In its extensive dealings with the Wrought Iron Bridge Company, Winneshiek County was simply following a regional trend. As this county and hundreds of others in the Midwest contracted with the Ohio-based bridge company in the 1870s, Wrought Iron quickly became one of the largest bridge fabricators in America. And its president, David Hammond, distinguished himself as one of the country's most prolific bridge innovators.

Born September 12, 1830, on a farm in Plain Township, Ohio, David A. Hammond had moved to Canton, Ohio, at the age of eighteen. There he served as an apprentice carpenter to William Prince, a locally prominent builder. By 1860, Hammond had formed his own construction company and was building, among other things, several small-scale timber roadway bridges. With John Laird, owner of a local foundary, and Washington R. Reeves, a local metal worker, he developed a combination bridge in which he substituted iron for wood on some of the tension members and connection details. Hammond patented this design, the first in what would be a long series of bridge patents issued to him. In 1862, Hammond was contracted to build an iron bridge over the Middle Branch of Nimishillen Creek in Canton, for $1200. "It was strictly a wrought-iron bridge," stated The American Pictorial Monthly, "made out of bars and bolts." Hammond and Reeves built the 60-foot bridge - their first all-metal span - in an 18'x 30' blacksmith shop using a one-horse power drill. [37]

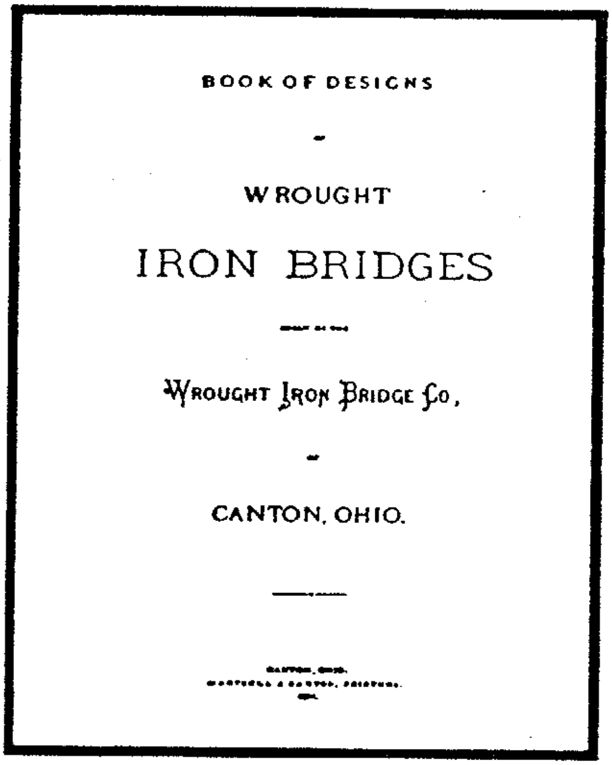
In 1864, Hammond and Reeves formed a partnership to engage in bridge work and general contracting. That year they jointly patented their first bowstring arch-truss design (described in more detail later) and built a small fabricating plant on the Fort Wayne Railroad near the West Branch of Nimishillen Creek. Not satisfied with the small-scale construction undertaken by his partnership with Reeves, Hammond formed the Wrought Iron Bridge Company in 1865 and for the next four years operated both bridge companies from the same facility. As Wrought Iron increased its construction activity, the cramped facilities suffered under the strain.[38]

In 1870, Hammond and Reeves dissolved their partnership and Reeves returned to metalworking. Hammond continued to expand his bridge fabrication enterprise. In January 1871, the Wrought Iron Bridge Company was incorporated with an initial capitalization of $106,000.[39] The first officers were Hammond, Reeves and Michael Adler. Later joining Hammond on the board of directors were C. Aultman, Hiram H. Wise, Alexander Hurford and Job Abbott, a patent attorney turned bridge engineer. The company built a new fabricating plant at East Ninth and Saxton Streets, opposite the passenger station of the Fort Wayne Railroad, increasing his production capacity tremendously. Hammond's success throughout the 1870s was phenomenal. In 1871, the company sold 100 bridges worth $200,000. The following year sales had doubled to $400,000, and by 1873 production had increased to a half million dollars.[40] By August 1877, the Wrought Iron Bridge Company employed three hundred men, working around-the-clock to produce the 12,000 feet of iron bridges then under contract.[41] Like most bridge fabricators of the time, Wrought Iron cut and assembled the members for its iron bridges, but did not manufacture the wrought iron. An 1880 account describes the company's operation:

> The material they use in construction of bridges is specifically manufactured for them under the most rigid specifications, as to tensile strength and quality, and is critically tested on its arrival at the shops. Their bridges are built on scientific principals, approved by long and thorough experience, and the utmost caution is excercised in their erection. In all the work they have executed, there has not been a single case of failure or accident, under protracted usage for road travel or excessively trying tests. Such an exceptional record is certainly worth of consideration. Their facilities for accurate and reliable work are unequaled by those of any similar establishment, and enable them to complete contracts with great dispatch.[42]

The Wrought Iron Bridge Company marketed its bridges through the traditional means of solicitation and advertising. The company opened branch offices in several midwestern states from which it fielded general agents. Essentially traveling salesmen, these agents visited with city and county officials in their territories, explaining the company's bridge designs and presenting proposals for competitive bid lettings. The company advertised in national and regional trade periodicals such as Isaac Potter's County Roads (shown in Figure 8). Additionally, it circulated illustrated pamphlets which showed representative examples of its work. In 1874, Wrought Iron printed its "Book of Designs" (shown in Figure 1). This served both as an advertisement for the company and as a pattern book of standardized bridge designs that the company manufactured. The fronticepiece of this illustrated pamphlet tries to dispel the lingering questions regarding the safety and economy of iron and clearly demonstrates who the targeted customers were:

> To County Commissioners and Others:
>
> The large amount of money annually required for the construction and maintenance or railroad and highway bridges, calls for the most careful investigation by all those interested in public economy, as to what means are necessary to reduce this cost of manufacture, and naturally leads to inquiries as to whether iron bridge building will contribute to this result; whether iron bridges have been sufficiently tested to render their adoption no longer an experiment, but a certain success; whether cast or wrought iron should be adopted for bridge work; whether wrought iron, if adopted, will be effected by corrosion or other causes; what the proper capacity of an iron bridge should be; what are the best plans for iron bridges, and what is the best mode of obtaining an iron bridge of proper construction.[43]



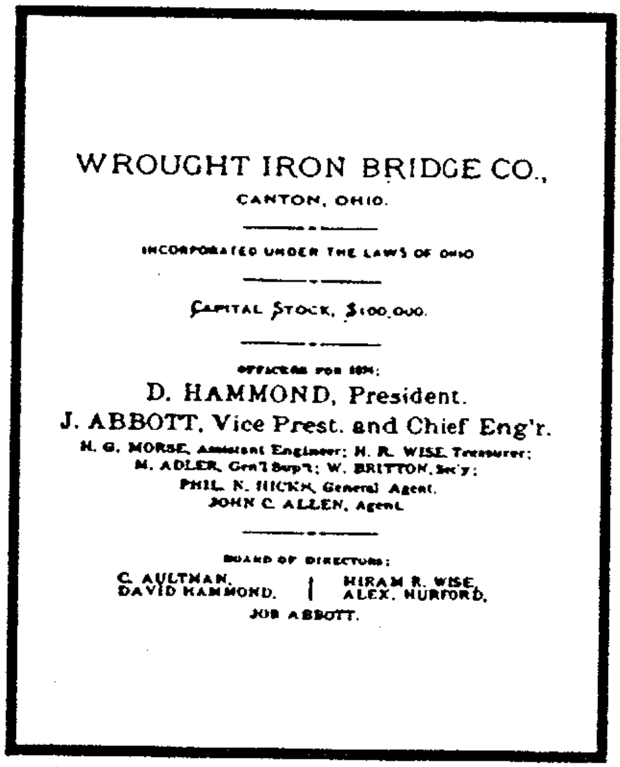
BOOK OF DESIGNS

WROUGHT

IRON BRIDGES

Wrought Iron Bridge Co,

CANTON, OHIO.



WROUGHT IRON BRIDGE CO.,

CANTON, OHIO.

INCORPORATED UNDER THE LAWS OF OHIO

Capital Stock, $100,000.

D. HAMMOND, President.

J. ABBOTT, Vice Prest. and Chief Eng'r.

H. G. MORSE, Assistant Engineer; H. R. WISE, Treasurer;
M. ADLER, Gen'l Supt; W. BRITTON, Sec'y;
PHIL. N. HICKS, General Agent.
JOHN C. ALLEN, Agent.

BOARD OF DIRECTORS:

C. AULTMAN, DAVID HAMMOND, | HIRAM R. WISE, ALEX. HURFORD,
JOB ABBOTT.

[44]

Figure 1

As indicated by the Book of Designs, the primary superstructural type marketed by the Wrought Iron Bridge Company in the 1870s was the bowstring arch-truss made up of wrought and cast iron components. The bowstring was the most commonly erected all-metal bridge of the 1870s, due in large part to Wrought Iron and its main competitor, the King Bridge and Manufacturing Company of Cleveland, Ohio. The first and second largest bridge manufacturers in the country during the decade, both companies fabricated standardized versions of their own patented bowstring designs.

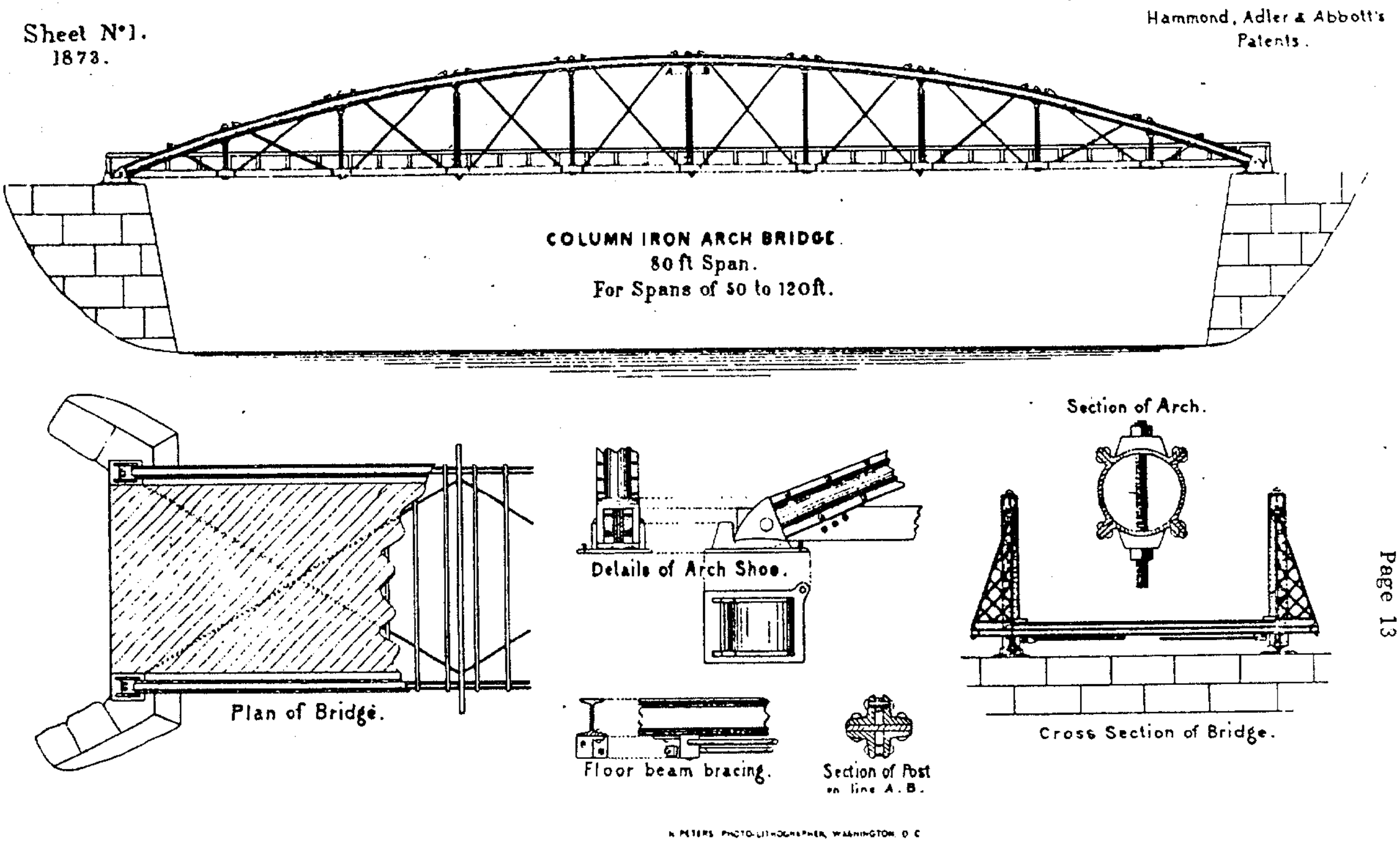
By altering the configuration of the primary arches and suspenders on its bridges, Wrought Iron was able to produce a series of bowstrings covering a range of span lengths from 50 to 350 feet. The shortest bowstring was what Wrought Iron termed a Column Arch Bridge (shown in Figure 2). This bridge, according to the company, "was specially designed for country bridges of moderate spans, and has proved to be remarkably well adapted to such purpose; its moderate cost, great strength and stiffness and neat and ornamental appearance making it much superior to any other arch bridge for short spans."[45] The column arch bridge, intended for spans between 50 and 120 feet, employed a cylindrical wrought iron arch made up of four flanged quarter round segments riveted together. It was a pony configuration - Wrought Iron's only pony arch - with no overhead lateral bracing.

For span lengths ranging from 80 to 140 feet, Wrought Iron designed a Column and Channel, or Column and Thimble, Arch Bridge (shown in Figure 3). The primary arches consisted of four riveted quarter round sections, with two channels inserted on the horizontal axis. "Although designed especially for large spans," the Book of Designs stated, "we have succeeded in adapting it in the most perfect manner, as is attested by the very large number of spans erected by us within the [80-140-foot] limits."[46] By varying the size of the column and channel members, the company could vary the size of the arches from 8-1/2" to 11-1/2" deep and from 11-1/2" to 15-1/2" wide.

Wrought Iron's Column, Plate and Channel Arch Bridge (shown in Figure 4) was designed for spans ranging from 140 to 180 feet. The arches were configured much like the column and channel bridge, with a stiffening wrought iron diaphragm inserted between the quarter round sections. Intended for the span range most commonly specified in county bridge construction, the column, plate and channel arch was Wrought Iron's most popular bridge type.

For longer span bridges, Wrought Iron marketed two other types of bowstrings: the Column, Plate and Channel Arch Bridge (shown in Figures 5 and 6) and the Double Column and Channel Arch Bridge (shown in Figure 7). Although outlined in the Book of Designs, these last two bridge types were rarely erected. The longest column and channel bridge known to have been constructed was a a double-265-foot span bridge built ca. 1874 in Foxburg, Pennsylvania.[47] No double column and channel bridges are known to have been fabricated.

Figure 2



Sheet N°1.
1873.
Hammond, Adler & Abbott's
Patents.
A B
COLUMN IRON ARCH BRIDGE.
80 ft Span.
For Spans of 50 to 120ft.
Section of Arch.
Plan of Bridge.
Details of Arch Shoe.
Floor beam bracing.
Section of Post
on line A. B.
Cross Section of Bridge.
N. PETERS, PHOTO-LITHOGRAPHER, WASHINGTON, D.C.

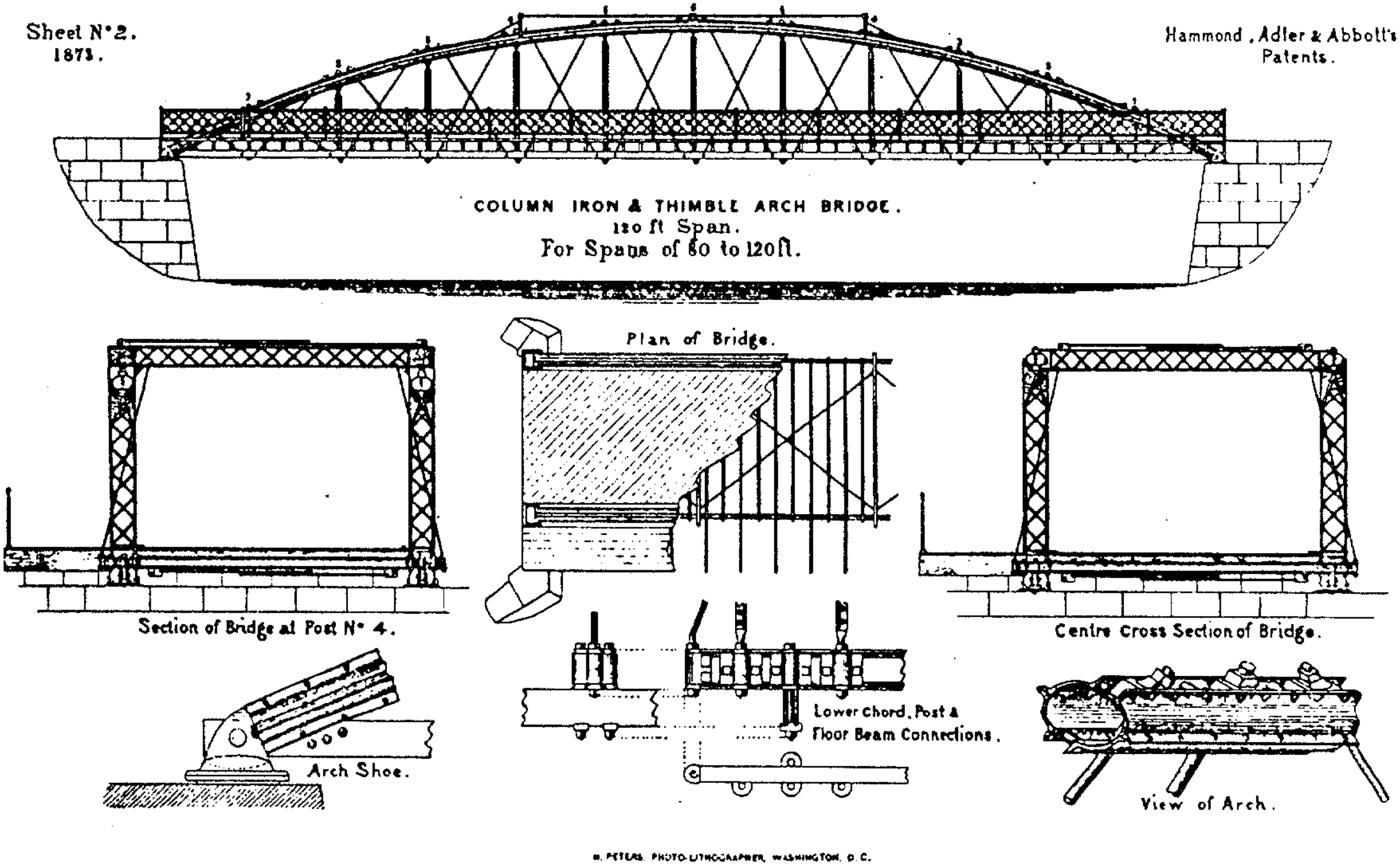

Sheet N°2.
1873.
Hammond, Adler & Abbott's
Patents.
COLUMN IRON & THIMBLE ARCH BRIDGE.
120 ft Span.
For Spans of 80 to 120 ft.
Section of Bridge at Post N° 4.
Plan of Bridge.
Centre Cross Section of Bridge.
Arch Shoe.
Lower Chord, Post &
Floor Beam Connections.
View of Arch.
H. PETERS, PHOTO-LITHOGRAPHER, WASHINGTON, D.C.

Figure 3

Figure 4

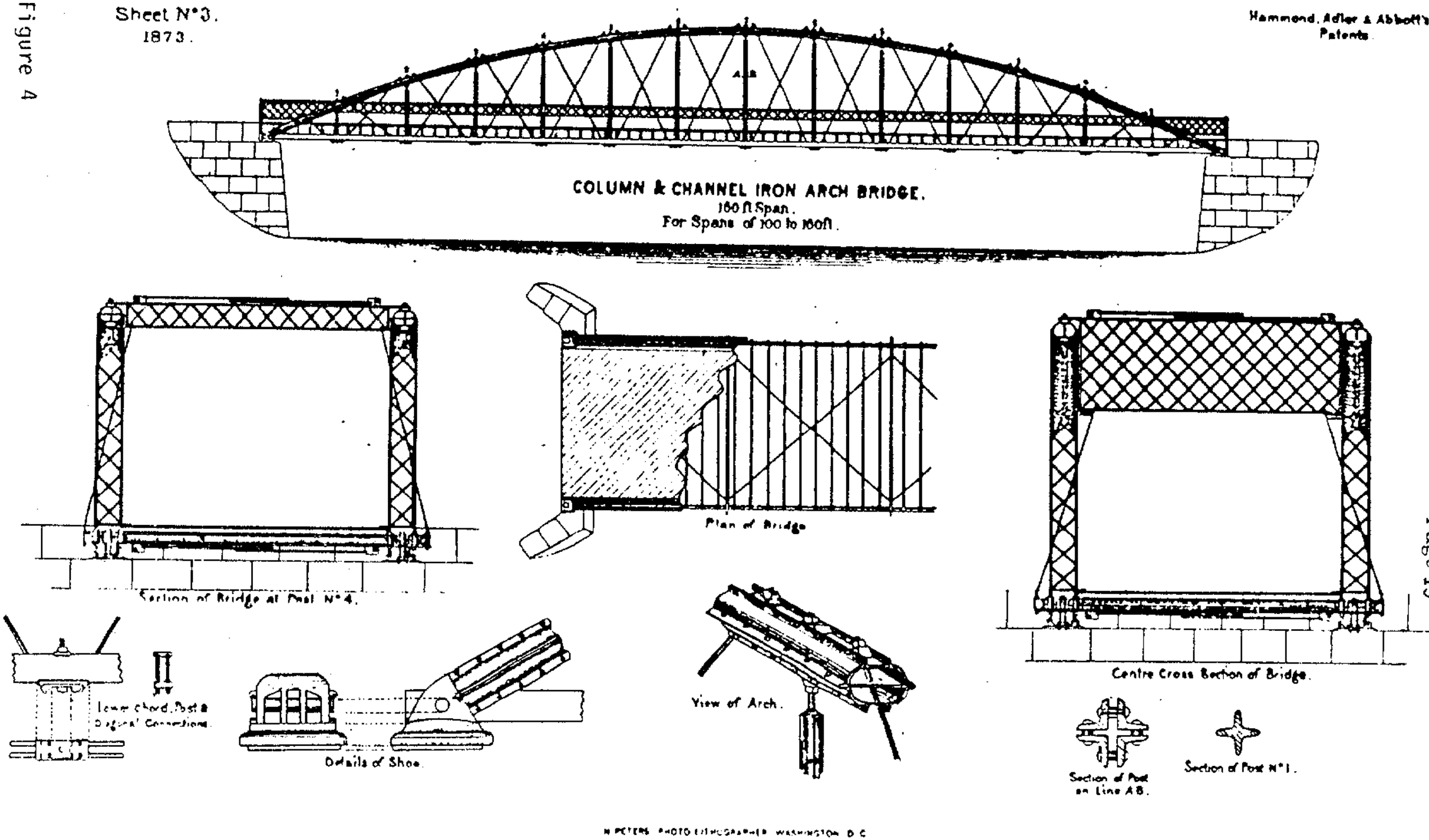

Sheet N°3.
1873.
Hammond, Adler & Abbott's
Patents.
COLUMN & CHANNEL IRON ARCH BRIDGE.
160 ft Span.
For Spans of 100 to 160 ft.
Section of Bridge at Post N°4.
Plan of Bridge
Centre Cross Section of Bridge.
Lower Chord, Post & Diagonal Connections.
Details of Shoe.
View of Arch.
Section of Post on Line AB.
Section of Post N°1.
N. PETERS, PHOTO-LITHOGRAPHER, WASHINGTON, D.C.

Figure 5

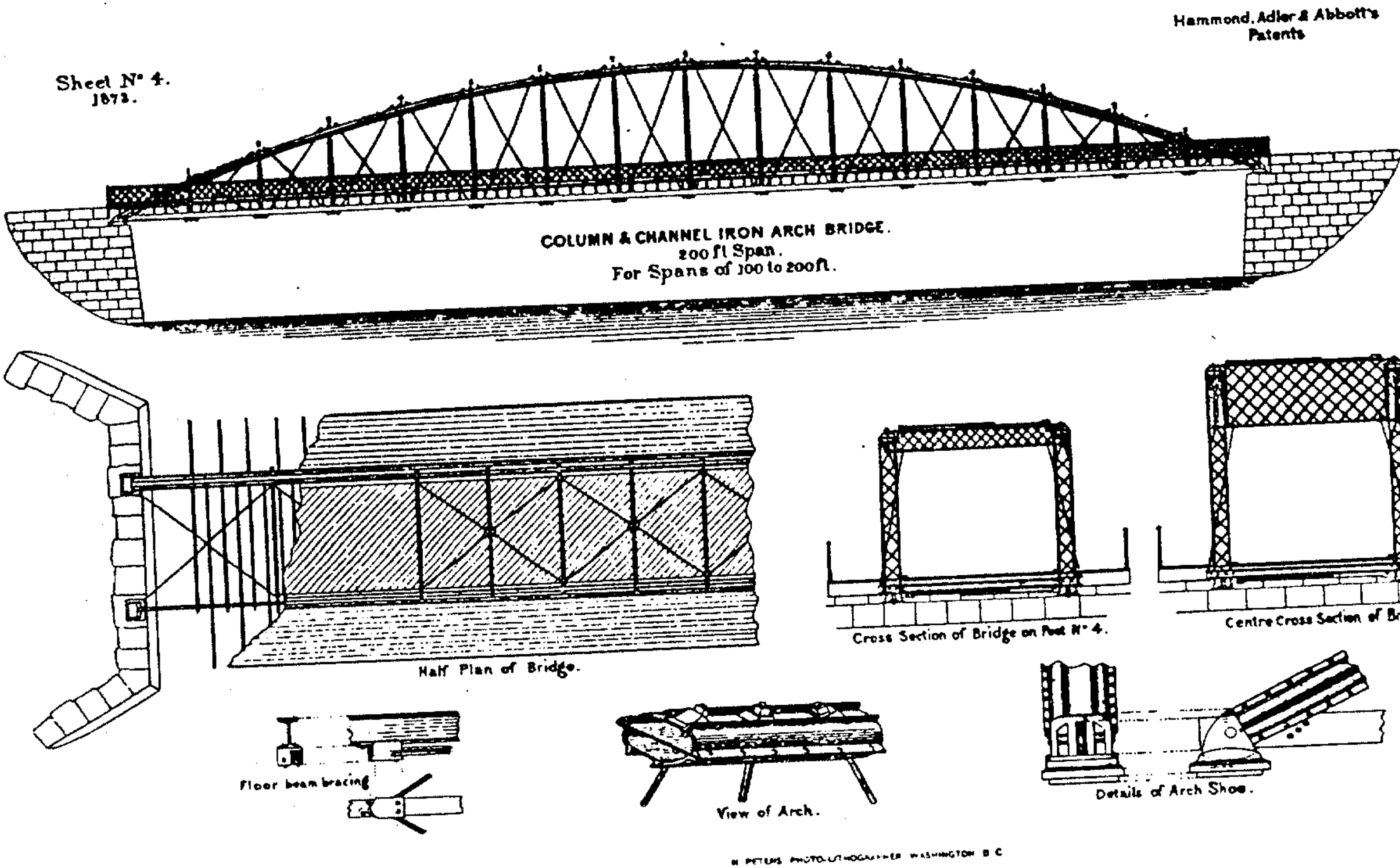
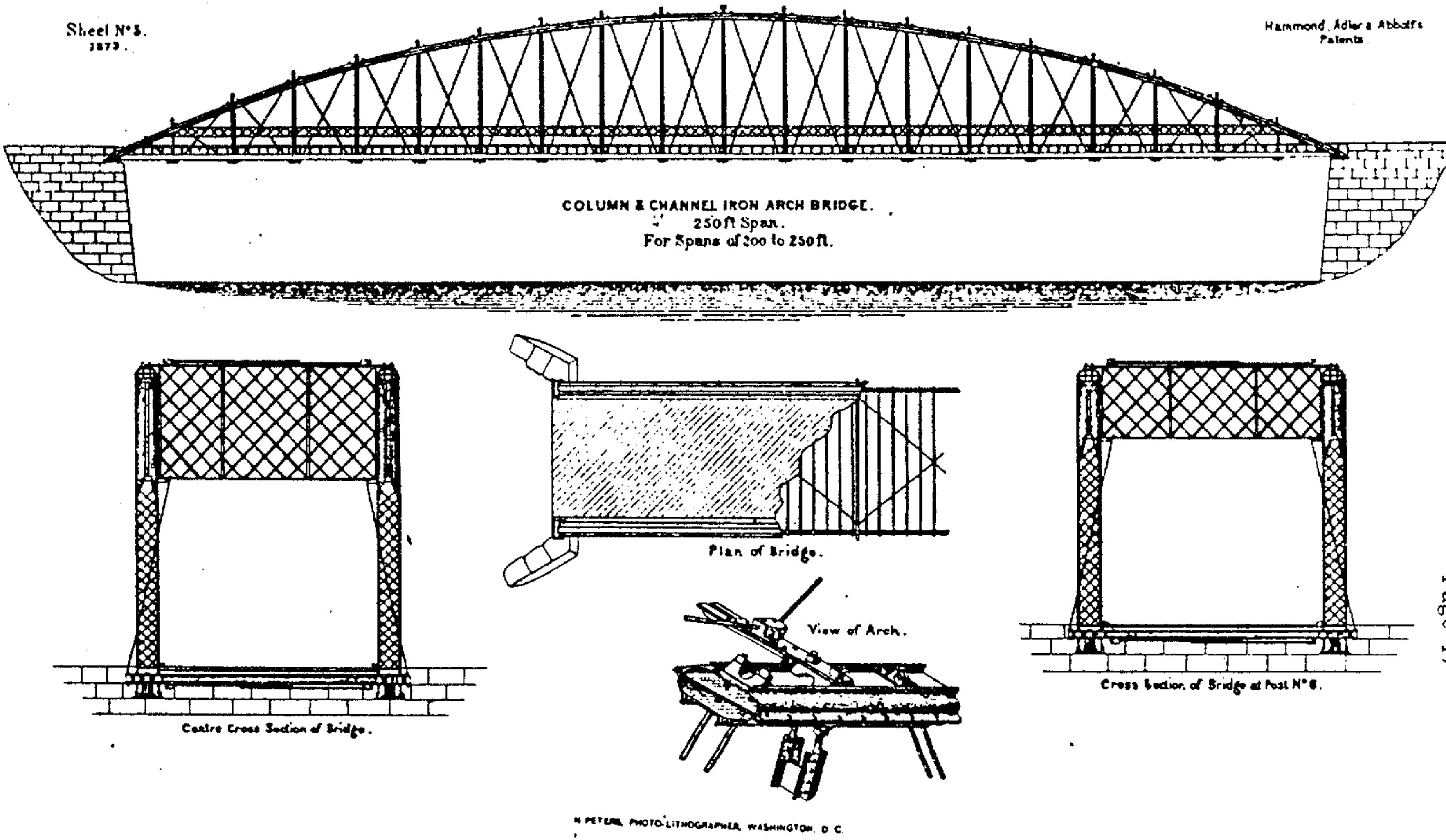
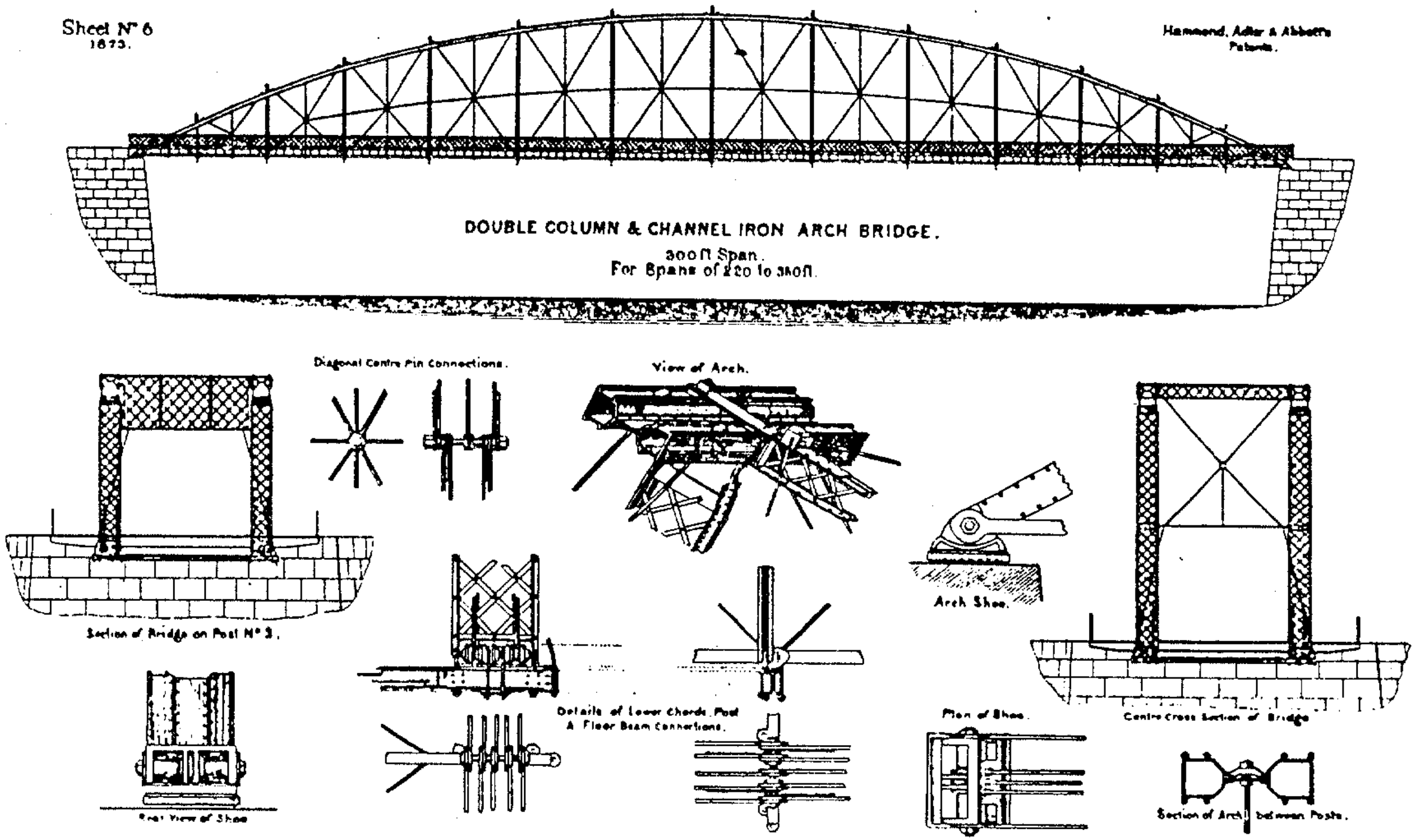

Sheet No 4.
1873.
Hammond, Adler & Abbott's
Patents
COLUMN & CHANNEL IRON ARCH BRIDGE.
200 ft Span.
For Spans of 100 to 200ft.
Half Plan of Bridge.
Cross Section of Bridge on Post No 4.
Centre Cross Section of Bridge.
Floor beam bracing
View of Arch.
Details of Arch Shoe.
N. PETERS PHOTO-LITHOGRAPHER WASHINGTON D C

Figure 6


Sheet No 5.
1873.
Hammond, Adler & Abbott's
Patents.
COLUMN & CHANNEL IRON ARCH BRIDGE.
250 ft Span.
For Spans of 200 to 250 ft.
Plan of Bridge.
View of Arch.
Centre Cross Section of Bridge.
Cross Section of Bridge at Post No 6.
N PETERS, PHOTO-LITHOGRAPHER, WASHINGTON, D.C.


Sheet N° 6
1873.
Hammond, Adler & Abbott's
Patents.
DOUBLE COLUMN & CHANNEL IRON ARCH BRIDGE.
300 ft Span.
For Spans of 220 to 360 ft.
Diagonal Centre Pin Connections.
View of Arch.
Section of Bridge on Post N° 3.
Arch Shoe.
Details of Lower Chords, Post
& Floor Beam Connections.
Plan of Shoe.
Centre Cross Section of Bridge
Section of Arch between Posts.

WROUGHT IRON BRIDGE CO.

Iron and Steel

BRIDGES, VIADUCTS,

GIRDERS, TURN-TABLES,

Power-Houses, Electric-Light Stations,

STEEL AND IRON ROOFS.

COMMUNICATE WITH NEAREST OFFICE.

Canton, OHIO. **136 Liberty Street,** NEW YORK CITY. **1309 Monadnock Building,** CHICAGO, ILL.

New York Life Building, Kansas City, Mo.

As the Wrought Iron Bridge Company marketed these bowstring configurations extensively around the country, other bridge fabricators were also erecting and patenting their own bowstrings bridges. Squire Whipple patented his "Iron Bowstring Bridge" in 1841 (Patent No. 2064; 24 April 1841).[48] Like most successful inventions, his bridge design spawned numerous other variations, most of which deviated from his patent just enough to avoid infringement. Over the next thirty-five years, dozens of patents were issued for improvements on Whipple's design. These included such configurations as the triangular wrought iron tubular arch patented by Cincinnati inventor Thomas Moseley (Patent No. 16,572; 3 February 1857), the square wrought iron tubular arch patented by Cleveland inventor Zenas King (Patent No. 33,384; 3 February 1861) and the parallel plate arch patented by Wilmington, Ohio, inventors Johnathan and Zimbi Wall (Patent No. 148,010; 24 February 1874).[49] In his 1874 Book of Designs, Hammond gives a brief history of the early development of iron bridge fabrication:

> The building of highway iron bridges, begun by Whipple in 1846-'50, was carried on to a limited extent until 1861. Moseley [of Moseley and Company, Cincinnati] patented a wrought-iron arch bridge in 1857, and erected several spans in 1858 to 1861; King and Frees [later King Iron Bridge and Manufacturing Company, Cleveland] began building wrought-iron bridges in 1859-'60, and Hammond and Reeves [later, the Wrought Iron Bridge Company, Canton] began building wrought-iron bridges in 1864-66. Wrought iron bridge work for highway purposes has made rapid progress from that date to the present time, almost supplanting cast iron, as was the case

> with railway bridges, and forcing the public to concede its superiority over wood or cast iron, whenever they were brought into comparison. Starting from New York in 1845, iron highway bridges have grown in public favor until they are now found in almost every State in the Union, and even those States, such as Maine, New Hampshire and Michigan, whose facilities for building wooden bridges are unrivalled, are abandoning wooden for iron bridges.[50]

Most of the bowstring patent activity centered in New York - Whipple's home state - and Ohio, among whose inventors David Hammond was the most active. In the 1860s and 1870s, he and his colleagues at Wrought Iron produced more than sixteen different bridge designs.[51] During this period, they were by far the most prolific bridge innovators in Ohio, and on a national level were surpassed by only the venerable Captain James Eads in bridge patents issued. Whipple may have invented the bowstring, but no other inventor in 19th Century America did as much as David Hammond to perfect the form.

Hammond's first bridge, patented with Reeves in 1864 (Patent No. 43,202; 21 June 1864), featured an inverted U-shaped arch made up of three flat iron bars clamped together at regular intervals.[52] His second patent, issued in 1866 (Patent No. 56,043; 3 July 1866), showed an arch composed of two I-beams - termed double-T irons - covered by an iron plate. "The nature of my invention," he stated in the specification, "consists in the novel construction of a wrought-iron arch of double-T iron and novel clamping pieces, and also in the combination of a covering piece which excludes moisture, and also serves to prevent any lateral movement of the arch... whereby I obtain an arch of great strength and simplicity with a comparatively small weight and cost of construction."[53] The accompanying drawing shows a pony configuration, with suspenders improbably oriented perpendicular to the arch, rather than vertical. The arch was evidently intended only for short-span roadway applications. Hammond continued to refine his arch designs and filed revised specifications and drawings for both with the patent office in 1867 and 1869.[54]

In 1869, he patented yet another arch design (Patent No. 86,538; 2 February 1869), presented as an improvement to his 1864 patent, "said improvements consisting, first, in the use of channel or L-iron for the arch-pieces, in the place of the plate-iron there shown, by the use of which we are enabled to firmly rivet the arch-pieces and covering piece together, instead of depending wholly on the clamping-bolts, clamping-pieces and suspension-rods and bracing for the binding of said pieces together, as is the case in our previous patent, whereby we greatly increase the resistance of our arch to any horizontal deflection, and thus greatly increase its strength."[55]

With each patent application, Hammond refined his bowstring design. His fourth bridge patent, issued in April 1870, delineated for the first time the tubular arch configuration which would later become the trademark for the Wrought Iron Bridge Company. In this patent (Patent No. 102,392; 26 April 1870), Hammond described three Phoenix-tube wrought iron arches roughly equivalent to his later column arch, column and channel arch and column, plate and channel arch. The result, Hammond asserted in the specification was "a tubular arch of great strength and stiffness, which admits of a very economical distribution and proportion of material to any required case of construction."[56]

Clumsy though it looked, this was the direct predecessor to Hammond's fifth and final arch bridge patent. Issued in February 1873, this patent (Patent No. 135,802; 11 February 1873) was the basis upon which the Wrought Iron Bridge Company fabricated thousands of bowstring bridges across North America in the 1870s. The specifications described a series of bowstring arch-truss designs which used Phoenix tubes for the primary arches. Although his preceding patent specifications and accompanying illustrations were relatively brief, Hammond describes in lengthy and painstaking detail every aspect of this series of bridges. Significantly, this patent was the first to delineate an extremely long-span (up to 350 feet) bowstring through design.

One particular technological issue that Hammond and the others sought to address with their patents was the inherent lateral instability of the bowstring arch-truss. "It is well known to bridge constructors," Hammond stated in 1873, "that the principal defect in the practical working of bow-string girders as heretofore constructed, especially in long spans, has been their want of stiffness to resist the action of a rolling load."[57] Live loads placed on the bridge deck are transferred to the floor beams and then to the verticals, which are suspended from the primary arches. The tensile force of the suspenders tends twist the compression arches sideways, especially if the load is applied with any eccentricity from the neutral axis of the arch. This is countered in most arch patents by the installation of overhead struts to tie the two primary arches together and make a rigid structure. The arch's curved configuration, however, makes placement of these struts impossible in the outer panels, necessitating an extremely rigid arch construction to overcome the twisting action. For all but his short-span arches, Hammond specified tubular arches that were stronger laterally than they were axially. For his longest spans (between 220 and 360 feet), he actually doubled the tubes and connected them with a continuous solid web to create an immensely rigid frame.[58]

The counties and municipalities of Iowa were among the best customers of the Wrought Iron Bridge Company. The period of extensive rural road and bridge construction in the state during the 1870s coincided with Wrought Iron's ascendance in the industry, combining to create a booming market for the bridge company's regional sales representatives. Winneshiek County's almost exclusive relationship with Wrought Iron may have been an extreme case. (Other bridge companies such as the King Iron Bridge Company of Cleveland also marketed heavily in eastern Iowa during this period, and bridge superstructure contracts were let primarily on the basis of cost, not company.) Nevertheless, the

Wrought Iron Bridge Company was extremely active in the region. In 1874, Wrought Iron listed several of its recently erected bowstrings in Iowa. Winneshiek County bridges are indicated by an asterisk:

Sidney	85-foot span;	12-foot roadway	Column Arch
Shenandoah	42-foot span;	12-foot roadway	"
Hall's Mill	90-foot span;	16-foot roadway	"
Columbus Junction	95-foot span;	16-foot roadway	"
Watson's Ford	75-foot span;	12-foot roadway	"
*Fort Atkinson	84-foot span;	16-foot roadway	"
Ridgeway	70-foot span;	16-foot roadway	"
Red Oak Junction	100-foot span;	18-foot roadway	"
Orford	113-foot span;	14-foot roadway	Column and Channel Arch
Chelsea	140-foot span;	14-foot roadway	"
Quasketon	125-foot span;	16-foot roadway	"
Fairbanks	145-foot span;	16-foot roadway	"
Nora Springs	120,125-foot spans;	16-foot roadway	"
Independence	(2)145-foot spans;	18-foot roadway	"
Cedar Falls	(3)115-foot spans;	16-foot roadway	"
Keosauqua	(4)151-foot spans;	16-foot roadway	"
Cedar Rapids	(6)120-foot spans;	18-foot roadway	"
Watsell's Ford	140-foot span;	16-foot roadway	"
*Decorah (Gillece)	104-foot span;	16-foot roadway	"
Nora Springs	115-foot span;	16-foot roadway	"
Springville	153-foot span;	16-foot roadway	"
Palo	85-foot span;	16-foot roadway	"
Marshalltown	100-foot span;	16-foot roadway	"
*Decorah (Plymouth)	130-foot span;	15-foot roadway	"
*Decorah (Drake)	130-foot span;	17-foot roadway	" [59]

In 1877, the company built a six-span iron bridge, with a total length of 960 feet, at Columbus Junction in Louisa County. This was Iowa's longest highway bridge to date.[60] As Winneshiek and other counties continued to purchase arch and truss superstructures from Wrought Iron, the aggregate length of the firm's spans in the state accumulated. By 1885, David Hammond's company had installed 21,600 feet of bridges in Iowa: almost equaling the total output by the company across the country in its first nine years. Only New York, Ohio, Indiana and Illinois had purchased more structures from Wrought Iron.[61]

That year, David Hammond's bridges could be found in 41 of the state's 99 counties.[62] Although these were distributed in all areas of Iowa except the northwest corner, Wrought Iron's strength clearly lay in the eastern part of the state. Over 70% of the counties in which Wrought Iron's bridges had been installed were east of Des Moines, and almost 60% were east of Waterloo. One particular stronghold for the company was the northeast tier of counties.

Winneshiek, Howard, Chickasaw, Floyd, Mitchell, Fayette, Clayton, Buchanon, Delaware and Dubuque Counties had all bought bridge superstructures from Wrought Iron in the 1870s and 80s. Allamakee County remained the only holdout.[63] Iowa's list of Wrought Iron's bridges in 1885 included the following structures (Winneshiek County bridges indicated by an asterisk):

Shell Rock, Butler County	(3) 85-foot spans;	17-foot roadway
Mitchell, Mitchell County	(2)128-foot spans;	16-foot roadway
Osage, Mitchell County	(2)240-foot spans;	16-foot roadway
*Decorah, Winneshiek County (Twin)	(2)116-foot spans;	16-foot roadway
Black Hawk County	(3)150-foot spans;	16-foot roadway
Center Grove, Dubuque County	96-foot span;	16-foot roadway
Waterloo, Black Hawk County	155-foot span;	16-foot roadway
*Decorah, Winneshiek County (Bluffton)	116-foot span;	16-foot roadway
Webster City, Hamilton County	150-foot span;	16-foot roadway
Palo, Linn County	(2)165-foot spans;	16-foot roadway
Paris, Linn County	160-foot span;	16-foot roadway
Ivanhoe, Linn County	(2)130-foot spans;	16-foot roadway
Stone City, Jones County	115, 117-foot spans;	16-foot roadway
Rochester, Cedar County	(4)151-foot spans;	16-foot roadway
Pine Mills, Muscatine County	96-foot span;	16-foot roadway
Jackson, Adair County	84-foot span;	16-foot roadway
Rockford, Floyd County	260-foot span;	16-foot roadway
Fremont County	102-foot span;	14-foot roadway[64]

Despite its frequent expansion of facilities, Wrought Iron's tremendous workload in the mid-1870s caused the company occasionally to fall behind on its fabrication schedule. This in turn created problems for the customers as contracted bridges waited for completion. Winneshiek County experienced such delivery problems with the Wrought Iron Bridge Company in 1875. "Owing to the failure of the Iron Bridge Co's. in fulfilling their contracts on time," George Winship complained in January 1876, "We are compelled to postpone grading and finishing our abutment walls until spring on a number of bridges. In fact there are but two of our Iron bridges erected in 1875 that is [sic] entirely completed."[65]