted to the granite end-tower pedestals (photos 3 and 4).

iron end tower to every panel point along the bottom chord (figure 1 and photo 1). These adjustable eyebars are hung in matching pairs from each end-tower cap (five pairs from each tower cap) by wrought-iron pins. One pair of suspension bars extending from each tower attach flush to the sides of each vertical column (just above where the panel braces pass into the base) with a through-column pin held in-place by nuts on both sides. An adjustable connection ties together the suspension bars, diagonal panel bracing, and vertical to a transverse floor box-beam.[7] The suspension bars were straightened during the bridge's 1982-83 rehabilitation.

The cast-iron end towers (photo 3) support the entire weight of the bridge superstructure (and any incumbent load) and transfer it vertically down into the abutments and pier. Each span uses two towers at either end for a total of eight altogether on the bridge. Each tower is made of a group of four inclined, octagonal, cast-iron columns (tied together by horizontal cross bracing) mounted on a square granite pedestal. Each tower is topped with a heavy cast-iron tower cap (figures 5 and 6) made of a single solid casting. The tower-cap casting is quite detailed, being where the top chord, the main suspension bars, the outermost panel's diagonal bracing rod and the portal strut all come together. Two large wrought-iron pins secure four sets of the main suspension bars to the cap by passing through an eye forged in the end of each bar, while threaded bolts secure the outer panel's main suspension bar and diagonal panel bracing. Originally, an ornate four-sided wooden box with a pyramidal, overhanging tin roof covered each tower cap to protect the multitude of connections here.[8] Although decayed and missing some pieces, they remained on the bridge into the 1960s, but were eventually destroyed by vandals. Enough was salvaged, however, that they could be accurately replicated and replaced in the 1983-84 restoration (photo 3).

Each end tower rests on a square, granite pedestal (photo 3). In turn, these pedestals rest on two 25'-high, 35'-long granite abutments and a single granite mid-river pier. The abutments and pier were constructed in 1888, which post dates the period of significance for the superstructure, and thus they are non-contributing resources. The abutments and pier exhibit cut-stone ashlar masonry, (each stone is rock-faced, with hammer-finished edges) and taper towards the top. The upstream side of the river pier comes to a point, or cut-water, to lesson the impact of water, ice, and debris against the stonework. The abutments and pier dissipate the bridge's weight into the bedrock.

On each span, the two truss lines are transversely (or laterally) connected by a combination of cast-iron compression members and wrought-iron tension members. These cross-members act to give the bridge lateral stiffness and prevent the top chord from buckling sideways when under compression.[9] The portal

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[7]Inside the hollow base, hidden from view, the pin connecting the panel bracing and the pin connecting the main suspension bars are encircled by a wrought-iron "compensating link." This compensating link hangs from the (upper) main suspension bar pin. Two threaded wrought-iron eye-bolts suspended inside the column from the (lower) panel bracing pin pass down through the transverse floor box-beams and through a cast floor-beam stirrup plate. Adjusting nuts tightened upwards against the stirrup plate hold the various members in place. See figures 3 and 4.

[8]Vogel, "Speculations on the History and Original Appearance of the Last Bollman Truss," 435.

[9]Seven cast-iron struts are set into sockets along the top chords--two ornate castings between the end towers (the entrance portal struts), and one tapered I-beam strut crossing between each of the five panel points along the top chords. Four horizontal wrought-iron rods form diagonal bracing between each transverse strut--one end of each rod passes through the strut, the other end through the top chord and is held in place by a nut on both ends. Six tapered, cruciform cast-iron beams run longitudinally along the center line of each span, set into sockets

struts are larger, more ornate castings than the other cross pieces. Each portal strut exhibits ten circular piercings (five on each end of the beam). The solid middle section of the portal strut is accentuated by a taller portion culminating in a peak at the center line of the bridge (photo 2). On the extreme north and south entrances to the bridge, the central section of the portals originally held six cast-iron strips with the following information in raised, 2.5"-tall letters: top left "W. BOLLMAN, PATENTEE"; bottom left "BALTIMORE, MD."; top center "BUILT BY B&O R.R. CO."; bottom center "1869"; top right "PATENTED 1852"; bottom right "RENEWED 1866".[10] These were missing by the time the bridge was rediscovered in the mid-1960s, and replaced with cast-aluminum replicas during the bridge's rehabilitation in 1982-83.

Each span's floor system is supported by a transverse box-beam hung across the width of the bridge beneath the foot of each vertical (or panel point). The box beams are each supported by cast-iron stirrups hung from two long wrought-iron eye-bolts hanging out of the bottom of each vertical.[11] These box beams have been rebuilt; originally, the box beams were a combination of cast- and wrought-iron, with cast-iron channels forming the tops and bottoms, and wrought-iron plates forming the sides (figures 3 and 4). Five square cast-iron plates acted as internal stiffening diaphragms. The sides were riveted to the top and bottom channel beams and the internal diaphragms by wrought-iron rivets. Cast-iron end plates were fitted onto both ends of each box beam. The box beams were further supported by a trussed-beam arrangement (in the form of an inverted queen-post truss) formed by running two wrought-iron rods underneath each beam and anchoring it through the cast-iron end caps. These suspension rods were held about 2' below the box beams by wood spacing blocks setting in cast-iron stirrups connected to the suspension rods. This trussed beam arrangement dated to ca. 1909, when the railroad repaired the earlier box-beam support system.[12] However, the original box beams had degraded over the years, so during the bridge's 1982-83 rehabilitation all were rebuilt by incorporating new steel side and bottom plates while retaining the original cast-iron top channel plate.[13] The rebuilt beams were bolted back together with round-headed bolts to replicate the original rivets. The original cast-iron end caps were replaced with a steel plate bolted just inside the end of the beams. The ca. 1909 trussed-beam arrangement was removed altogether, as the new steel box beams (photo 4) needed no extra support considering the relatively light loads the bridge carries. Other secondary members between the lower chords ensure lateral stiffness.[14]

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in the center of each of the transverse beams. See figure 1, plan view.

[10]Vogel, "Speculations on the History and Original Appearance of the Last Bollman Truss," 431. Only the plates' ghost marks remained by the mid-1960. Vogel determined the content of the plates from photos of other contemporary Bollman trusses. "Renewed" refers to the renewal of Bollman's patent, not a rebuild of the bridge.

[11]The eyebolts pass down through the beam and the beam's supporting stirrup plate. The cast-iron stirrup is tightened upwards against the beam by locking nuts on the end of each eye-bolt.

[12] HAER No. MD-1, drawing No. 4. This was a replacement for a similar, earlier system used on all Bollman trusses.

[13]Eric DeLony, "The Bollman Bridge at Savage, Maryland: Restoring America's Quintessential Metal Truss," *The Journal of Preservation Technology* (Volume 27, Number 1-2): 28.

[14]A cruciform cast-iron beam acts as a longitudinal strut between each of the transverse floor beams. These struts are set into cast-iron sockets on the side of each floor beam along the bridge's center line. Four wrought-iron rods form cross bracing between each transverse floor beam, with the ends of each rod passing through the floor beams and secured by nuts (figure 1 plan view).

Finally, two lines of I-beams, resting directly on the floor box-beams, run longitudinally across the entire length of the bridge on either side of the bridge's center line. Wooden railroad ties lie directly on these beams and support the crosstie plates and rails for the rolling stock. The railroad track, with a standard gauge of 4'-8.5", is centered along the length of the bridge.[15] A wooden, pedestrian walkway was added to the bridge on the west side of the rails during the rehabilitation in 1983-84.

Originally, the bridge was painted with an eye-catching combination of colors which, perhaps by design, highlighted the structural roles of the various members. The body of the bridge (generally the heavier cast-iron compression members) and the end towers were painted oxide red (or barn red). The thin tension members, suspension bars, diagonal panel bracing, and certain recessed panels in the end towers and portal bracing were painted a light shade, probably deep ivory.[16] The central panel of each end tower cover was white and the remainder deep ivory. This paint scheme had rusted away by the 1960s, but during the bridge's rehabilitation the entire structure was sanded, cleaned, and painted entirely red, while the end tower covers were painted completely white. Funding was not, nor is now, available to fully repaint the bridge to its original color scheme.

To summarize, the bridge underwent minimal alterations during its history at Savage, save the rebuilding of the floor beams in 1983-84. The cast- and wrought-iron members making up the truss lines still perform their original function.

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[15]When in main line service, this bridge most likely supported two sets of tracks. The width of the bridge is sufficient for two trains to pass side-by-side, and spans built specifically for single-track use averaged about 16' wide compared to the 25'-6' width of the Savage bridge. Furthermore, purely single-track Bollman trusses did not incorporate the longitudinal strut along the center line between the top two chords, and used only two bracing rods (instead of four) across the top of the bridge between each panel point. Use of one track after its removal to Savage was more than sufficient as it was a dead-end industrial spur and likely saw no more than a few freight cars per week. Locomotives, the heaviest rolling stock the bridge was likely to bear, were probably not often run across the bridge. Freight cars may have been backed in, or possibly pulled over to the mill-side with a simple pulley system.

[16]Vogel, "Speculations on the History and Original Appearance of the Last Bollman Truss," 437. Vogel determined the color scheme through analysis of historic photos of other Bollman trusses. It is not known if the railroad repainted the spans after their move here.

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 X C__ D__ E__ F__ G__
NHL Criteria:	4
NHL Criteria Exclusions:	2
NHL Theme(s):	VI. Expanding Science and Technology 2. technological applications
Areas of Significance:	Engineering Transportation Invention
Period(s) of Significance:	1869
Significant Dates:	1869
Significant Person(s):	
Cultural Affiliation:	
Architect/Builder:	Wendel A. Bollman
Historic Context:	XIV. Transportation E. Railroads XVIII. Technology B. Transportation H. Construction

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

SUMMARY STATEMENT OF SIGNIFICANCE

The Bollman truss railroad bridge at Savage, Maryland, is the sole-surviving example of a revolutionary design in the history of American bridge engineering.[17] This bridge truss configuration was invented and patented by Wendel A. Bollman, a major figure in nineteenth century civil engineering. It was the first successful all-iron bridge design to be adopted and consistently used (from 1850 to ca. 1875) on a railroad.[18] In this case, the railroad was the Baltimore and Ohio, for which Bollman worked twenty-two years, his last ten as Master of Road.[19] Furthermore, this bridge is one of the oldest standing iron railroad bridges in the United States. The bridge was moved from its original location to Savage in 1888. Usually structures moved from their original location are not eligible for NHL designation, however, the exception to criteria exclusion 2 is met because this bridge is nationally significant for its architectural merit, i.e., its method of construction.

HISTORY

Ironically, the site of the Bollman truss at Savage, Maryland, represents both the beginning and end of the Bollman's revolutionary design. Here in 1850, Bollman erected his very first operational Bollman truss for the B&O. It was not the same bridge that stands here today, a fact that for many years led to confusion over the construction date of the currently standing bridge. Two years prior to receiving his patent, Bollman erected what was essentially a full-size test bridge, a single-span, 76'-long Bollman truss on the same spot that the current bridge stands. Tests were carried out on this early span, as well as another span erected the next year at Harpers Ferry, that proved his bridges more than capable of safely carrying the heaviest railroad rolling stock of the time.[20] However, the first Savage bridge was either washed out by a flood or removed by the railroad because of structural inadequacy at some point prior to

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[17]A very remote possibility exists that a Bollman truss stands in Central or South America, since Bollman's company sent bridges there, but there is no evidence that any do. Also, there is occasionally confusion between Bollman's patented suspension truss design and bridges which were built by his bridge company but did not incorporate the suspension truss principle. There are a handful of existing Bollman company bridges, usually based on the Warren truss system, but the Savage bridge is the only known remaining bridge with the patented Bollman suspension truss design.

[18]Vogel, "The Engineering Contributions of Wendel Bollman," *Contributions from the Museum of History and Technology: Paper 36* (1964), 79. There Vogel states that, "Bollman's bridge truss, of which the first example was built in 1850, has the very significant distinction of being the first bridging system in the world employing iron in all of its principal structural members that was used consistently on a railroad."

[19]The B&O, America's first common-carrier rail line, was a leader in railroad-related civil engineering. During the early age of American railroading (1828-1860), it was studied by civil engineers from around the world as a case study in railroad construction through difficult terrain. The Appalachian Mountains forced the B&O's engineers to surmount obstacles--rivers, mountains, and valleys--that no railroad had ever crossed before in such numbers. This helped drive the B&O's engineers to ground breaking designs in civil engineering.

[20]Wendel Bollman, *Iron Suspension and Trussed Bridge as Constructed for the Baltimore and Ohio Railroad Company at Harper's Ferry, and on the Washington Branch of this Road*, (Baltimore, John Murphy and Co.), 10.

1887-88, the year the B&O rebuilt (and realigned) the industrial spur which had existed here since ca. 1835.

During the 1888 rebuilding, the company extended its line from the former dead end at the Savage textile factory and continued it up the Little Patuxent River on a grade laid considerably higher on the slopes of the river valley. The higher crossing also meant that the new bridge needed to be over twice as long (160') to cross the intervening valley, thus the need for a new, longer bridge. Instead of building an entirely new bridge, the B&O, which was in the process of replacing many of its nearly obsolete Bollman trusses at this time, decided to “recycle” this one. It had been fabricated in 1869, most likely at the B&O’s Mount Clare bridge shop, and served for nineteen years somewhere on the B&O’s lines. In 1888, the railroad removed the current structure from main line service and re-erected it here on new abutments and a new central pier that allowed for a crossing much higher above the riverbed.[21] Bollman bridges were prefabricated, and their disassembly and movement were relatively simple processes--attributes first exhibited by Bollman trusses. After workers built timber falsework, the two spans probably took no more than a week to re-erect. While unfit to carry the heavy main line traffic, it was more than adequate to carry the relatively light freight cars carrying material to and from the textile mill.

The bridge remained in use until 1915, when the textile mill the siding served was closed. The only known maintenance during this time was in ca. 1909 when the railroad rebuilt the trussed beam arrangement under the transverse floor beams. After 1915, the bridge sat unused and derelict until preservationists rediscovered the bridge in the early 1960s. During a structural rehabilitation of the bridge in 1983-84, the structure was cleaned and sanded, the suspension bars straightened, and the floor beams rebuilt incorporating plate steel. While rebuilding the floor beams the earlier (ca. 1909) trussed beam arrangement under the beams was removed, as well as the cast-iron end caps on each beam, which were replaced with steel plate. The cast lettering over each portal, and the wooden boxes over each end-tower cap, were recreated in a historically accurate manner and placed on the bridge. Finally, it was painted entirely red, except for the end-tower boxes which were painted white, and a wooden walkway was added to the span. Today it is within a public park and is owned and maintained by the Howard County Commission.

<u>The Bollman Truss and Its Role in the Development of All-Iron Bridges</u>

The first railroad bridges built in the United States were masonry arches, such as the B&O’s 1829 Carrollton Viaduct in Baltimore, but their high cost soon led engineers to rely on cheaper though less durable wooden spans. By the late 1830s, the structural limitations of wooden bridges combined with the ever increasing weight of railroad locomotives and rolling stock pressed civil engineers to develop and refine various types of all-iron trusses. Indeed, the needs of railroads spurred the advancement of bridge building technology in the nineteenth century like no other factor. Certainly no other contemporary transportation systems needed bridges of such superior strength or durability. The shock of heavy, fast-moving trains combined with their extreme weight required railroad bridges to possess attributes far superior to that of standard highway bridges. Also, compared to wood, iron spans were largely immune from fire and rapid decay, and able to sustain greater loads. A major hindrance was a lack of understanding of stress analysis and the properties of iron among pioneering civil engineers who, in America, were not usually academically trained. The lack of experience with iron led a few American

[21]Vogel, “Speculations on the History and Original Appearance of the Last Bollman Truss,” 425-429.

engineers to refine their methods of calculating stress and strain in order to further unravel iron's physical properties and ensure safer bridges. Wendel Bollman and his contemporaries, such as Squire Whipple and Herman Haupt, worked to instill the rationality of mathematics and science to iron-bridge design at a time (ca. 1850) when the calculation of structural stresses for trusses was still in its infancy, and helped bring about the flourishing period of iron bridge construction in the United States lasting until ca. 1890.

Compared to wrought iron, cast iron was a relatively inexpensive material, but it was brittle and worked well only in compression. It was easily cast into ornate compression members of any form desired, although for many years few engineers trusted large castings for bridges and opted for wooden compression members instead (quality control was notoriously lax in early foundries). On the other hand, because wrought iron worked well both in tension and compression, it was an ideal material for bridge building. However, it was labor intensive and produced by small-scale shops and was not used for large compression members until after the Civil War. Thus, in this early period wrought iron was forged into long, thin, rod or eye-bar tension members. In the interim between all-wood and all-iron bridges, engineers built many composite spans of wood and iron, usually wooden covered bridges with cast-iron used for low risk components like "shoes" for timber beams and wrought-iron rods added between the timbers to strengthen the span.[22]

The first successful all-iron bridge in this country was a highway bridge based on the tried-and-true arch, not the truss. The 1839 Dunlap Creek Bridge at Brownsville, Pennsylvania, on the National Road, carried its load on hollow cast-iron arches. It was later reinforced and still exists today, but is largely hidden by more modern commercial buildings. Some engineers relied on more imaginative use of the arch, such as the Whipple iron-bowstring arch, patented (and in use) in 1841. Otherwise, all-iron trusses began as updated iron versions of older wooden-truss designs, such as the Town or Howe trusses, and were first patented in the early 1840s. A notable exception was the newly created Pratt truss layout patented in 1844--the patent stated that it could be built with iron or wood, or a combination thereof.

Engineer Richard Osborne designed America's first iron truss railroad bridges, all incorporating cast- and wrought-iron Howe truss layouts and all built in 1845-47 on the Reading Railroad. The first, a 34' span, was built at Manayunk, Pennsylvania, in 1845. One truss line of the Manayunk bridge is now part of the John Bull locomotive display at the Smithsonian Museum of American History in Washington. The 69'-span Reading-Halls Station bridge, this country's oldest standing iron railroad bridge, is another Osborne span built on the Reading's line ca. 1846. Sometime after 1888 it was removed from its original location and re-erected near Muncy, Pennsylvania, to carry a farm road over the Reading's tracks (a function it still serves). Osborne built approximately six short iron Howe truss spans (of which only these two survive), but each was unique, with little standardization, and not conducive to mass production and the lower costs it brought. As a result, even with Osborne's success iron bridges did not catch on quickly. By 1850 the country possessed only a handful of iron railroad bridges, and those in service were looked upon with suspicion brought on by the failures of some early iron spans.[23] The public fears of early iron bridges were often well-founded. Like Osborne's bridges on the Reading, each structure was unique,

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[22]Some railroads, particularly in the West, continued using wood-and-iron bridges throughout the century.

[23]For instance, the Erie Railroad, ca. 1849, built a small number of all-iron Rider and Whipple trusses on its line. The collapse of one in 1850 caused the railroad to remove the remainder and replace them with wood-and-iron bridges.

empirically designed, and built on a case-by-case basis with little in the way of standardization. Bollman's design, coming just five years later, helped make standardization a hallmark of American bridge engineering, and helped begin a more rapid changeover from wood to cast- and wrought-iron railroad bridges.

In Britain, where the world's first all-iron bridge originated in 1779 at Coalbrookdale, the development of iron bridges had followed a different course, partly because of the availability of capital and a mature iron industry that could supply large cast- and wrought-iron bridge members. By 1850, British engineers like Robert Stephenson were building massive all-iron bridges, but these were generally based either on the arch, or otherwise giant, hollow box girders--not intricate truss arrangements (there were exceptions, but these were relatively rare). But, the earlier British trend of building masonry railroad viaducts or earthen embankments in lieu of truss bridges had stymied the development of smaller scale wooden--and consequently iron--trusses. In America however, the plethora of wooden truss designs eventually evolved into a similar variety of all-iron trusses. Here, engineers like Bollman advanced the use of all-iron bridges, but were concerned less with monumental bridges as with the creation of shorter spans that were cheap, easy to erect, efficient, and safe.

During the 1840s, Bollman worked his way up though the B&O's engineering department (he began his career in 1836 as "foreman of bridges") under the guidance of chief engineer Benjamin Latrobe Jr.. He was made the B&O's first "master of road" in 1848.[24] This position (which Bollman held for ten years) put all the B&O's tracks, buildings, tunnels, and bridges under his care. Most importantly, Latrobe gave Bollman the time and resources to increase his knowledge of iron's physical properties and develop a totally new truss design. While Bollman may have begun developing his unique truss arrangement during the 1840s, he did not receive a patent until January 6, 1852.[25] The patented design used a combination of cast and wrought iron, reflecting the nature of each metal and the state of the American iron industry--cast iron in the compression members and wrought iron in the tension members. This was "the proper condition of the two metals...," said Bollman.[26] Bollman trusses were a remarkable sight, distinguished by the web of wrought-iron diagonals radiating downward from the tops of granite end towers, the octagonal top chords, and the aesthetic treatment given to the major castings. Although complicated in appearance, they were simple to erect. Numbers were cast into each piece for easy identification and each bridge was test assembled at the B&O's shops, disassembled, and taken to the bridge site. Held together with bolts, mortise-and-tenon joints and wrought-iron pins (the only rivets were in the floor beams), Bollman bridges could be erected with greater ease and required fewer skilled laborers than either wooden or masonry bridges, a key factor in their adoption by the B&O.

There is a precursor to the Bollman truss, from which Bollman possibly derived his particular design. Robert Vogel, the foremost authority on Bollman and his bridges, described it as, "A basic technique commonly used to increase the capacity of a simple timber beam--that of trussing--i.e., placing beneath the beam a rod of iron that was anchored at the ends of the beam and held a certain distance below it at

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[24]Antoinette Lee, *A Biographical Dictionary of American Engineers*, (New York: American Society of Civil Engineers), 12.

[25]Wendel Bollman, "Construction of Bridges," U.S. Patent No. 8,624, January 6, 1852.

[26]Bollman, *Iron Suspension and Trussed Bridge as Constructed for the Baltimore and Ohio Railroad Company at Harper's Ferry, and on the Washington Branch of this Road*, 6.

the center by a vertical strut or post."[27] While using such simple trussed beams for short spans, Bollman probably realized that by multiplying the iron rods and vertical posts the span could be lengthened considerably; out to about 150 feet, in fact. The incorporation of iron into the design was only logical, especially considering the influence of his superior, Benjamin H. Latrobe, Jr., who likewise was a pioneer in the use of iron in composite wood-and-iron bridges but had never built a successful all-iron span. The Bollman truss superficially resembles another suspension truss developed soon after by his colleague on the B&O, Albert Fink, which was called the Fink truss. Fink's was, in essence, a refined version of Bollman's suspension truss concept.[28] The suspension systems were actually different enough that Fink was also awarded a patent on May 9, 1854. Fink's design allowed for the truss to have suspension bars of equal length to supporting each panel point, while on the Bollman truss the suspension bars coming from one tower were not equal in length to those from the opposite tower (except those that met at the center of the bridge). One benefit of the design was that Fink's truss used less iron, and could span up to 200 feet. While used on the B&O in numbers less than that of the Bollman truss, it found more usage on other railroads than the Bollman design. Both truss designs were indeed similar in that they consisted of numerous independently acting trusses--the failure of one suspension member would not catastrophically affect the remainder. It also meant that individual floor beams and secondary members could be replaced without placing falsework under the entire bridge.

In his early tests for the design Bollman had used wood for the compression members, but soon he incorporated a new structural member he had invented to replace both the wooden verticals and wooden stretchers. It was a hollow, pipe-like, "octagonal without, circular within" cast-iron structural member, and it made Bollman's all-iron truss possible.[29] Such members make up the top chord and verticals of the Savage bridge. The iron averaged 1" in thickness, making the columns both light and strong and less likely to hide major casting flaws than a solid member. As top chord stretchers they were made in panel-length sections and connected to the vertical posts by mortise-and-tenon joints, mimicking the earlier woodworking tradition. Bollman's hollow columns were the forerunner of the *Phoenix column*, a similarly hollow--although wrought-iron--structural member which Bollman created during the mid-1850s. Since iron shops could not supply wrought-iron members large enough to use as compression members, Bollman used curved sections of rolled wrought iron (with standing flanges so the segments could be riveted together on the outside) to create hollow columns. Although Bollman never used Phoenix columns on Bollman suspension trusses, the invention was later patented (1861) and manufactured by the Phoenix Iron Company and gained great popularity.

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[27]Vogel, "The Engineering Contributions of Wendel Bollman," 88.

[28]Soon after adopting the Bollman design, Latrobe also made the Fink truss (a somewhat similar design) a standard B&O bridge-type. The result was a mix of Bollman and Fink trusses on the B&O's main stem between Baltimore and Wheeling. There are two known standing Fink truss bridges. One is a deck truss, formerly serving as a highway bridge over a railroad spur in Lynchburg, Virginia. Its origins are murky, but the bridge was probably fabricated in the 1870s and used on one of the Norfolk and Western Railroad's lines prior to its removal and re-erection at the Lynchburg location in 1893. It is approximately 50' long. In the 1970s, when the highway was widened, a new bridge replaced the Fink deck truss, which was repaired and relocated in the city's Riverside park to serve as an exhibit. In 1979 the American Society of Civil Engineers declared it a National Historic Civil Engineering Landmark. The other remaining Fink is a 108'-long through truss at Zoarville, Ohio. Fabricated in 1868, this single span was once part of a three-span railroad bridge at Dover, Ohio. In 1905 the bridge was demolished, except for this span which was re-erected to carry a now-abandoned highway over Conotton Creek.

[29]Bollman, *Iron Suspension and Trussed Bridge as Constructed for the Baltimore and Ohio Railroad Company at Harper's Ferry, and on the Washington Branch of this Road*, 8.

The Bollman truss was called an "all-iron" bridge, but it incorporated a considerable amount of wood for stringers and crossties ("all iron" referred to the load-bearing members of the truss). Also, a roofed wooden box covered the top of each abutment tower to protect the multitude of connections there. Still, the independently-acting diagonals prevented major damage from failure of a suspension bar or fire, "In case of fire, the floor may be entirely consumed without any injury to the side truss," Bollman wrote.[30]

So, the essential load-bearing members of a Bollman truss are the long wrought-iron bars extending from the end towers, working in combination with the top chord and verticals. Wrought-iron tension members had been used on bridges for at least thirty years. James Finley's wrought-iron chain suspension bridges (for road use only) were, perhaps, the most extreme examples. But chain or wire-rope suspension bridges were considered to lack the rigidity required for railroad use and were used only in special instances, such as Roebling's railroad bridge across the Niagra gorge completed in 1855. Otherwise, in most structures wrought-iron members had been limited to secondary roles (such as the vertical rods supporting the deck on Howe trusses) while the primary load-bearing members were wooden compression members. This was where Bollman's design--relying on the long, wrought-iron bars acting under tension to carry the entire load from the bridge deck directly back to the end towers--differed from most other trusses which used wrought iron only in secondary members. This arrangement was called a *suspension truss*, and it combined the principles of the suspension bridge and the standard triangular truss into a form acceptable for railroad use.[31]

The design came at a critical time for the railroad. In 1851-52, when the B&O was building the final link of the main stem between Cumberland and Wheeling, Latrobe boldly decided to use iron bridges, adopting Bollman's new truss as the B&O's standard bridge-type. Furthermore, the original wooden bridges on the line's older sections nearer Baltimore were in dire need of replacement because of their age and the increasing size, weight, and speed of trains. After the first Bollman truss was successfully erected at Savage (on the site of the current bridge) in 1850, the B&O's iron foundries at Mt. Clare in Baltimore were expanded to handle the increased number and size of castings required for the main stem's new bridges, and Bollman trusses began appearing all along the line between Baltimore and Wheeling. The design's approval for standard use by an engineer of Latrobe's status, on a railroad as prominent as the B&O, helped convince engineers (and a somewhat skeptical public) in both the United States and Europe that cast- and wrought-iron truss bridges were no longer experimental curiosities, but scientifically designed structures possessing superior qualities of strength, economy, safety, and durability. The Bollman truss was the epitome of this ideal in the 1850s. Indeed, no Bollman truss is known to have had a catastrophic, loading-induced failure. The B&O began building Bollman trusses in earnest after 1853, reaching an apex in the years just after the Civil War (Bollman's patent was renewed in 1866). They could be found all along the B&O's original main stem in both deck- and through-truss

[30]Ibid. This "fire-proof" claim was proven early in the Civil War, when the Bollman Winchester span at Harpers Ferry survived the destruction by fire of the rest of the wooden covered bridge. The Bollman's wooden floor beams were burned and a locomotive was run through the deck, but the truss lines remained sound and were reused for a short time until the span was finally blown-up by pouring black powder explosives into the hollow vertical members and igniting it.

[31]The suspension bars were relatively easy to make and were adjustable. According to Bollman's patent, "The rods from the centre to abutments [have] but an eye at one, and a screw at the other, end; with a weld or two between according to length. The long counter rods have two knuckles and one swivel for adjustment of strain, and convenience in welding, as well as in raising the whole."

versions. The B&O probably erected more than one hundred Bollman trusses on the main stem and its various branches during the three decades it was used.[32]

In 1858, Bollman and two of his assistants, John Tegmeyer and James Clark, left the B&O to start their own bridge company in Canton, Maryland, just west of Baltimore. It was among the earliest bridge-building companies in the United States, one of the first bridge companies to specialize in all-iron spans, and it built Bollman trusses as well as other truss layouts. At first called W. Bollman and Company, after the Civil War the name changed to the Patapsco Bridge Company. The company fabricated bridges at its own shops and the disassembled bridges could be shipped nearly anywhere. Bridge companies like Bollman's revolutionized the bridge-building industry, mass producing bridges using off the shelf components that could be readily assembled to meet the buyer's needs.

As time and experience helped reveal weaknesses in his design, Bollman altered and strengthened certain portions of the truss. The end towers, made of granite on the first three Bollman trusses, were changed to cast iron on later versions to simplify erection (he retained the granite end-tower pedestals as an essential component of the truss system). The portals and structural members of post-Civil War Bollman trusses, like that at Savage, were made more substantial than those built before the war to account for increasing locomotive weight, and flanges were cast into the first panel of the top chords to increase their strength.[33] After the war, new Bollman bridges had decorative cast-iron portal transoms identifying (among other things) himself as the patent holder and the year of fabrication, and the 1866 patent renewal date.[34] With these attributes, Bollman's design reached its apex. The Bollman bridge at Savage exhibits all three attributes: cast-iron end towers on granite pedestals, top chord flanges, and portal transom information plates.

While the Bollman truss was popular on the B&O, it was not extensively used by other railroads, primarily because Bollman closely guarded his patent and rarely licensed it to others. One notable exception was the six-span, 435'-long Bollman truss bridge at Quincy, Illinois, which carried the Chicago, Burlington and Quincy Railroad over Quincy Bay, a branch of the Mississippi River. It was built in 1867-68 by the Detroit Bridge and Iron Company under licensing from Bollman. The two central spans formed a pivoting drawbridge, rotating on the central pier to allow riverboats to pass.[35]

Meanwhile, the flowering of cast- and wrought-iron bridges had led to a variety of accepted truss layouts, many of which outperformed the Bollman truss. Among the last, and the largest, of the B&O's Bollman truss bridges were its two Ohio River crossings: the bridge from Benwood, West Virginia, to Bellaire, Ohio; and a similar span crossing from Parkersburg, West Virginia, to Belpre, Ohio. The Benwood bridge (finished in 1871) used nine Bollman deck trusses from 106' to 108' long, and a combination of six Linville and Piper trusses from 209' to 350' long at mid-river to form a continuous

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[32]Vogel, "Speculations on the History and Original Appearance of the Last Bollman Truss," 429.

[33]Ibid., 431.

[34]Ibid.

[35]Vogel, "The Engineering Contributions of Wendel Bollman," 92.

iron bridge 1,435' long with an equally long masonry approach viaduct.[36] The Parkersburg bridge (also finished in 1871) was similar in form, but incorporated an incredible twenty-eight Bollman deck spans.

The Bollman truss design had certain inherent problems which helped lead to its eventual demise. For one, it used more iron than other bridge trusses of comparable strength. Moreover, the variety of diagonal lengths responded unevenly to temperature changes and needed constant readjustment.[37] Most problematic, in longer spans (over 100') the longest diagonal rods were almost horizontal, lessening their effectiveness and causing an unacceptable deflection under heavy loads. This factor kept Bollman trusses from reaching lengths greater than 150'. This is graphically illustrated by the Benwood/Bellaire bridge, whereby Bollman trusses could only be used in the shorter (108') approach spans while the mid-river spans (350') were modified Whipple trusses. For nearly twenty-five years, however, the Bollman truss was completely satisfactory for the B&O's short-to-medium-length bridges, and they remained committed to the design. Indeed, many first generation Bollman trusses were replaced with the stronger post-Civil War versions toward the end of the design's useful life.

The B&O and Bollman's own company constructed Bollman trusses from 1850 to ca. 1880, when the increasing weight of rolling stock finally made the Bollman design obsolete. New all-steel designs took the place of cast- and wrought-iron bridges, including Bollman's, after 1890. During the 1890s, hundreds of aging cast- and wrought-iron bridges were dismantled and replaced. By that time, most engineers had settled into using steel Pratt or Warren truss layouts, which had finally proven their superiority over all other truss types and are still the most popular truss layouts to this day. Some Bollman truss bridges remained into the 1930s carrying light-use branch lines, often reinforced with structural steel to give them a few more years of service. None, save the twin spans at Savage, have survived intact. Today this structure is the best representative of America's original acceptance of iron bridges as a safe, durable, and economical answer to the needs of this country's railroads.

<u>Wendel A. Bollman</u>

Wendel A. Bollman (1814-1884) was an innovative figure in the engineering field, coming from a traditional carpentry background but emerging as a leader in the more theoretical, scientific, and mathematical aspects of bridge engineering and iron trusses. Bollman was thoroughly modern in his professionalism and reliance on mathematical formulae, but also held a penchant for empirical analysis. Historian Robert Vogel has described Bollman as "perhaps the most successful of the self-taught engineers and probably one of the last. He may be said to be a true representative of the transitional period between intuitive and exact engineering."[38] Today, Bollman is known in the fields of technological history and civil engineering as one of the originators of the American iron-truss bridge.

For much of his life, Bollman worked as a civil engineer for the B&O Railroad. Interestingly, his acquaintance with the B&O began in his youth. He was born in Baltimore on January 21, 1814, the son of a German emigrant and baker, the seventh of eight children. He attended Bassford's free school on

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[36]J.E. Greiner, "The American Railroad Viaduct, Its Origin and Evolution," *Transactions of the American Society of Civil Engineers* (Volume 24, June, 1897): 146.

[37]Vogel, "The Engineering Contributions of Wendel Bollman," 90.

[38]Ibid., 82.

Courtland Street in Baltimore and a private school. When Wendel's father died, he left his mother in a poor financial state. So in 1825, around the age of eleven, Bollman went to work in a drugstore run by a family friend in Shepherdstown, Virginia (now West Virginia), 10 miles northwest of Harpers Ferry, (West) Virginia. The next year he moved to Harpers Ferry, but there he contracted a serious illness, perhaps Cholera, and he was forced to return to Baltimore for treatment.[39] While recuperating, the young Bollman joined in the procession through the city streets for the laying of the Baltimore and Ohio Railroad's cornerstone.[40] Soon after, Bollman found a job as carpenter's apprentice on the railroad. During 1829-1830, he became a rodman on a surveying crew under newly-hired Benjamin Latrobe Jr. on the B&O's main stem west from Baltimore. Bollman worked for the railroad for only a year before he left to start his own carpentry business, through which he began cultivating his civil engineering skills.

In 1837, Bollman returned to Harpers Ferry to build a house for a local resident when James Murray, an engineer from the B&O's Road Department, asked him to come back to work for the railroad as foreman of bridges.[41] Bollman accepted, and his first order of duty was rebuilding a portion of the B&O's Harpers Ferry bridge. This time he remained with the company building bridges, tunnel linings, trestles, and wayside structures for more than twenty years. Bollman was made "master of road"--a position second only to the chief engineer--for his last ten years. Just prior to the Civil War, he left to form his own successful bridge company. During the war, his replacement Bollman truss spans helped keep the B&O open--a strategic necessity for the North. After the conflict he remained active in his bridge business (occasionally building structures for the B&O under the auspices of his own firm) while becoming president of the Western Maryland Railway Company and participating in various civil engineering societies.

While Bollman began as a carpenter, his most significant works were of iron. Although best known for his iron bridges, Bollman made ground breaking use of the material in many types of structures, only a few of which are mentioned here. In the mid-1850s, while supervising the lining of the B&O's numerous tunnels, he developed a cast-iron lining system that was safer and easier to erect than the usual brick arch--the first such use of iron tunnel lining in this country. Aside from the bridges on the B&O's lines, Bollman's company built two large bridges in Chile, several in Cuba, and around 1863 built the first all-metal bridge in Mexico near Vera Cruz.[42] One of his most difficult engineering jobs was spanning the Cape Fear River in North Carolina. During 1867-68, Bollman sank two cast-iron cylinders, or pneumatic caissons, into the riverbed some 80' below the water's surface, reportedly "one of the first instances of the use of the process in America."[43] He also built a cast-iron framework in 1873 for the dome on Baltimore City Hall. Wendel Bollman died in Baltimore, the city which had supported so many of his works, on March 14, 1884.[44]

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[39]"The Late Wendel Bollman," *The Railroad Gazette* (March 14, 1884): 200.

[40]Ibid.

[41]Lee, 12.

[42]Ibid.

[43]Lee, 12.

[44]"The Late Wendel Bollman," 200.

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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 No. MD-1.

Primary Location of Additional Data:

_X_ State Historic Preservation Office
__ Other State Agency
__ Federal Agency
__ Local Government
__ University
__ Other (Specify Repository):

10. GEOGRAPHICAL DATA

Acreage of Property: 1/8 Acre

UTM References:	Zone	Easting	Northing
	18	342220	4333120

Verbal Boundary Description:

The property consists of the superstructure, abutments and pier of the Bollman truss railroad bridge spanning the Little Patuxent River (adjacent to the junction of Gorman Road and Foundry Street) consisting of all cast- and wrought-iron members, and end towers, and the eight granite end-tower pedestals. The superstructure is 160' long, 25'-6" wide, and approximately 21" high; its long axis sits on a north-south axis.

Boundary Justification:

The boundary includes the essential components of the bridge superstructure, the Bollman suspension truss system, and the supporting abutments and pier.

11. FORM PREPARED BY

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Date: July 16, 1999.