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Papers 69–72
On Technology

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Publications of the United States National Museum

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In these series, the Museum publishes original articles and monographs dealing with the collections and work of its constituent museums—The Museum of Natural History and the Museum of History and Technology—setting forth newly acquired facts in the fields of anthropology, biology, history, geology, and technology. Copies of each publication are distributed to libraries, to cultural and scientific organizations, and to specialists and others interested in the different subjects.

The *Proceedings*, begun in 1878, are intended for the publication, in separate form, of shorter papers from the Museum of Natural History. These are gathered in volumes, octavo in size, with the publication date of each paper recorded in the table of contents of the volume.

In the *Bulletin* series, the first of which was issued in 1875, appear longer, separate publications consisting of monographs (occasionally in several parts) and volumes in which are collected works on related subjects. *Bulletins* are either octavo or quarto in size, depending on the needs of the presentation. Since 1902 papers relating to the botanical collections of the Museum of Natural History have been published in the *Bulletin* series under the heading *Contributions from the United States National Herbarium*, and since 1959, in *Bulletins* titled "Contributions from the Museum of History and Technology," have been gathered shorter papers relating to the collections and research of that Museum.

The present collection of Contributions, Papers 69–72, comprises *Bulletin* 252. Each of these papers has been previously published in separate form. The year of publication is shown on the last page of each paper.

Frank A. Taylor
Director, United States National Museum

Papers

Papers 69–72

On Technology

United States National Museum Bulletin 252

Contributions from

The Museum of History and Technology:

Paper 69

JAMES MILLHOLLAND AND EARLY RAILROAD ENGINEERING

John H. White

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Figure 1.—James Millholland (1812–1875), pioneer railroad master mechanic. As this signature shows, he spelled his name variously. (From *World's Railways*, p. 45.)

John H. White

James Millholland And Early Railroad Engineering

From the apprentice on the "Tom Thumb" to the master machinist of the Philadelphia and Reading Railroad, the career of James Millholland spanned nearly a half century in the early development of the American railroad. One of the great mechanics of the 19th century, he is remembered not only for his highly original innovations, the most outstanding of which was the conversion of the wood burner to the anthracite burner, but also for his locomotives, which were plain, practical machines, highly distinctive from the ornate locomotives of the period.

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JAMES MILLHOLLAND is remembered today as one of the foremost railway master mechanics of the 19th century. He was fortunate in also having been esteemed in his lifetime for having perfected numerous railway mechanisms and, most particularly, for his work on anthracite-coal-burning locomotives. He was born on October 6, 1812, in Baltimore, Maryland, and there received a private education.[1] Gifted with an aptitude for mathematics and influenced by his father, who manufactured ship fittings, young Millholland inclined naturally toward mechanics as a life work. In 1829, at age 17, he was apprenticed to George W. Johnson, a Baltimore machinist, there gaining his first experience in working on a locomotive engine, Peter Cooper's famous *Tom Thumb*.

Cooper, in an effort to persuade the new Baltimore and Ohio Railroad to adopt steam power, had started to build this light steam locomotive in 1829. He had worked out the general arrangement and assembled a

[1] Railroad Gazette (August 28, 1875), vol. 7, p. 362. (Obituary notice.)

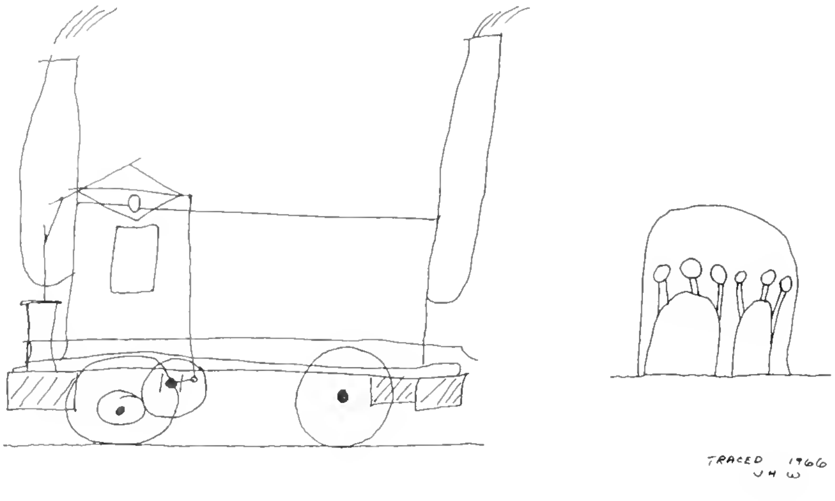

Figure 2.—TRACING OF MILLHOLLAND'S sketch of the *George W. Johnson*, built in 1831 for the Baltimore and Ohio Railroad.

boiler and cylinder, but, busy with other affairs in New York, he asked George Johnson to complete the machine. Thus young Millholland had a direct hand in the building of the *Tom Thumb*—completed in 1830—and shared in a pioneer effort to introduce mechanical transport in America. Considering Millholland's later involvement with anthracite coal, it was somewhat prophetic that the *Tom Thumb* was designed to burn this fuel.

Millholland next assisted his employer in building a second locomotive, named the *George W. Johnson* in honor of its designer. It was completed in 1831 and won $1000 as second prize in a contest sponsored by the Baltimore and Ohio Railroad. The *Johnson* employed a curious assemblage of design features, including walking beams, geared transmission, and a divided firebox, but the machine was not a success and was retired after brief service.

The only authentic illustration of the *Johnson* is a little sketch made by Millholland in 1873 (fig. 2). The several illustrations which were subsequently published are based on this sketch.[2]

Millholland left his native city for New York in 1832 and entered the employment of the Allaire Works, a firm famous for marine engines. With the exception of a brief sojourn in Mobile, Alabama, where he worked on a sawmill during 1836, he stayed with Allaire until 1837. In his 25th year, like most other young mechanics, he was obscure and unknown, but, unlike most, Millholland was about to embark on a distinguished career.

His great opportunity came in 1838 when he returned to railroad work in Baltimore and was appointed master mechanic of the Baltimore and Susquehanna Railroad. The prestige of his new position possibly was more apparent than real, for the Baltimore and Susquehanna was a threadbare little company whose serpentine road wound a distance of 58 miles between Baltimore, Maryland, and York, Pennsylvania. It had 80 bridges, too many curves, and too few locomotives or cars. The novice master mechanic soon was put to the test of keeping in working order the road's 10 engines, which could not have been more poorly adapted to the needs of the company. Three were British made. The rest were built on patterns similar to the British engines by the Locks and Canals machine shop of Lowell, Massachusetts. All of the engines proved too light for steep grades and too rigid to negotiate the road's sharp curves. Fortunately, the company had a fairly well-equipped repair terminal in Baltimore, adjacent to the present Mt. Royal Station, known as the Bolton shops. Millholland there began remodeling the road's motive power as fast as funds permitted.

One of the most extensive locomotive remodelings Millholland executed for the Baltimore and Susquehanna was the reconstruction of the *Herald*,[3] the first engine on the line. It was a Sampson-class

[2] Reconstructions of the *Johnson* appeared in *Railway Age* (July 7, 1893), vol. 18, p. 531, and in J. G. PANGBORN, *World's Railways* (New York: Winchell Printing Co., 1894), p. 52.

[3] The facts presented on the *Herald* are from the Baltimore and Susquehanna Railroad's annual report for 1854, and in *Railroad Advocate* (May 26, 1855), vol. 2, p. 2.

Figure 3.—The *Baltimore* (1837) built by Locks and Canals and reconstructed by Millholland in later years with a leading truck and cast-iron crank axle. (From Thomas Norrell.)

0-4-0, a standard design of its English maker, Robert Stephenson & Co. The engine had proved entirely unsatisfactory for the Baltimore and Susquehanna, and had been rebuilt in October 1832—only a few months after its delivery—as a 4-2-0 wheel arrangement. By 1846, however, it was found too small for further service and accordingly was taken into the company shops for major remodeling. Millholland fashioned a powerful 13-ton 0-6-0, nearly twice the weight of the original *Herald*, from which only the boiler was used. Other major features of this remodeling were a gear drive for power and low speed, and a lateral-motion arrangement for each driving axle to permit navigation of sharp curves. The engine was intended for the movement of trains through city streets between the railroad's various Baltimore terminals. The *Herald* was still in service in 1857, but was sold for scrap two years later.

Millholland's gifts as mechanic and innovator first received notice in a report by the *American Railroad Journal* for November 6, 1845, on the use of cast iron for making crank axles. Inside-connected engines, which were then popular, were fitted with wrought-iron crank axles. Although wrought iron was the strongest material available, it was not only costly, but its variable quality and fibrous character made it unreliable for use in crank axles. These broke frequently, creating a costly hazard and serious accidents.

Millholland's insistence upon cast-iron crank axles seemed preposterous because the metal was brittle and unable to withstand great impact stresses. He eschewed ordinary cast iron, however, and insisted on the best cold-blast Maryland iron—the kind used for cannons and car wheels—which had a tensile strength of about 30,000 pounds per square inch.

In its report, the *American Railroad Journal* noted that Millholland's cast-iron crank axle had been used successfully since June 15, 1845. The engine in question, unidentified except that it was built in Lowell, was unquestionably one of the light Locks and Canals locomotives mentioned above. It was described as having a leading truck, a single pair of driving wheels, and a pair of trailing wheels, making it a 4-2-2. The crank axle weighed 1150 pounds before turning, which compared favorably to a similar unmachined wrought-iron axle weighing 1164 pounds. It had been cast by J. Watchman of Baltimore at a cost of $69, whereas the wrought-iron axle cost $291 before machining. Not only was the cast-iron crank cheaper, but it was equally as strong as the wrought-iron one. The *American Railroad Journal* continued its report:

> A few evenings since, the engine with the cast iron crank axle, was, together with its tender, thrown entirely off the track, by a large hog getting under the wheels behind the cow-catcher—no damage having been done to any part of the engine, it was thus shown that the cast axle can bear without injury the sudden and violent strain to which it was subjected by this accident, as well as the wrought iron crank axle. There is therefore good reason for believing that this improvement, which will so materially reduce the cost of replacing a broken crank axle, may with perfect safety be introduced into general use.

The Baltimore and Susquehanna subsequently fitted its other inside-connected engines with cast-iron crank axles. No evidence exists that other roads followed suit, but the Baltimore road seemed well pleased with Millholland's innovation. In a letter to Robert Stephenson and Co., dated March 8, 1850, Robert S. Hollins, secretary of the Baltimore and Susquehanna, stated: "Our preference is the *Cranked Axle Locomotive*, but repeated breaking of the axle; Every Locomotive having broken one or more, we were induced to try *cast iron*, and after an experience of 5 years, we have adopted them entirely, never yet having broken a *Cast Iron Crank Axle*." [4] This statement, made two years after Millholland had left the Baltimore and Susquehanna, testifies that the cast-iron crank axle was a success on its own merit and not merely because it was a "pet" of the presiding master mechanic. According to Millholland's eldest son, James A. Millholland, one of these crank axles was sent to his father years later, presumably in the 1860's, after the engine had been scrapped.[5] This trophy laid around the Philadelphia and Reading shops for some years, only to be junked during a clean up.

In addition to rebuilding existing machines and developing the cast-iron crank axle, Millholland built two new locomotives at the Bolton shops. The first of these identical machines, the *General Taylor*, was completed in October 1846; the other, the *Wm. H. Watson*, in March 1847.[6] Intended for freight service, these machines were large for the times, each weighing

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[4] *Engineer* (May 29, 1914), vol. 117, p. 601.

[5] Letters dated May 11 and 18, 1888, from James A. Millholland to J. E. Watkins, a curator at the Smithsonian Institution.

[6] *American Railroad Journal* (December 19, 1846), vol. 19, p. 811, states that the *Watson* "was lately built." The March 1847 date is given in the Baltimore and Susquehanna's annual report for 1849.

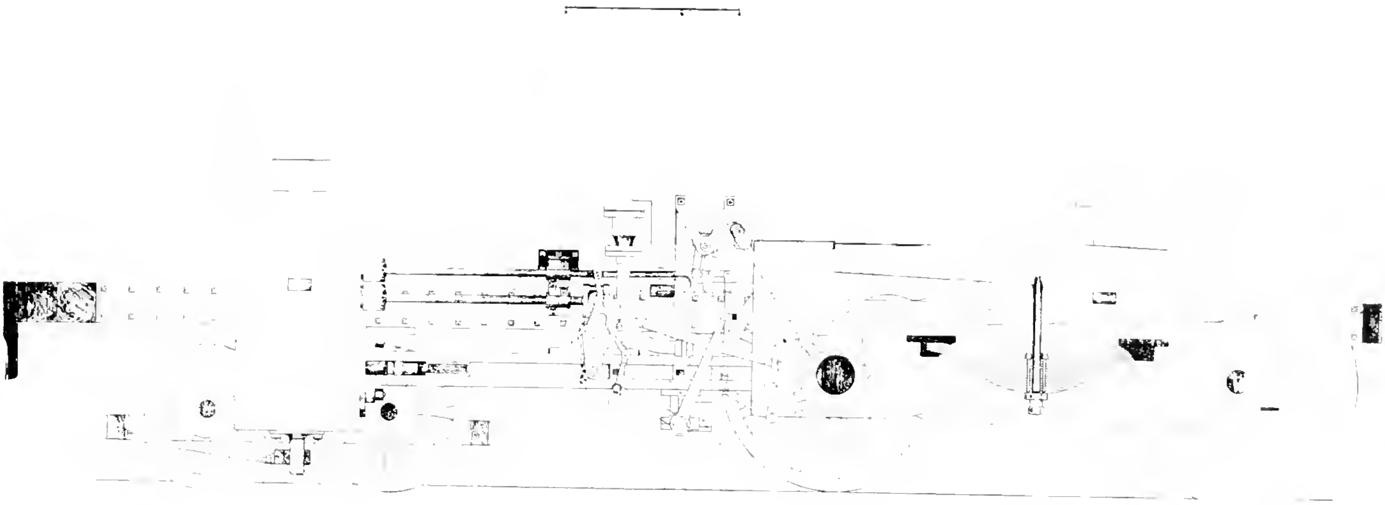

Figure 4.—THE FREIGHT LOCOMOTIVE *Wm. H. Watson* WAS DESIGNED AND BUILT BY JAMES MILLHOLLAND at the Bolton shops of the Baltimore and Susquehanna Railroad in 1847. It was fitted with a cast-iron crank axle. (From an original drawing in the Smithsonian Institution.)

26½ tons. They had 18- x 18-inch cylinders, 48-inch-diameter driving wheels, and were inside-connected, fitted with massive cast-iron crank axles each of which measured about 8½ inches in diameter (fig. 4). A separate cutoff was employed, both valves being driven by a single eccentric. Both the *Taylor* and the *Watson* appear to have been wood burners, since they had small, deep fireboxes.

Millholland's energies were not confined to locomotive work, for he also contributed improvements to car and bridge design. His advocacy of railway-car springs made of wood paralleled his cast-iron cranks as a bold substitution of a cheaper, unconventional material for heavy service. Millholland secured a patent (No. 3,276) for wooden springs on September 23, 1843, and their use by the Baltimore and Susquehanna was reported the following year:

> The freight cars in general use on this road are superior, in many respects, to any we have seen, that is, they carry a greater amount of freight in proportion to the weight of the car, than on most roads. They have six wheels, the body is made light but strong, resting on *wood* springs, consisting of two pieces each 2 inches by 6, and 13 feet long, of white ash plank. Other companies will do well to examine them and either adopt, or improve upon them.[7]

[7] *American Railroad Journal* (October 1844), vol. 17, p. 292.

The Baltimore and Susquehanna annual report for 1843 notes the construction of 29 six-wheel freight cars "on the plan invented by James Millholland." Such cars cost $450, weighed 8500 pounds, and had a capacity of 12,000 to 14,000 pounds. The same report mentioned the construction of a "similar" car for passenger service, apparently meaning one with six wheels and on wooden springs. The 1844 annual report shows the construction of 37 more six-wheel cars, 24 of which were built in the company shops, the remainder by private contractor. By 1850 the road reported 159 six-wheel freight cars of various styles. Six-wheel cars were in themselves unusual. The only other United States railroad known to have them was the Baltimore and Ohio, which had over 200 six-wheel iron coal hoppers. Six-wheel tenders, however, were common in the 1840s and 1850s, and six-wheel cars were used extensively by foreign roads. In addition, wood springs were used later on thousands of four-wheel coal "jimmies" of the Reading, Lehigh Valley, Central of New Jersey, and other roads. Some of these continued in regular service through the 1890's. Millholland received $1000 for the use of his wood spring and other patents while he was in the service of the Reading.[8]

[8] The Minutes of the Board of Managers, preserved by the Reading Company, Philadelphia, Pennsylvania. Cited hereafter as Minute Books.

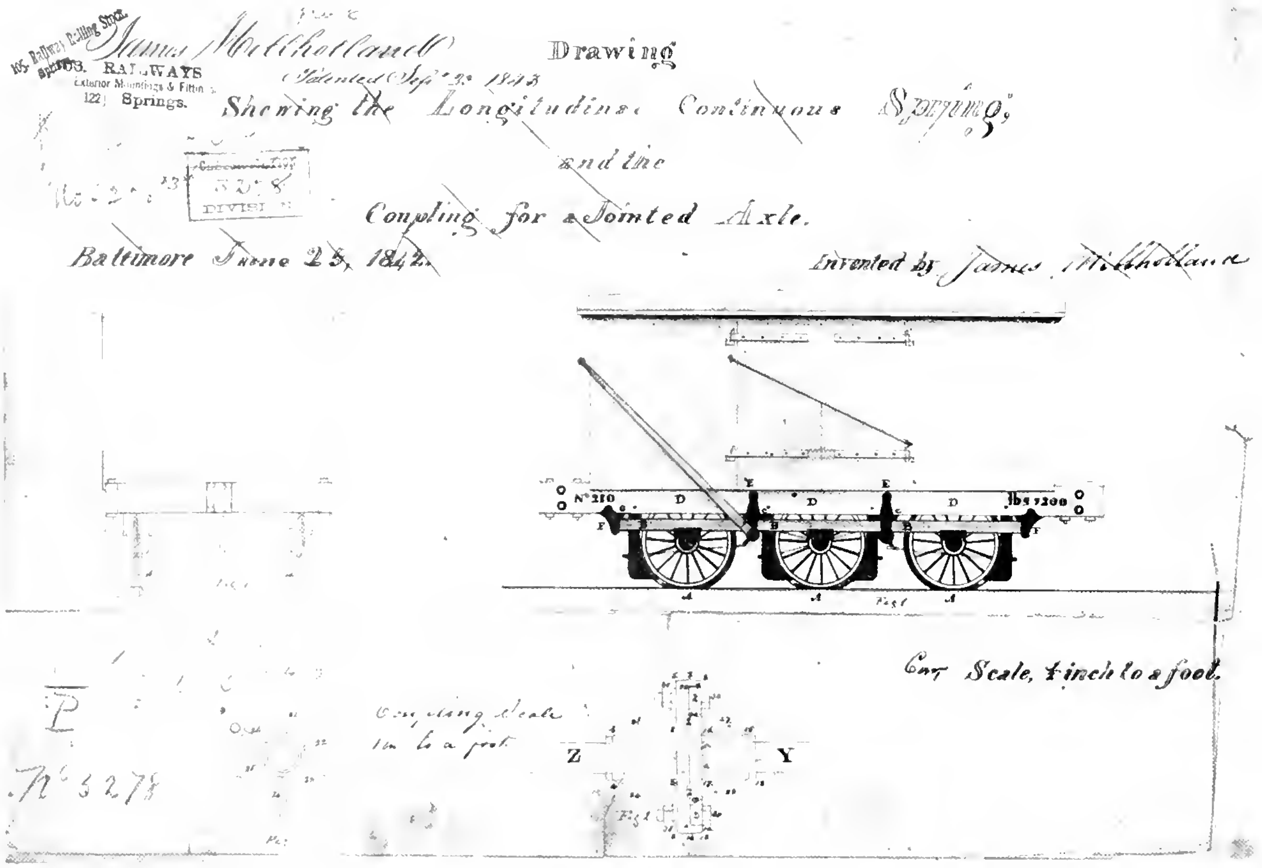

Figure 5.—The 1843 wooden-car-spring patent showing a six-wheel freight car. The drawing is so well detailed and proportioned that it appears to be based on an actual car design, undoubtedly representing the type of car used on the Baltimore and Susquehanna Railroad. (From U.S. National Archives.)

Before leaving the subject of wooden springs, one canard about their origin should be put to rest. E. J. Rauch, an employee of the Philadelphia and Reading Railroad under Millholland, alleged in October 1893 that his former supervisor had not, in fact, invented the wooden spring.[9] Rauch claimed that about 1850 a hapless workman in the Philadelphia and Reading shops had patented the idea but, unable to effect its adoption, sold the patent to Millholland for a pittance. The allegation is without basis, since Millholland, as we have seen, had patented the spring several years before joining the Reading. Such stories are commonly attributed to famous mechanics by lesser mechanics, possibly in the hope of reducing great men to common level.

In addition to the six-wheel freight cars, Millholland built two passenger cars for the Baltimore and Susquehanna in 1846 and 1847. Little is known about these cars except that one was splendidly fitted with crimson cut-velvet curtains and a body painted dark claret.[10]

Aside from his contributions to railroad equipment, Millholland's single most important engineering enterprise was the plate-girder bridge. This single-

[9] Rauch repeated his allegation in a biographical sketch of Millholland, published in *Railway and Locomotive Engineering* (June 1903), vol. 16, p. 276. It was a friendly recollection but repeated in part the wood-spring story. This and several other errors suggest that Rauch may have drafted his article mainly from memory.

[10] *American Railroad Journal* (July 17, 1847), vol. 20, p. 449.

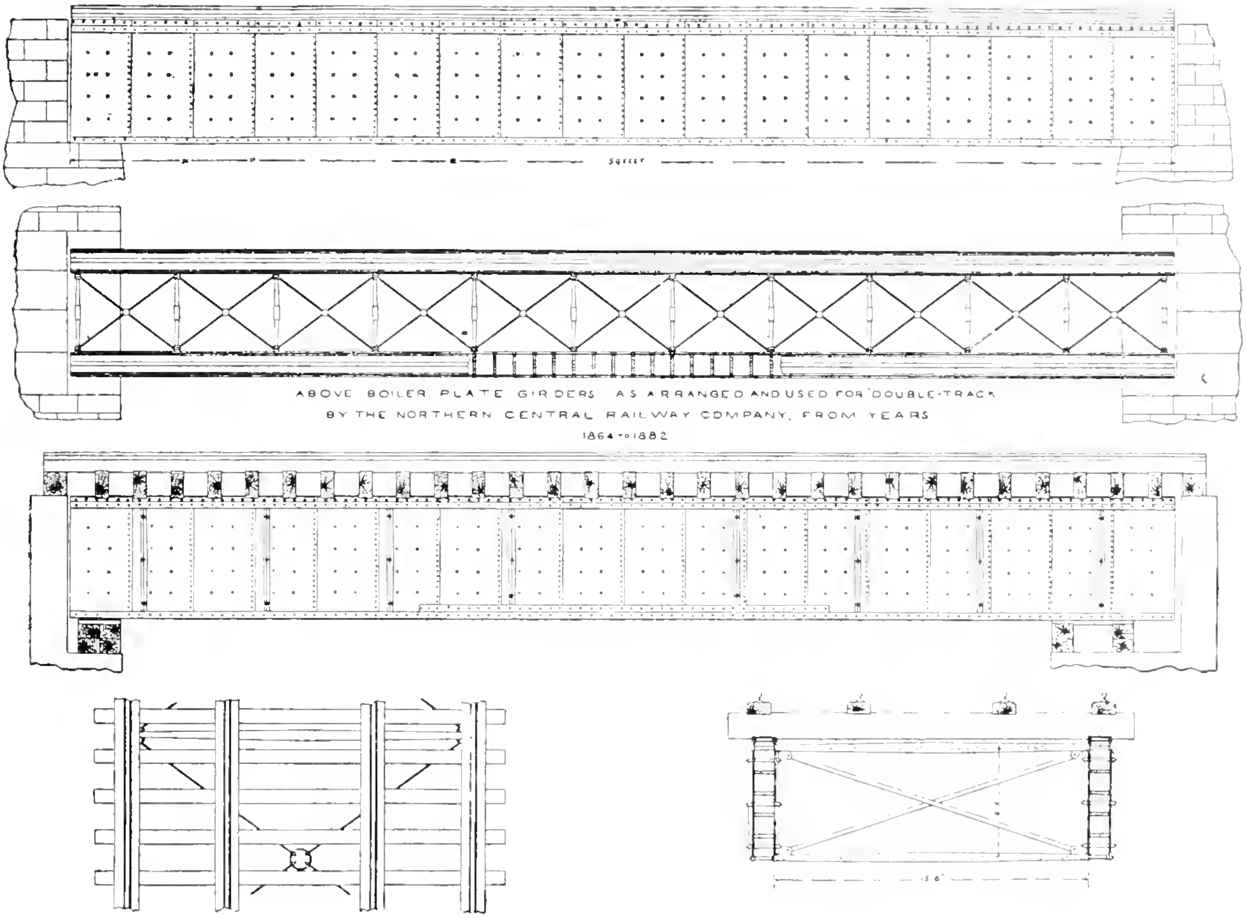

Figure 6.—The plate-girder bridge completed in 1847 by Millholland for the Baltimore and Susquehanna Railroad. (From *Engineering News*, October 20, 1888.)

track bridge was fabricated from 1/4-inch boiler iron. It was 6 feet deep by 54 feet long, weighing 14 tons. Built at the Bolton shops in the winter of 1846 and placed in service 19 miles north of Baltimore in April 1847, it was the first such bridge in America—and probably the first of its kind in the world. In 1864 it was rebuilt for a double track and continued in use for another 18 years [11] (see Appendix I).

In 1848 Millholland was in the prime of life, a recognized mechanic and respected engineer whose reputation had outgrown his position with the struggling Baltimore and Susquehanna. Accordingly, when in August 1848 the Philadelphia and Reading Railroad offered him the position of master machinist, he readily accepted.[12]

The Philadelphia and Reading was one of the best engineered railroads in the 19th-century United States. In contrast to most American roads, it was very well constructed, with generous curves, light grades, and heavy T rails. Its capitalized cost came to $180,000 per mile, more than six times that of most other American railroads. Running from Phila-

[11] *Engineering News* (October 20, 1888), vol. 20, p. 305, contains a drawing and reproduces a letter (May 1, 1849) from Millholland to Herman Haupt describing the bridge. *See also* C. W. Condit, *American Building Art: the 19th Century* (New York: Oxford University Press, 1960), pp. 106–107 and 301.

[12] Millholland gives the date of his employment with the Reading in a letter (November 9, 1860) to C. T. Parry of the Baldwin Locomotive Works. This letter is preserved by the Historical Society of Pennsylvania.

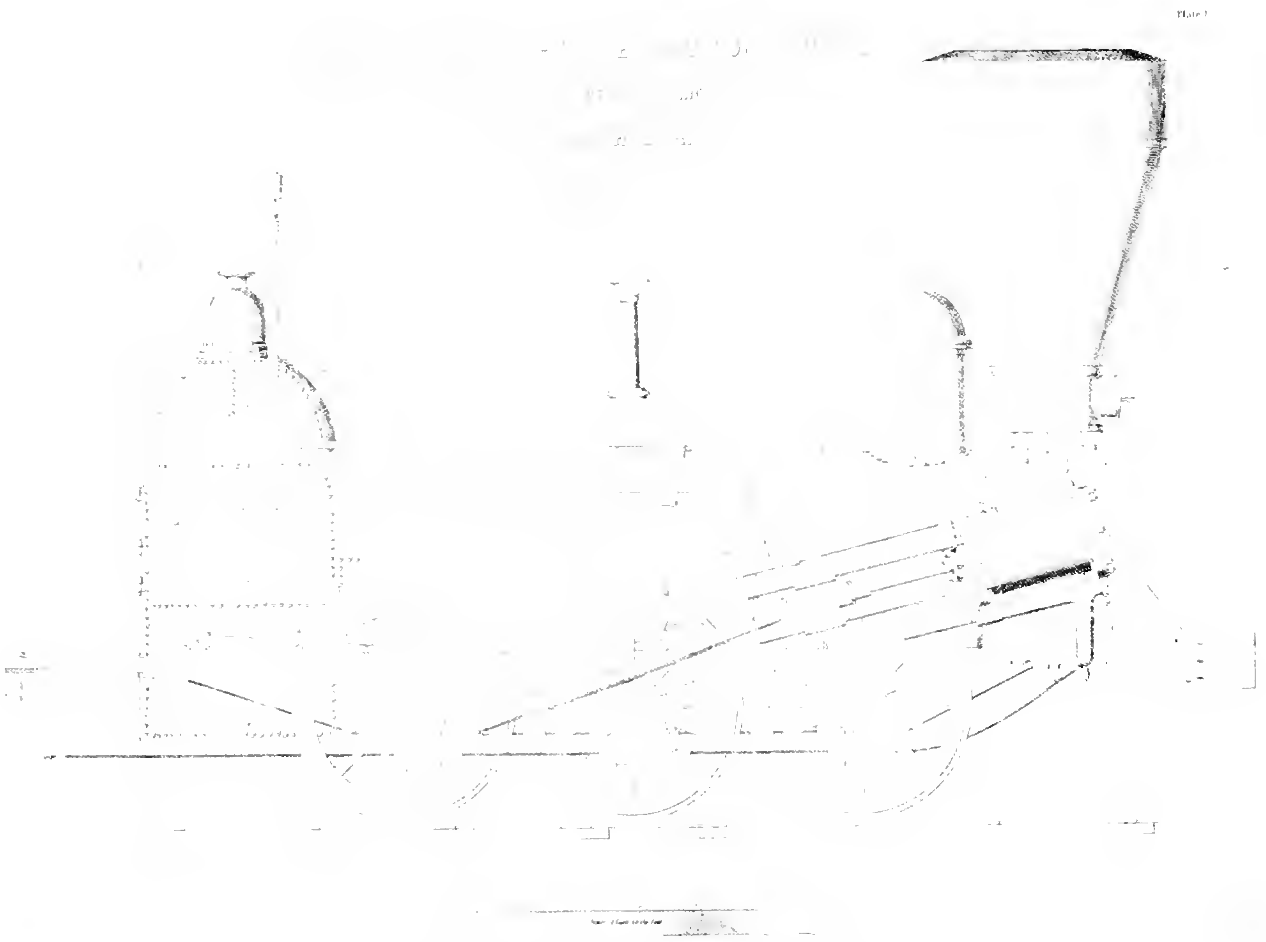

Figure 7.—THE *Philadelphia*, BUILT IN 1844 BY NORRIS BROTHERS for the Philadelphia and Reading Railroad. Shown as rebuilt 1848–1849 by Millholland. (From *American Locomotives*, 1849, by E. Reuter.)

delphia to the coal fields near Pottsville, the line was built as an anthracite carrier. In 1835, three years before it began to operate, the board of managers had decided it was "of the utmost importance that the locomotive engines to be constructed for this company be built with a view to the exclusive use of anthracite as fuel . . . ."[13] This plan was frustrated when experience showed that anthracite was all but impossible to burn in locomotives, and the line had to resort to wood.

Millholland's major problem was not simply to build a coal-burning locomotive—difficult enough in itself—but one that would burn anthracite. This dense, slow-burning fuel—sometimes called "stone coal"—was singularly inappropriate for use in the narrow and deep wood-burning fireboxes of the early 19th century. Anthracite burned best when spread thin over a large area. Wood, on the other hand, being highly combustible, was stacked thick and deep for best results in firing.

Because the Reading's primary traffic was anthracite, Millholland was expected to develop a practical plan for using this fuel in the company's locomotives. He labored ten years with the problem, and in the end, despite many failures, he achieved a remarkably successful design. Boiler and firebox improvement was Millholland's chief occupation, and he pioneered in this field. Most American motive-power officials of the period were content with wood burners, con-

[13] Minute Books, April 13, 1835.

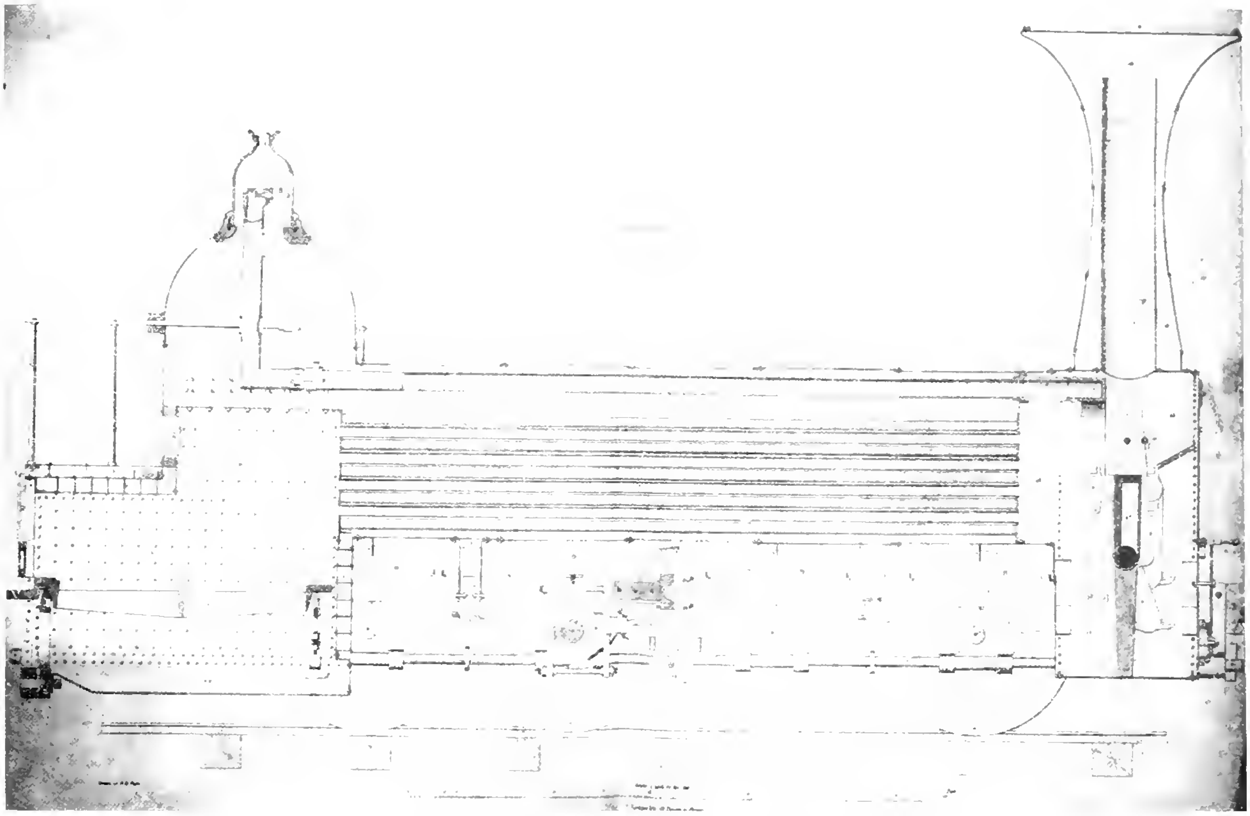

Figure 8.—The *Delaware* as built in 1846 by Ross Winans for the Philadelphia and Reading Railroad. It was not a successful anthracite burner and was rebuilt in 1850 by Millholland with a central-combustion-chamber boiler. (From *American Locomotives*, 1849, by E. Reuter.)

centrating their energies on the other basic problem of perfecting flexible running gears for the uneven and cheaply built tracks that characterized most railroads in the United States.

Millholland's initial attempt to produce an anthracite burner was on a Norris six-wheel connected engine, the *Philadelphia*.[14] Built in 1844, this wood burner had exploded shortly after being placed in service and already had been rebuilt once in the company's shops before Millholland's remodeling of 1848 or 1849. He made an effort to increase the grate area, but the machine was a dismal failure as a coal burner. The rebuilt *Philadelphia*, however, is noteworthy for its double-poppet throttle valve. (A valve of this type is shown at *n* in fig. 11.) This is one of the earliest recorded uses of the poppet throttle, which after 1870 became the standard throttle valve for all American locomotives. Millholland was probably the first in America to make large-scale use of this style of throttle.

Not long after the *Philadelphia's* rebuilding, Millholland attempted to modify the *Warrior*, an 0-8-0 flexible-beam freight engine built by Baldwin in 1846, for anthracite. The firebox was extended behind the rear driving wheels and widened to about 66 inches.[15] This was an enormous increase in grate

[14] Angus Sinclair, *Development of the Locomotive Engine* (New York: Sinclair Publishing Co., 1907), p. 288. Sinclair mistakenly states that the *Philadelphia* was a new locomotive and the first engine to be constructed by Millholland for the Reading.

[15] Rauch makes this statement in his article on Millholland in *Railway and Locomotive Engineering* (June 1903), vol. 16, p. 276. The Philadelphia and Reading annual report for 1858, however, lists the *Warrior* as rebuilt in 1858.

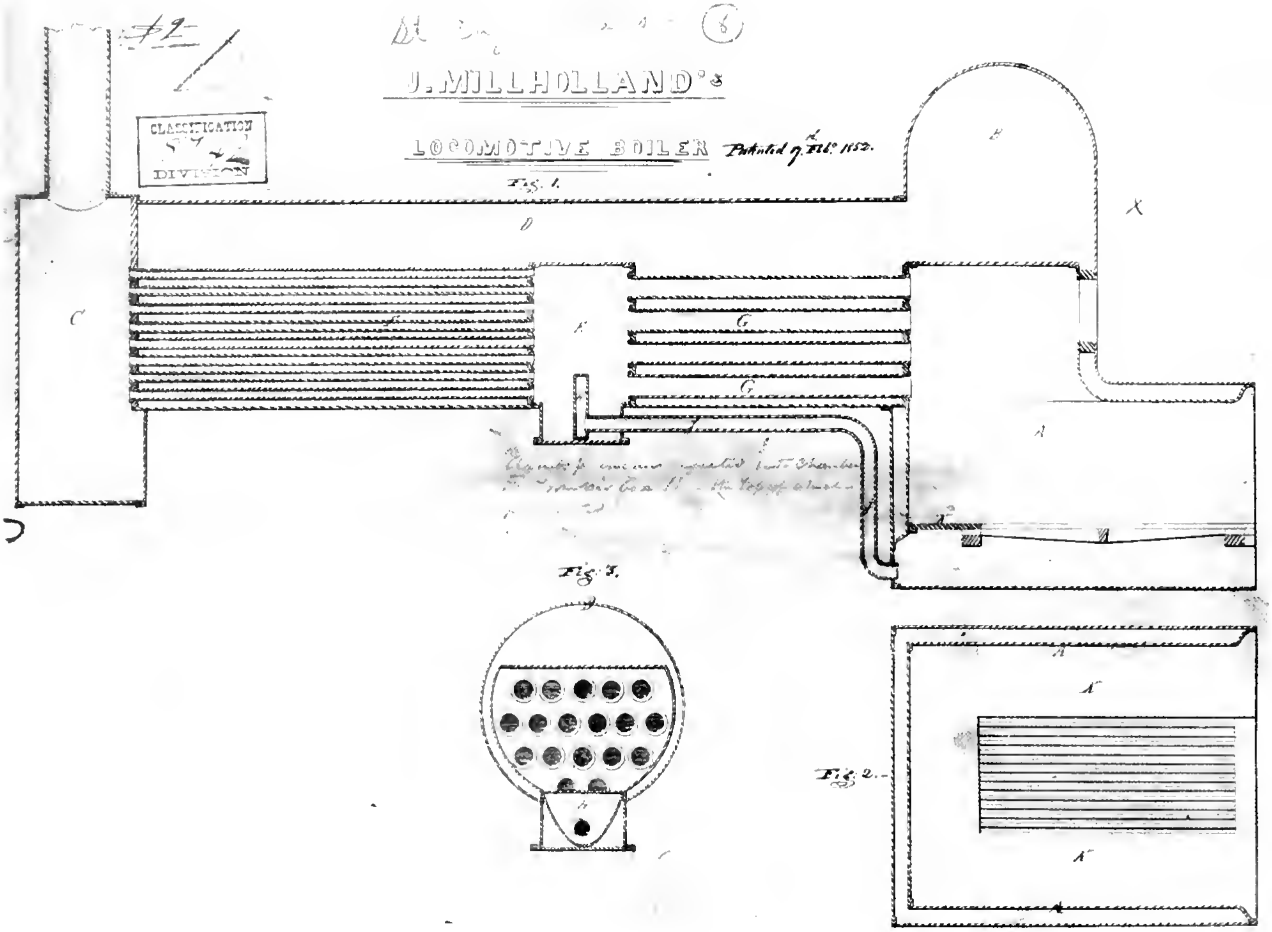

Figure 9. MILLHOLLAND'S PATENTED CENTRAL-COMBUSTION-CHAMBER BOILER with dead-plate fire grate. Note the similarity of this design to the general arrangement, excepting the patented features, of the *Delaware* boiler. (From U.S. National Archives.)

area, since the firebox in regular wood burners of the period was rarely more than 34 inches wide. Encouraged by the *Warrior's* performance, Millholland turned his hand to rebuilding more of the Reading's old engines.

Two years before Millholland joined the Reading, several coal-burning, eight-wheel engines had been purchased from Ross Winans, who had developed a successful coal burner some years earlier. Winans' engines were built to burn soft coal, a fuel far more readily combustible than anthracite. These engines did not succeed on the Reading, however, although Millholland recognized that their builder was correct in providing a large grate area. He rebuilt one of the machines, the *Delaware*, in December 1850, and two sister engines soon thereafter.

Some months later the *Scientific American*, commenting on the rebuilt engines, said that they were so successful that the Reading planned to rebuild all of their power on Millholland's new plan.[16] But the statement was premature, for the plan was, in fact, very defective. Whatever success was obtained with these engines should be credited to the method of firing and not to the firebox plan. Millholland had instructed the fireman to put only 7 inches of coal on the grates in place of the 18 inches previously used. (In the end, most locomotive authorities agreed that skillful firing was more important to successful coal burning than were the many complex boiler and

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[16] *Scientific American* (October 18, 1851), vol. 6, p. 35.

firebox designs advocated by various inventors and engineers, Millholland among them.) The *Scientific American* went on to state that cast-iron plates 9 inches wide on each side and 16 inches wide at the rear were placed on the grates in an effort to protect the firebox sheets from the direct action of the fire, and thus only the center portion of the grates was open. This arrangement may have preserved the firebox, but it hampered combustion by restricting the free passage of air to the underside of the fire.

A second and more important modification was the placement of the combustion chamber near the center of the boiler waist. The central combustion chamber was connected to the firebox by a number of large (3- or 4-inch-diameter) tubes; the gases were carried to the smoke box by regular small (2-inch-diameter) tubes. Ideally, all of the combustible gases *not* burned in the firebox would burn in the central chamber before passing to the smoke box. In practice, however, the temperature of the gases, already too cold for combustion, was further reduced in the central chamber, where they were mixed with more cold air. Millholland was overly concerned, as were many other engineers, with the quantity of air required for good combustion.

On February 17, 1852, Millholland secured a patent (No. 8,742) for the combination of dead-plate grates and central combustion chamber.[17] The

[17] The central combustion chamber had been patented in England six years earlier. See John Dewrance, British Patent, October 1846. The central-combustion-chamber boiler was revived in 1884 by A. J. Stevens, master mechanic of the Central Pacific Railroad. Seemingly unaware that this was an old idea, he reported in the January 1885 *National Car Builder* (page 2) on the successful tests of a locomotive boiler identical in plan to Millholland's. The incident aptly illustrates the many instances of inventors independently duplicating the work of others in attempting to solve identical problems.

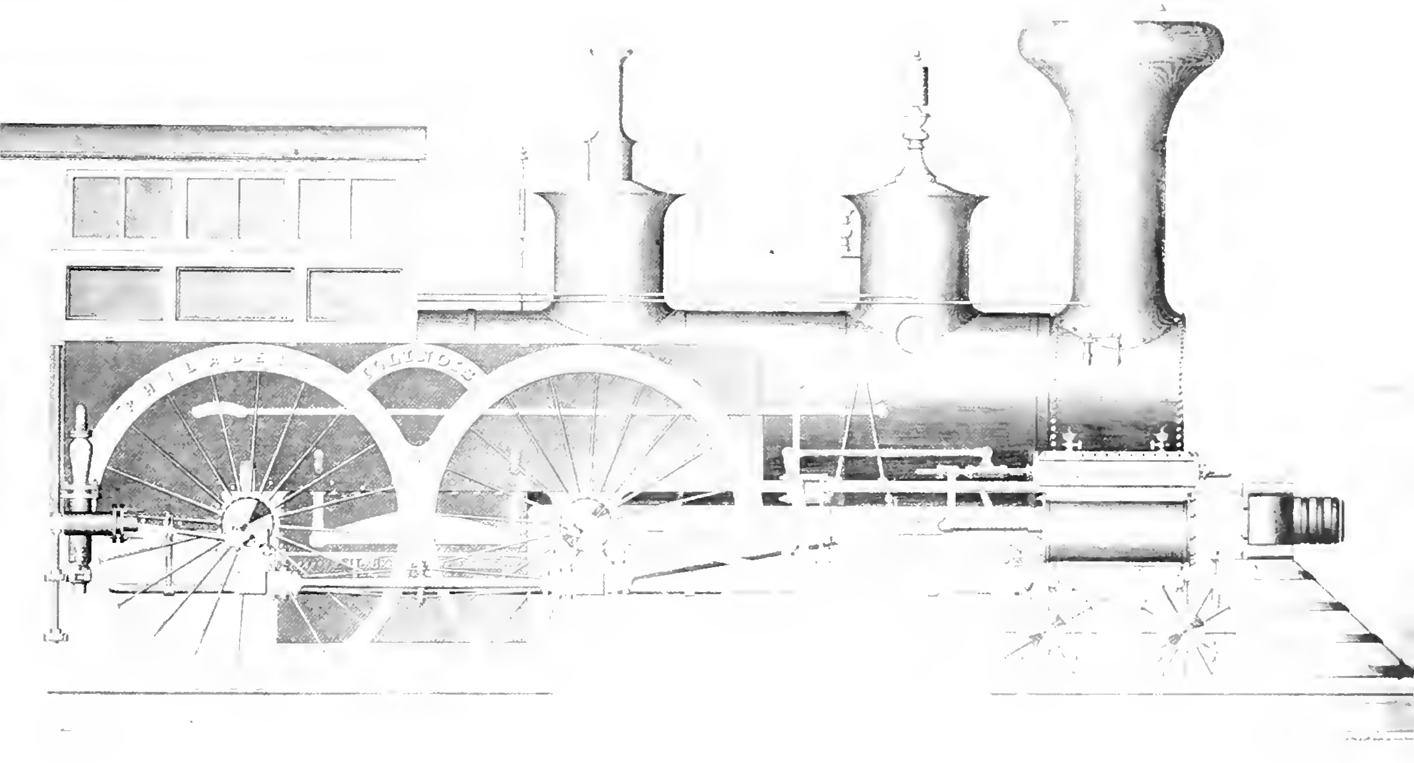

Figure 10.—The anthracite-burning express locomotive *Illinois*, built in 1852 by Millholland at the Reading Shops. The engine was not a success, but, after remodeling, continued in service until 1869. (Smithsonian photo 26807–G.)

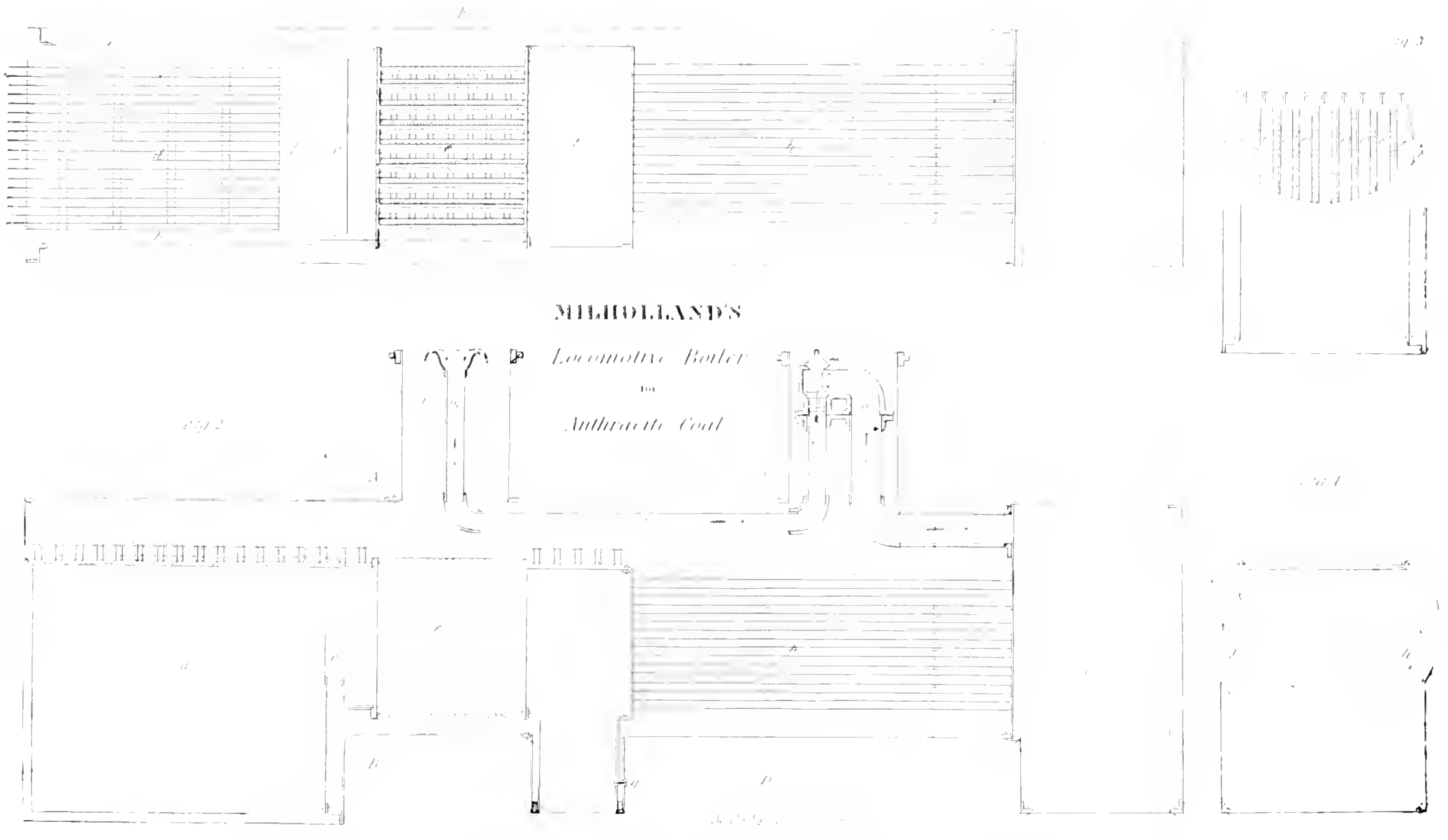

Figure 11.—Boiler of the *Illinois* varied somewhat from the 1852 patent. Note the water tables *e* and the double poppet-throttle valve *n*. (From *Journal of the Franklin Institute*, April 1853.)

TRIAL OF PASSENGER ENGINE "ILLINOIS"
Between Pottsville and Philadelphia

Trip	*Time*	*Cars*	*Wt. of train and engine, tons*	*Miles*	*Fuel*		*Water*		*Lbs. water per lbs. coal*	*Lbs. coal per mile*	*Date of Test*
					Wood, cu. ft.	*Coal, lbs.*	*Gals.*	*Lbs.*			
Pottsv. to Phila...	4.09	5	118	98	45.0	4,325	3,200.0	26,656	6.16	45.50	Nov. 19, 1852
Phila. to Pottsv...	4.28	5	118	98	45.0	5,000	3,700.0	30,821	6.16	52.60	Nov. 18, 1852
Pottsv. to Phila...	4.35	5 to Reading 6 to Phila.	127	93	31.2	4,175	3,196.0	26,622	6.37	44.88	July 15, 1856
Phila. to Pottsv...	4.27	6	132	93	29.1	5,079	3,600.6	29,992	5.90	54.59	July 7, 1856
Pottsv. to Phila. .	4.35	5 to Reading 7 to Phila.	135	93	30.1	3,896	2,909.7	24,237	6.21	41.88	July 17, 1856
Phila. to Pottsv...	4.27	6 to Reading 5 to Pottsv.	127	93	29.2	4,308	3,339.0	27,813	6.45	46.32	July 4, 1856

general arrangement of this combination is shown by the patent drawing (fig. 9). Of the design's many failings, complexity and high cost were the chief defects. It was difficult enough to keep boiler tubes tight in a conventional boiler with two tube sheets; Millholland's had four. The boiler was weakened also by the large hole required for the central combustion chamber. Because of smaller surface area and greater wall thickness, the large tubes connecting the firebox and the chamber were less effective than the small tubes in transferring heat. The combustion chamber impeded the draft. The dead plates restricted free burning of coal to only the open center part of the grates. Despite these defects, Millholland followed this design for the next three years.

After the Winans engines, the next locomotive of record to be rebuilt with the patented boiler was the *Allegheny*. Originally an eight-wheel freight locomotive constructed by Baldwin in 1848, the Philadelphia and Reading annual report for 1851 notes that it was rebuilt with Millholland's "improvements" in November 1851. Other old engines were similarly reconstructed.

The next step, obviously, was to build a new locomotive with the patented boiler. Accordingly, Millholland completed the *Illinois* in May 1852 at the Reading shops. Aside from their boilers, the *Illinois* and its sister the *Michigan* were notable for several other mechanical peculiarities. Among these were 7-foot-diameter *wrought*-iron driving wheels, outside valve gear, truss connecting rods, and an unusually long cylinder stroke of 30 inches. In appearance these locomotives were distinctive, if not beautiful, and they were certainly unlike any product of commercial builders.

In addition to the large lithograph of the *Illinois* (fig. 10)—issued at the time of its construction in an apparent attempt to advertise Millholland's patent—a detailed drawing of the boiler was reproduced in the *Journal of the Franklin Institute* (fig. 11).[18] This drawing shows the development of Millholland's ideas up to the time when the boiler patent drawing was prepared (February 1852). The patent drawing shows a dome boiler with an extended firebox identical to that used by Winans in 1846. The Franklin Institute drawing shows a "straight" boiler and two steam domes, but without the dome firebox—a remarkably improved design over the patent drawing. It should be noted, however, that Millholland introduced a new horror to a design already weighed down with liabilities. A series of nine water tables (marked as *e*) were used in place of the large tubes to connect the firebox and the central combustion chamber. These provided a new source of leaks and further diminished the boiler heating surface.

The *Illinois* was built to haul express passenger trains, and we are fortunate to have a record of her service between 1852 and 1856, shown in the table on this page.[19]

[18] *Journal of the Franklin Institute* (April 1853), vol. 25, p. 271.
[19] *Railroad Gazette* (October 27, 1882), vol. 14, p. 655.

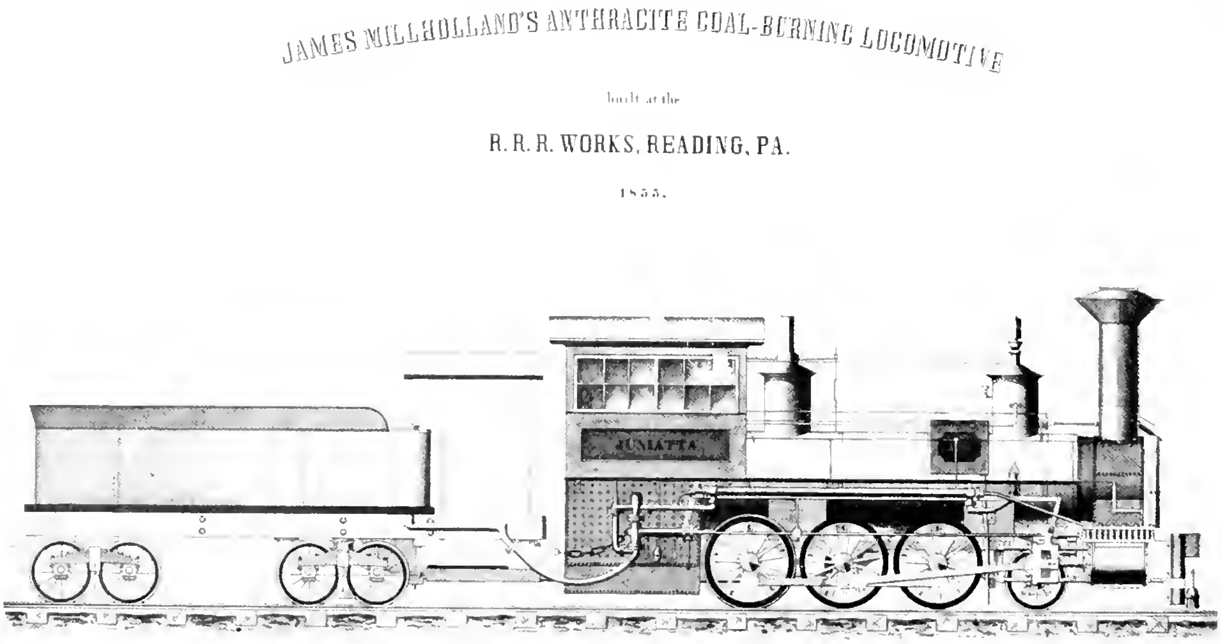

Figure 12.—The *Juniata*, a Pawnee-class freight locomotive built in 1855 at the Reading Shops. Note the misspelling of *Juniata* in this contemporary lithograph. (From the Reading Company.)

The table indicates that a large quantity of wood was burned with the coal, testifying to the inability of Millholland's boiler to make steam. The combination of wood and coal was not unusual, having been used as early as the 1830's by the Philadelphia and Columbia Railroad. The failure of Millholland's boiler was noted by the *American Railroad Journal*, June 3, 1854, which explained that because of insufficient steam the cylinders of the *Illinois* had been reduced in diameter by 2 inches.[20] After the *Illinois* and the *Michigan*, no other engines were built on this design.

Not many months after the *Illinois* entered service, Millholland brought out another new locomotive named the *Wyomissing;* it was the first of the Pawnee class and an odd-looking machine.[21] A six-wheel, connected engine intended for freight service, its boiler was built on the 1852 patent, and like the *Illinois* it was a poor steamer. Unfortunately, no pertinent information or drawings exist for the *Wyomissing*. Two well-detailed lithographs were issued in 1855, however, of a sister machine, the *Juniata* (figs. 12 and 13). One view shows the complete machine, the other a longitudinal section of the locomotive. Again, the lithographs are thought to be attempts to promote Millholland's boiler patent. The backward-sloping outer wrapper of the firebox is the most remarkable feature shown in the illustrations. This distinctive form of firebox (adopted at about the same time by Winans) became the favored design for all subsequent locomotives built by Millholland. The elimination of crown bars and the substitution of stay bolts to support the crown (or top inside sheet) of the firebox was a progressive step. Unfortunately, the designer continued to use the abortive central combustion chamber. The boiler's efficiency was aided by a feedwater heater, a steam jet (meant to improve draft when the engine was stationary), and a variable exhaust. Millholland's use of these devices—none original with him—reveals his awareness of the innovations of other skilled mechanics.

[20] The *American Railroad Journal* does not specifically name the *Illinois* but mentions an express locomotive built by Millholland. The article erroneously gives the original cylinder diameter as 15 rather than 17 inches.

[21] Although the *Wyomissing* was the first Pawnee-class locomotive, the class was named for the *Pawnee*, the second of the design.

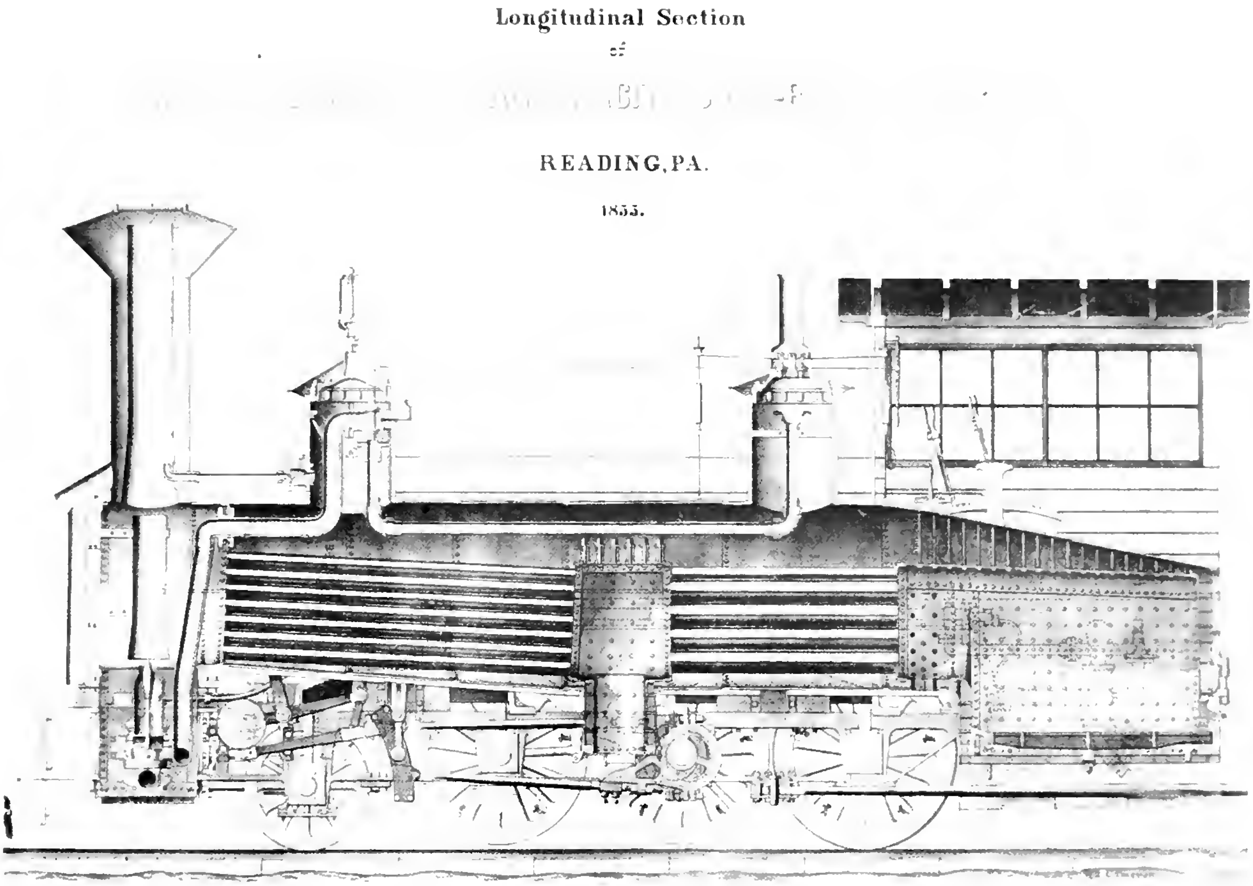

Figure 13.—A LONGITUDINAL SECTION of the *Juniata* from the companion to the lithograph shown in the preceding illustration. (From the Reading Company.)

Locomotives of the Pawnee class were more successful than the *Illinois*, and the Reading built about 15 over the next several years. The Pennsylvania Railroad and the Delaware, Lackawanna and Western Railroad, both desirous of finding good coal burners, had a small number of engines patterned after Millholland's Pawnee design. It might be added that the Pawnees were not true Mogul or 2-6-0 locomotives as is occasionally assumed. The leading wheels were attached to the main frame in the same manner as the drivers and could not swivel. Since the leading wheels were behind the cylinders, the Pawnees, like most coupled locomotives without trucks, were front-end heavy.

In January 1854 while Millholland was in the midst of developing a workable anthracite-burning locomotive, a great fire destroyed the Reading workshops. It was imperative to rebuild the shops quickly so that operations might be maintained, and Millholland never satisfied with half measures—immediately set to work on an elaborate and imaginative scheme. The fire occurred on a Sunday night; by the following Tuesday morning Millholland's draftsman had completed the preliminary drawings for a single-story, brick building measuring 482½ by 229 feet.[22] Its fireproof roof was made of corrugated sheet iron with an iron-truss frame supported by cast-iron columns.

[22] *Railroad Advocate* (February 10, 1855), vol. 1, p. 2.

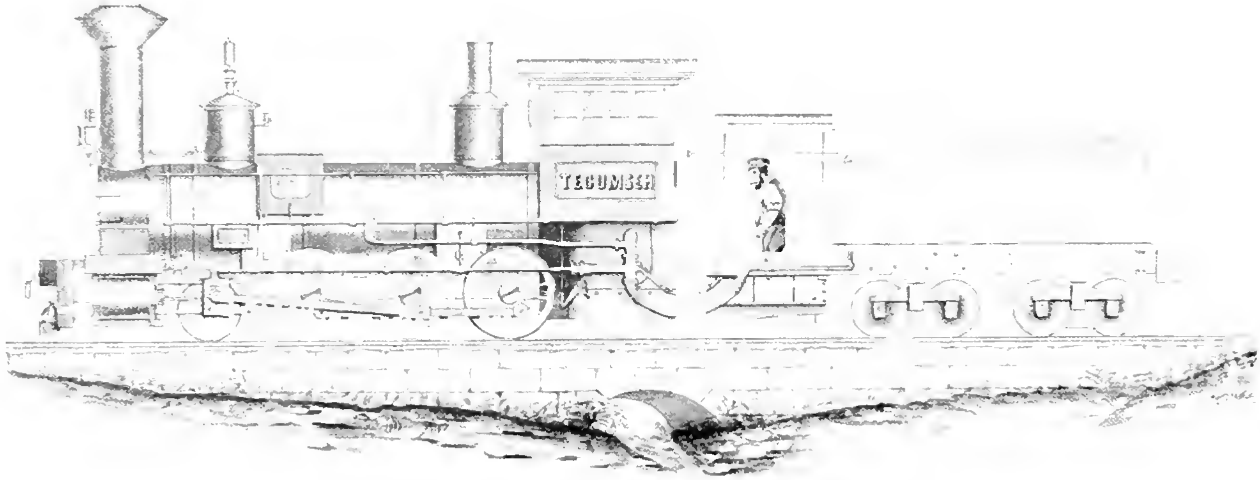

Figure 14.—The *Tecumseh* was completed in November 1853 at the Reading Shops. This Pawnee-class engine is illustrated by a contemporary watercolor rendering. (*Photo courtesy of the Atwater Kent Museum.*)

Half of this immense structure was completed within a year after the fire. It was fitted with a transfer table and stalls for 40 locomotives. A foundry, 120 by 30 feet, and a blacksmith shop, 163 by 30 feet, adjoined the main building. The car-repair, steam-hammer, and brass shops were on a separate plot not directly adjacent to the locomotive facilities. These shops were said to "surpass in extent and in convenience of arrangement, any similar works in the United States if not in the world."[23] A detailed diagram of the "grand plan" was published by the *Railroad Advocate*, January 24, 1857. While not all of Millholland's elaborate scheme was adopted, its essential elements were retained. By 1896, however, these shops were considered obsolete, and plans were underway to raise the roof of the main building to permit installation of a heavy-duty, overhead traveling crane.[24] It is uncertain if this remodeling project was undertaken, since new repair shops were constructed in 1902 on another site in Reading.

Not until Millholland had recognized the failure of his central-combustion-chamber boiler did the Reading achieve its goal of operating as a coal-burning road. Apparently Millholland dropped the patented boiler in 1855 or 1856, for the Reading's fleet of coal burners grew rapidly thereafter. In 1852 only 24 of the Reading's 103 locomotives were coal burners; by 1857 the proportion had increased to 100 coal burners in a total of 142 locomotives. A large part of this conversion must be credited to the generous purchase of Winans' Camels. Yet these ponderous, eight-wheel engines—developed primarily for soft-coal burning—were modified by Millholland because they never were entirely successful for anthracite. Even so, the increasing number of company-built locomotives indicates that Millholland was perfecting a dependable hard-coal burner. Another indication that its own shops were at last supplying a successful product came in 1855 when the Reading stopped buying from Winans.

The final and most positive proof that the patented boiler was at last abandoned is the small engraving of a Millholland locomotive boiler published in Douglas

[23] Ibid.

[24] *Locomotive Engineering* (April 1896), vol. 9, pp. 307–309, describes and illustrates the old Reading shops.

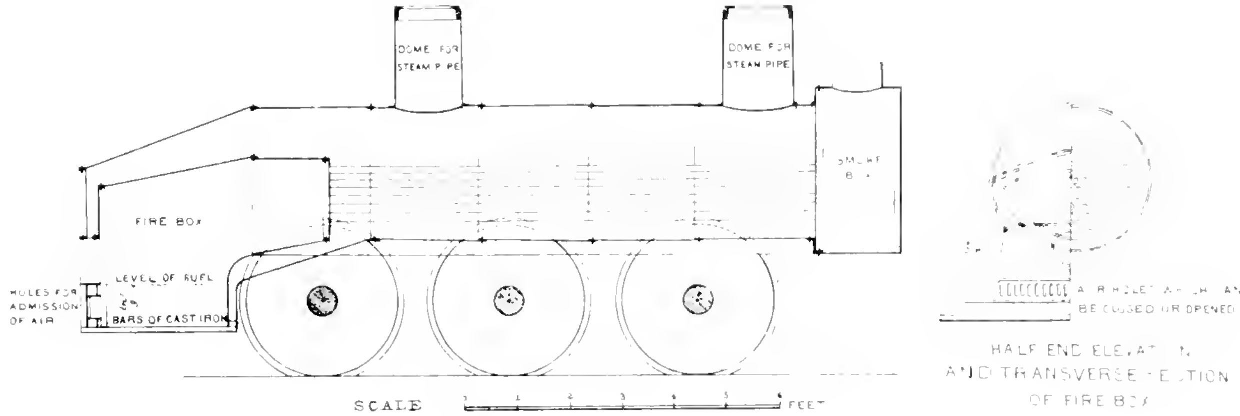

Figure 15.—This drawing of 1856–1857 indicates that Millholland had at last abandoned his impractical central-combustion-chamber boiler. Note the wide firebox shown in the end elevation. (From Galton's *Report on the Railways of the United States*, 1857).

Galton's *Report on the Railways of the United States*.[25] Galton gathered his information in the fall of 1856 for the British Parliament. It is assumed that he acquired the boiler drawing at the same time and that it was Millholland's latest design. This would establish the demise of the patent boiler at least as early as the fall of 1856, possibly in 1855. The engraving shows Millholland's design for an anthracite-burning firebox and boiler. The general plan is similar to that of the Pawnees, but the central chamber is not shown. The design is plain and straightforward, showing a simple combustion chamber at the firebox end of the boiler. An end-elevation view shows the grate to be 66 inches in width (fig. 15).

About 1858 Millholland introduced water grates, thus solving a chronic problem long associated with anthracite burners.[26] Ordinary cast-iron grate bars burned out quickly because of anthracite's intense heat and lack of insulating ash, although it was the practice to use coal of poor quality, one that would produce a large amount of ash to insulate the cast-iron grates from the direct heat of the fire. The water grate was a series of staggered iron tubes connecting the front and rear water spaces of the firebox. Circulation of water through the tubes prevented the grate's burning out. Although the idea was not original with Millholland, he introduced it in the United States and perfected its use. One advantage of the water grate, aside from its longer life, was that it permitted the use of better grades of anthracite.

By 1859 Millholland, for all practical purposes, had converted the Philadelphia and Reading to coal burning; only four wood burners remained on the property. The Reading thus became the first major railroad in America to convert from wood to coal, and it did so despite the attendant difficulties in devising a method to burn anthracite—a far greater challenge than if the native fuel was bituminous. Few other large roads converted until the early 1870's. The Reading might have converted even faster had it not been for Millholland's stubborn attachment to his patented boiler. But in all fairness, it must be agreed that his empirical rather than scientific methods solved the Reading's fuel problems years before any other major railroad achieved similar results.

Millholland paused to summarize his work in this field in a special memorandum published in the Philadelphia and Reading annual report of 1859 (see Appendix II). Previously his efforts had been alluded to sparsely in the road's printed reports,[27] and the

[25] London: Eyre & Spottiswoode, 1857.

[26] An exact date for Millholland's first use of the water grate cannot be determined. *Engineer* (February 8, 1861), vol. 11, p. 92, states that he used it for two or three years before he patented it April 16, 1861 (No. 32,076).

[27] Direct reference to Millholland in the Minute Books is also sparse; the management dealt directly with Millholland's superior, G. A. Nicolls, Superintendent of the Reading, and nearly all mechanical discussions mention only Nicolls.

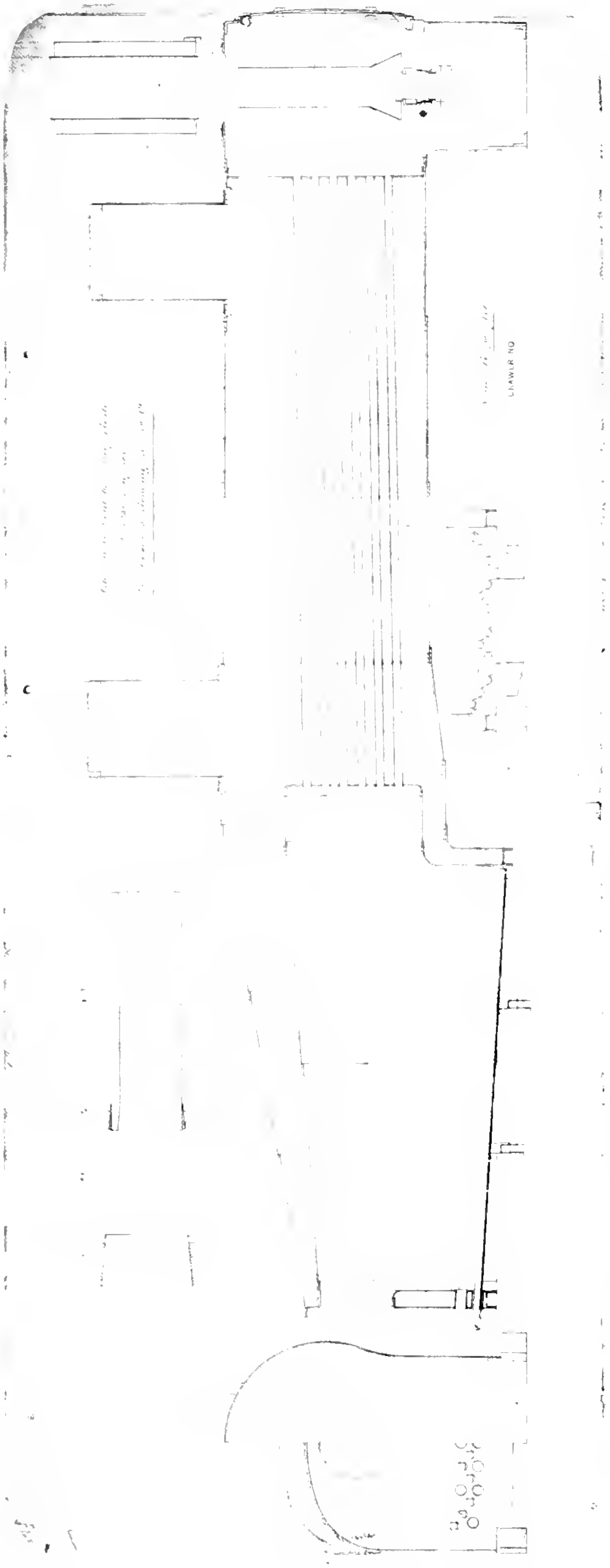

Figure 16.—An early but undated drawing of a Millholland boiler. The large-scale detail at the upper left shows the plug and method of setting the water grates. (From the Reading Company.)

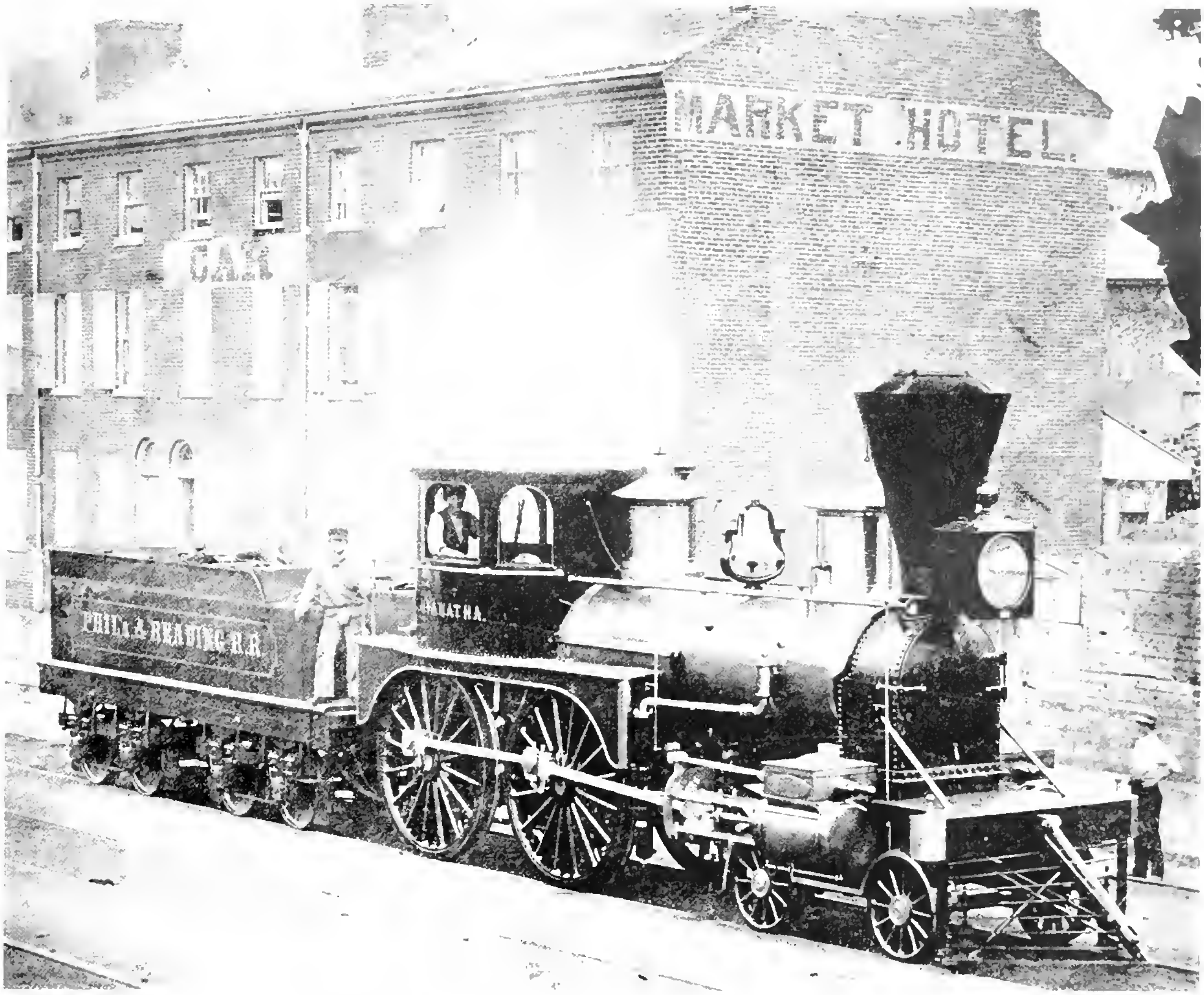

Figure 17.—This clean-line passenger locomotive, the *Hiawatha*, was built by Millholland in 1859. It was the first of a very successful class of passenger locomotives and was not retired until 1883. (Smithsonian photo 40630.)

master machinist rarely was invited to make any direct comment. Obviously, the management recognized the importance of Millholland's achievement and now wanted him to report directly to the stockholders.

In his report, Millholland briefly reviews the road's experience with the Winans engines and his progressive enlargement of the grate area from 17.68 square feet in 1847 to 24.5 square feet in 1854. Understandably, he makes no mention of the 1852 boiler patent or its dismal record. He does comment at length on the water grate and the substitution of iron for copper in fireboxes, in which his work was of equal importance. Copper had been favored for the inner wrapper of the firebox because it did not blister and break down as readily as the fibrous wrought-iron plate, but it was expensive, soft, and weak. Millholland reported that the renewal of a copper firebox cost $454 compared to $199 for iron, the difference lying in the price of materials. The copper sheets had to be made very thick, about ¾ of an inch, because they were weak and became even weaker when heated. The last and most important objection to copper was that it was a soft material and was rapidly worn away by the abrasive action of the fly ash (unburned particles of coal) as exhaust drew the smoke

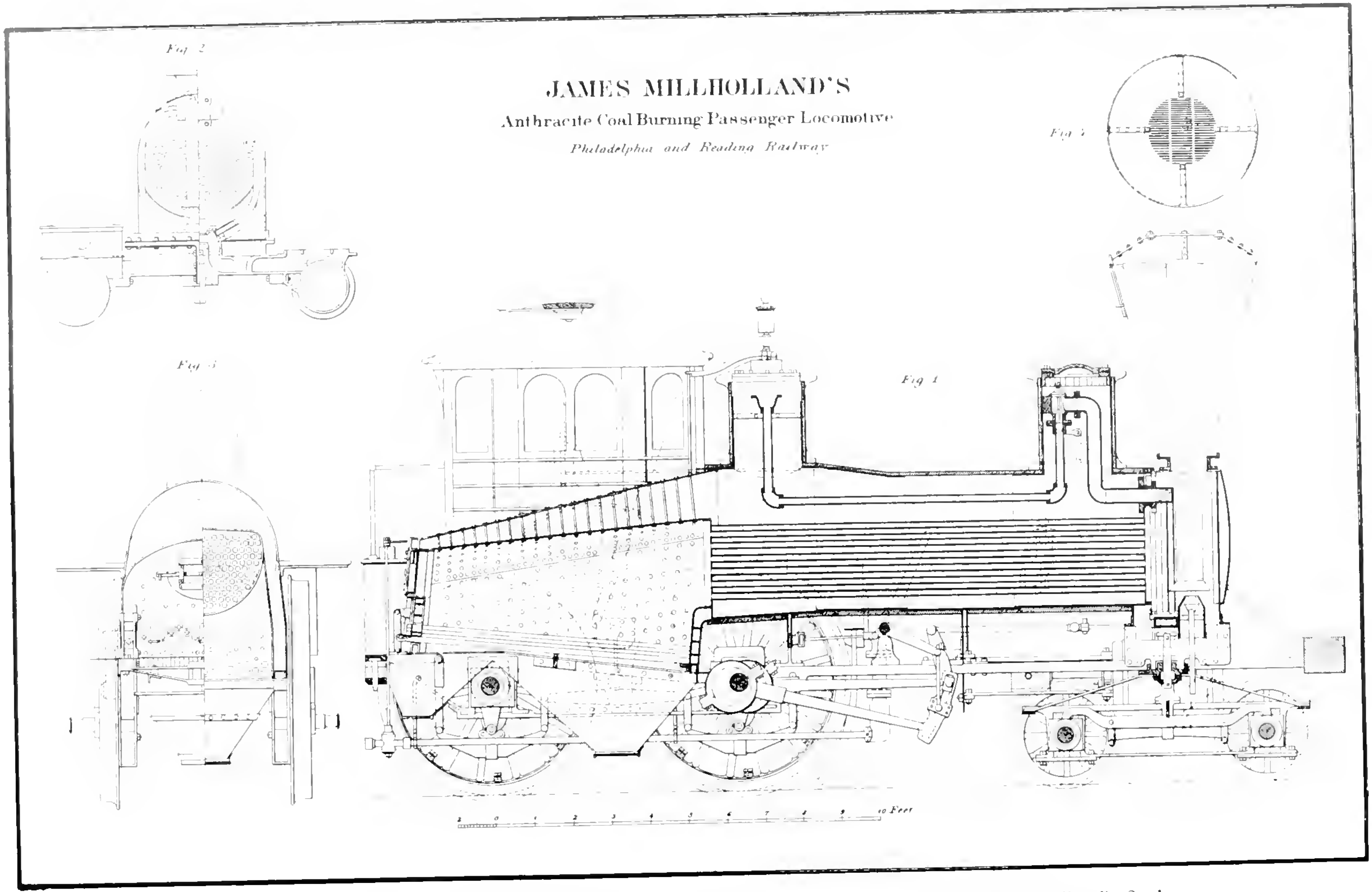

Figure 18.—Drawing of a Hiawatha-class passenger locomotive. The boiler shows Millholland's final design, which includes a sloping crown sheet, short combustion chamber at the firebox, and water grates. It also illustrates the smokebox superheater and cast-iron tires on the driving wheels. (From *American and European Railway Practice*, 1861.)

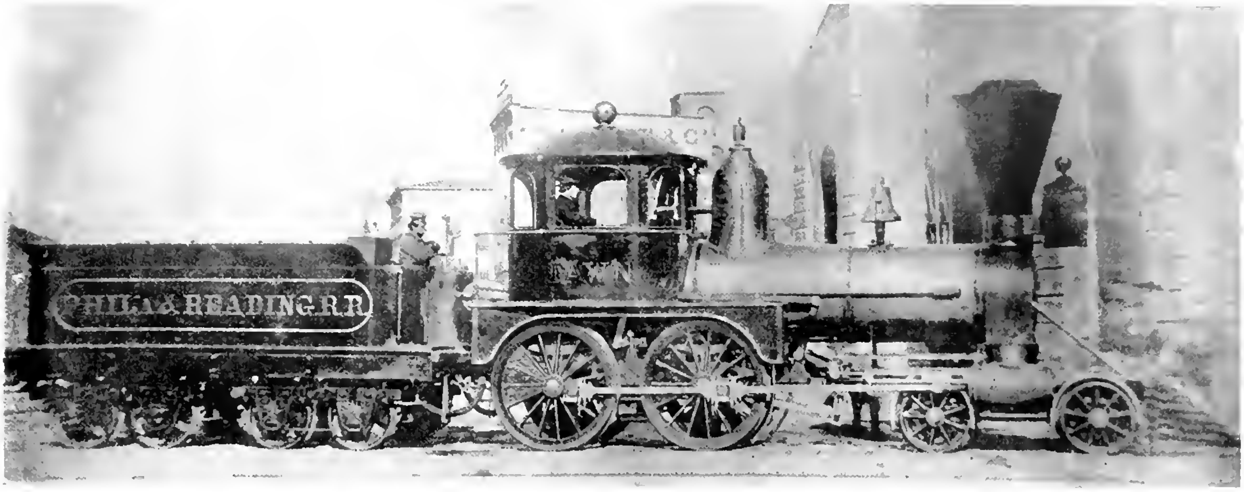

Figure 19.—THE *Fawn*, A LIGHT PASSENGER LOCOMOTIVE built by Millholland in 1860. (Chaney neg. 14479.)

through the firebox at great speed. Iron fireboxes lasted for 59,866 miles on the average; copper fireboxes, from 25,373 to 39,254 miles, depending on their construction.

Despite the success of his water grate and firebox, a report on the performance of Reading engines for 1857 was not altogether flattering to Millholland.[28]

Annual mileage..................	12,023/ locomotive
Cost of repairs per mile...........	11.6¢/ locomotive
Cost of coal per mile..............	13.4¢/ locomotive

Most American locomotives averaged about 20,000 miles per year and cost about 10 cents per mile for repairs. Fuel cost was a less definite matter since it varied widely from railroad to railroad. A good general figure for the period, however, is 20 cents per mile for wood. On some roads where wood was scarce or efficiency low, fuel costs were as high as 31 cents per mile. But, in fact, no true comparison can be made, for no cost figures exist for wood-burning locomotives doing the same heavy service as that performed by coal engines on the Reading. Although mileage figures for wood engines are plentiful for the 1850s (some ran 30 miles to a cord), little information is available on train weights. In short, Millholland's 19 miles per ton must be tempered by the knowledge that 700-ton trains were hauled, while the 25–30-mile-per-cord wood burners probably had hauled trains of no more than 200 tons.[29]

In theory, Millholland should have shown better economy than he actually achieved. Coal cost the Reading $2.55 per ton; wood, $4.33 per cord.[30] These fuels were even more disproportionate than indicated by cost, since 1 ton of anthracite is thermally equivalent to 1½ cords of wood. Hence $2.55 worth of coal, if efficiently burned, should do the work of $6.50 worth of wood. Millholland fell far short of this ideal, but he did produce a workable coal burner that performed with enough economy to drive wood burners off the Reading.

In the 1859 report Millholland confined his remarks to firebox and boiler improvement, yet he might well have mentioned his work on locomotive running gear. In 1857 he had built what is generally believed to be the first locomotive with a firebox *above* the frame.[31] This was achieved by a special design in which the top rail of the frame, rather than being straight, was set at about an 8° angle to the front pedestal, as shown in the drawing of the *Hiawatha* (fig. 18). The inclined arrangement permitted the firebox to pass over the top of the frame and yet keep

[28] Z. COLBURN and A. L. HOLLEY, *Permanent Way and Coal Burning Locomotives* (New York: Holley & Colburn, 1858), p. 118.

[29] Ibid.

[30] Ibid.

[31] The *Vera Cruz* is said to be the first locomotive with its firebox above the frame. There is some question, however, as to whether it was an old engine rebuilt in the Reading shops or a new machine constructed there.

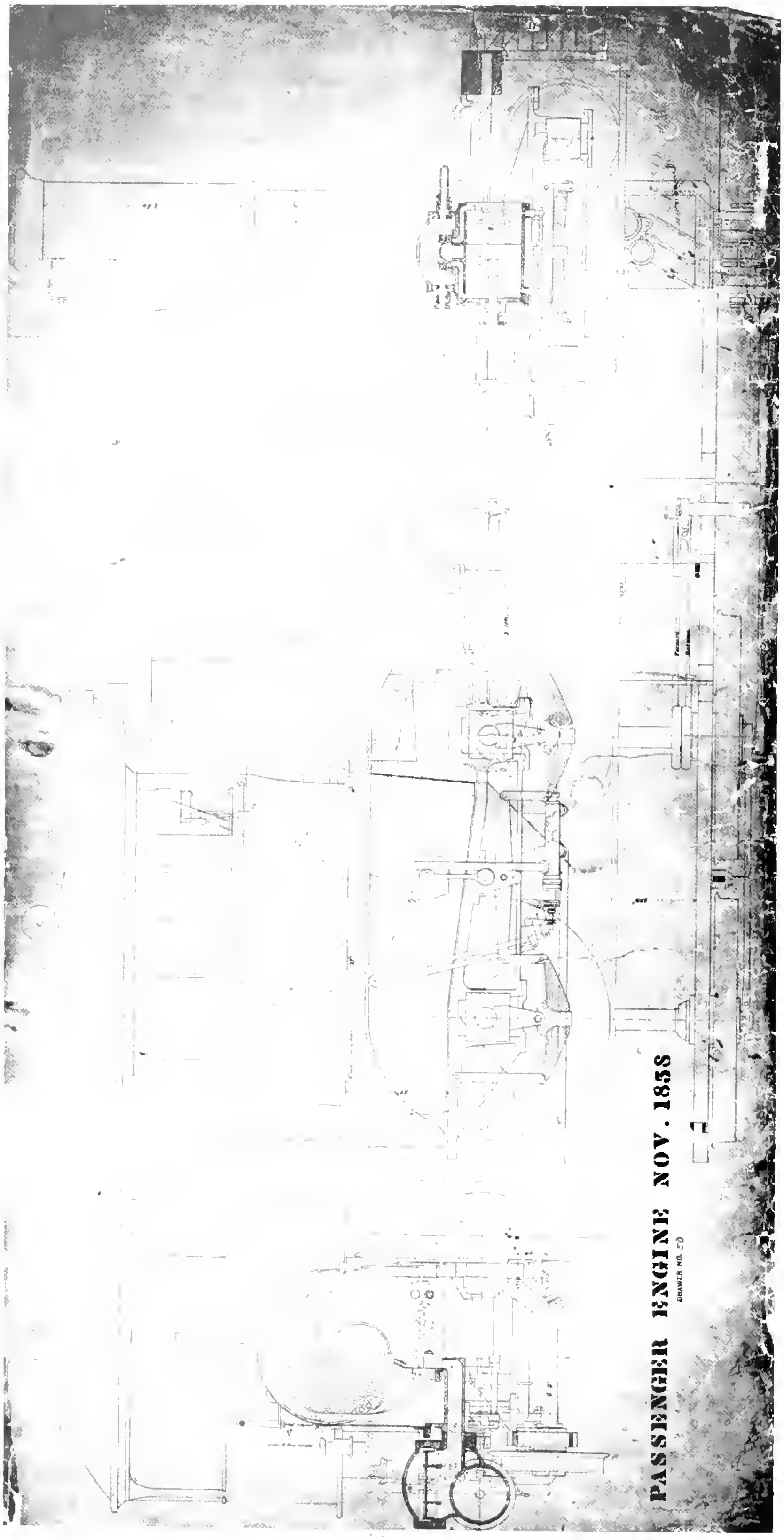

Figure 20.—An original drawing, presumably a design study for a Hiawatha-class 4-4-0. The Millholland injector mounted horizontally under the frame between the driving wheels was added to the drawing in later years. (From the Reading Company.)

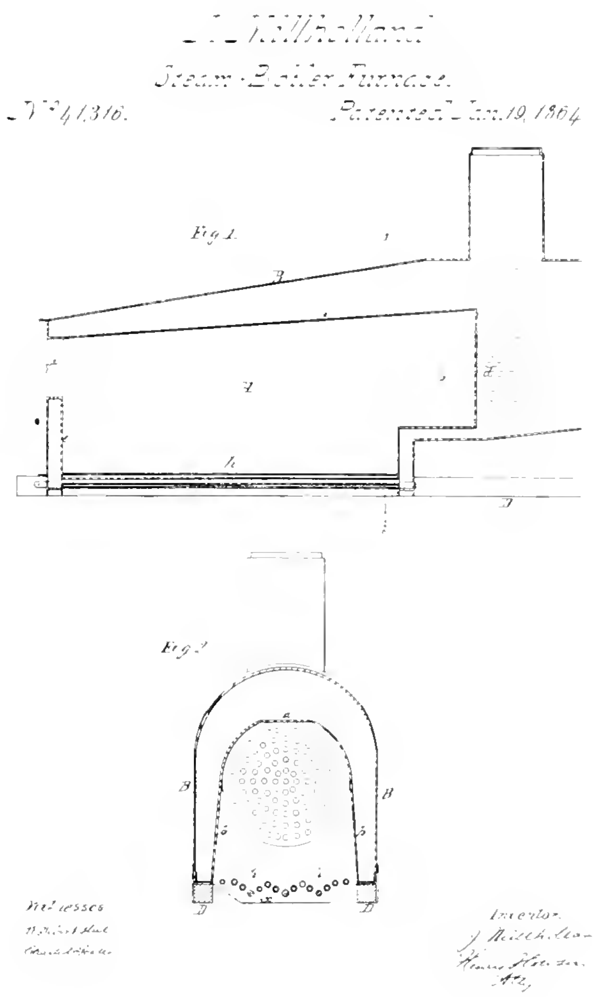

Figure 21.—This 1864 firebox patent shows Millholland's plan for a between-the-frames mounting of his water-grate firebox in order to achieve a lower center of gravity than his usual boiler-frame arrangement permitted. (From U.S. Patent Office.)

the entire boiler assembly low. It also provided a firebox some 10 inches wider than the conventional between-the-frame style. This Millholland frame was popular well into the 20th century.

Sometime in the early 1860s Millholland revived the old-fashioned riveted frame so popular with New England locomotive builders in the 1840s and 1850s. The frame's top rail was made from two wrought-iron bars about 1¼ inches thick by 6 inches deep. The pedestals were bolted or riveted between the top-rail bars, making a simple, heavy frame. No bottom rail was used. This style of frame probably was used first on the Reading's Gunboat class of 1863 and was still in use by the Reading in 1880.

Unquestionably influenced by Winans, Millholland preferred cast-iron driving-wheel tires. These were cheaper than wrought iron, and were extensively employed by the Baltimore and Ohio Company and by the Reading for wheels under 50 inches in diameter. They also had been used on the Baltimore and Susquehanna in 1840 during Millholland's superintendence, where he was credited with introducing cast-iron tires for large-diameter wheels in 1845.[32] While showing no inclination to abandon the cast-iron tire, Millholland in 1851 or 1852 (about the time Krupp produced his first steel tires) produced some of the world's first steel tires. These were made at the Reading shops and were fitted to the locomotive *United States*. A few other sets were made and gave good service, but for economy he preferred the cast-iron tire. Unfortunately, no contemporary account of this early use of steel tires can be found, and we must depend on the recollections of E. J. Rauch.[33]

Another unusual design favored by Millholland was one for solid-end connecting rods. The vast majority of 19th-century locomotives were equipped with straps bolted to the rods and provided with keys for alignment. The strap-end rod was liable to work loose or become misaligned by inept adjustment of the keys. The solid-end rod, having no straps, bolts, or keys, was not subject to these defects. It should be noted that Millholland's preference for solid-end rods was shared by several other mechanics, notably Ross Winans.

With the question of a practical coal-burning boiler answered by 1858, Millholland turned his attention to the design of new locomotives. The first of these new designs was an eight-wheel passenger locomotive named *Hiawatha*. It was an elegant machine, remarkably modern in appearance. The water grate, poppet throttle, and slope-back firebox were familiar Millholland features, but several novel devices were added. The round iron cab was the most obvious departure from standard American practice. It should be remembered that the Reading had been a pioneer user of iron cabs (about 1845), but never before had such an elaborate and decorative iron cab

[32] *American Railroad Journal* (November 6, 1845), vol. 18, p. 714.

[33] *Locomotive Engineering* (June 1896), vol. 9, p. 500.

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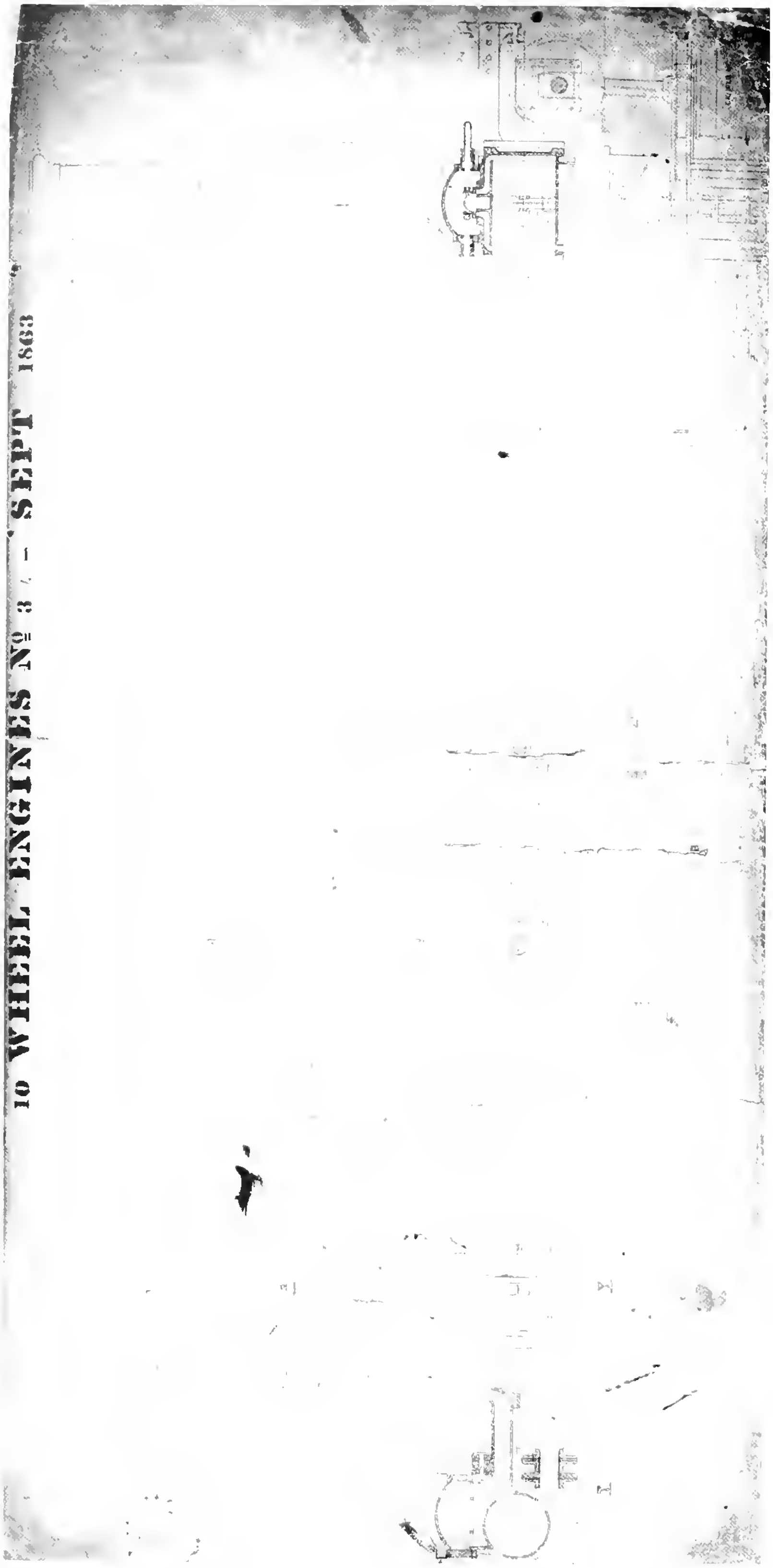

Figure 22. THIS ORIGINAL DRAWING OF A GUNBOAT-CLASS FREIGHT LOCOMOTIVE is dated September 1863. It was the third locomotive built on this standard Millholland design. (From the Reading Company.)

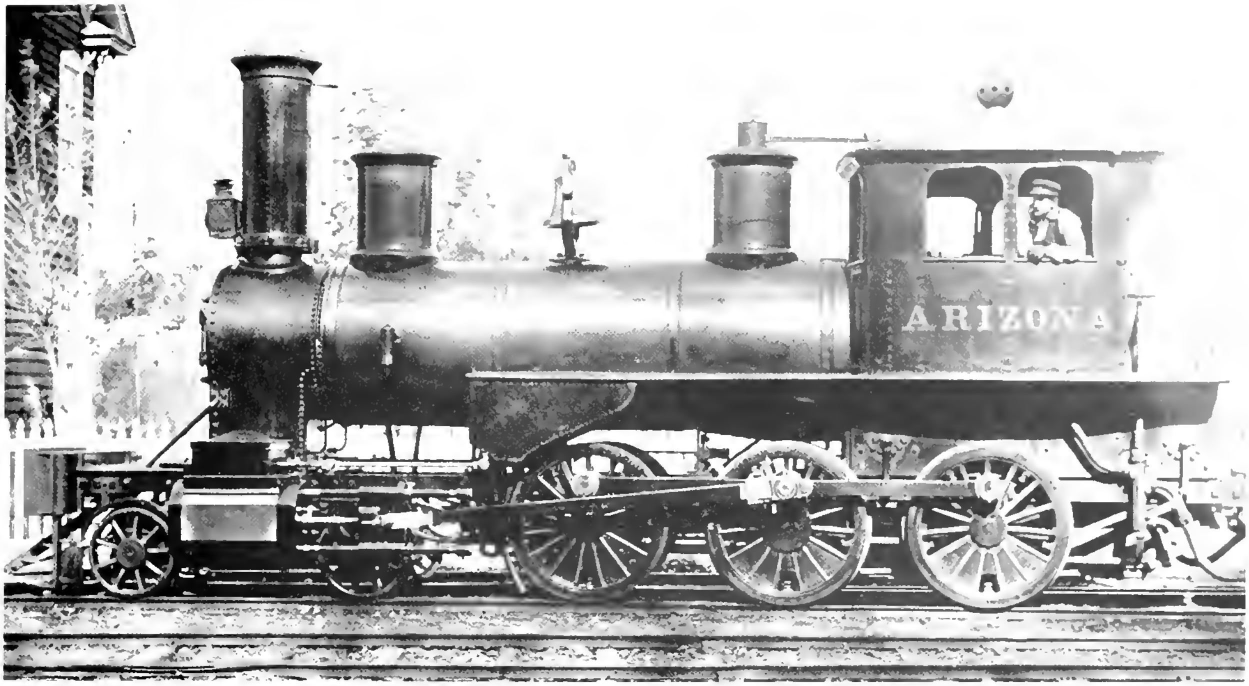

Figure 23.—The *Arizona*, a Gunboat-class freight locomotive built in 1863 at the Reading Shops. Note the feedwater injector fitted to the firebox behind the rear driving wheel and the solid-end connecting rods. (Chaney neg. 5382.)

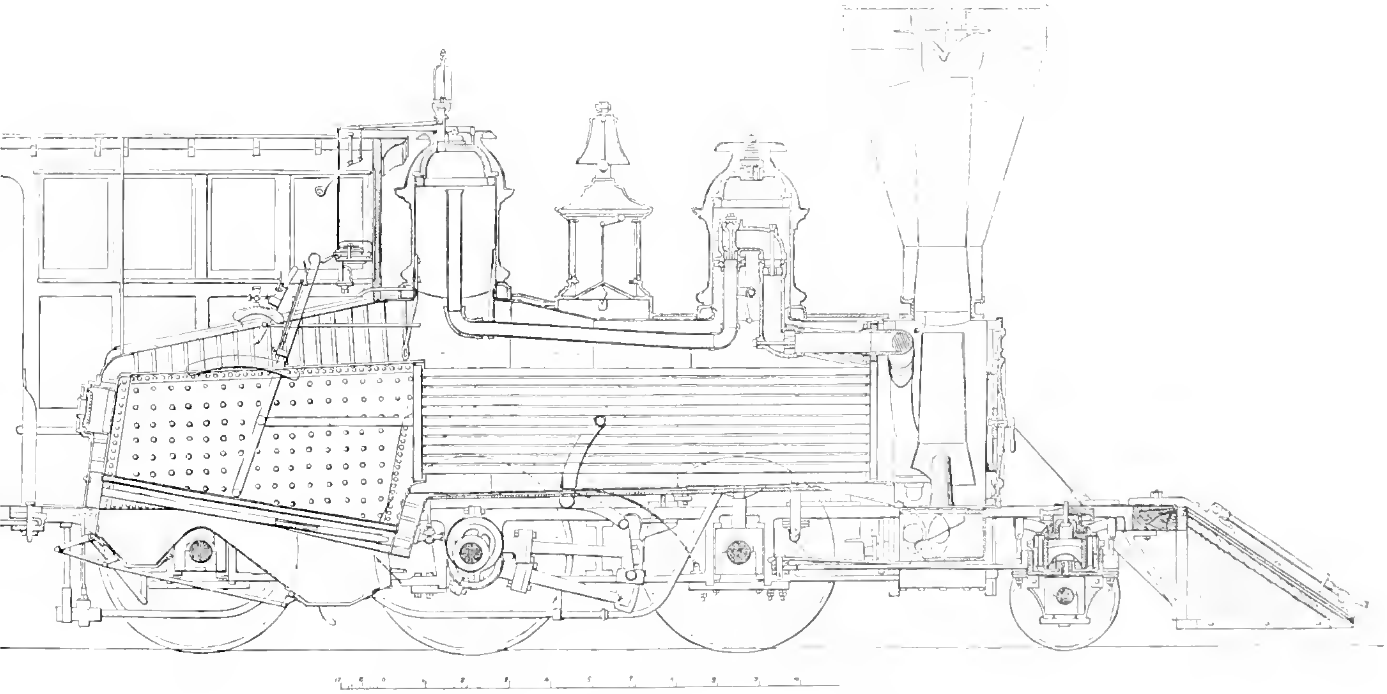

Figure 24.—One of several Mogul-type locomotives built in 1865 by Danforth, Cooke & Company for the New York and Erie Railway, fitted with a Millholland boiler. (*Engineering*, May 11, 1866.)

Figure 25.—The *Robert Crane* built in 1864 for the Reading and Columbia Railroad by the Lancaster Locomotive Works. This engine was based on the design of Millholland's Hiawatha class. (*Photo courtesy of the Lancaster County Historical Society.*)

been seen on the road. The *Hiawatha* was also notable for its superheater, a nest of pipes placed in the smokebox. While the *Hiawatha* drawing is the earliest known illustration of Millholland's superheater, he is credited with using it "some time" prior to 1861.[34] A few other roads were experimenting with the superheater at this time, but it was not adopted universally for locomotives until about 1910. In contrast to the *Illinois*, Millholland's first anthracite-burning passenger engine, the *Hiawatha* was a great success and served as the model for 44 other locomotives of the same design.

The adoption of Millholland's design by other roads provided sure evidence that his anthracite-burning firebox, patented (41,316) January 19, 1864, was a success. In 1860 the Central Railroad of New Jersey purchased three new locomotives with Millholland

[34] A. L. Holley, *American and European Railway Practice* (New York: Van Nostrand, 1861), p. 149.

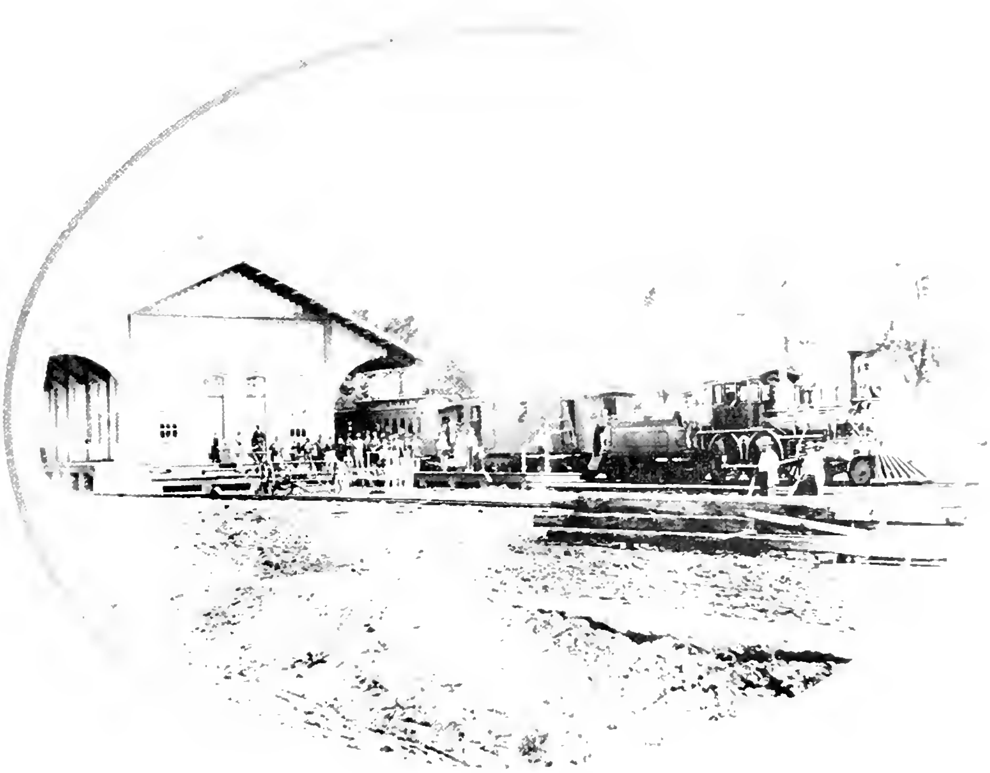

Figure 26.—The East Pennsylvania Railroad acquired the *Easton* in about 1860 from the Rogers Locomotive Works. It clearly has a Millholland boiler and other features of his design. The scene is Kutztown, Pennsylvania, in 1870. (From the Reading Company.)

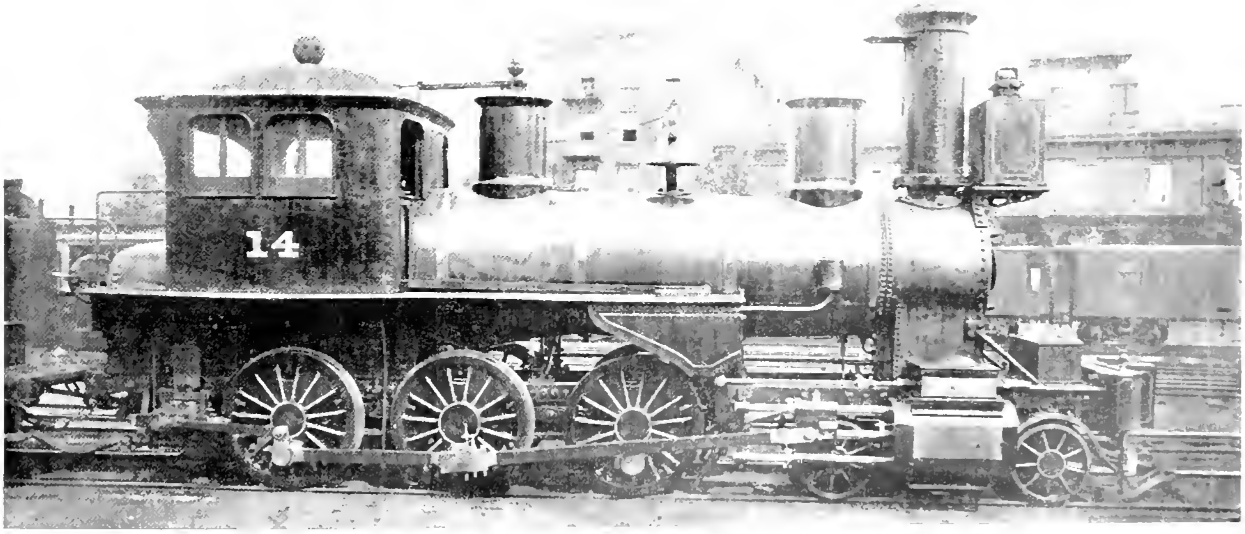

Figure 27.—A Gunboat-class freight locomotive built from Millholland's designs for the Pennsylvania Railroad in 1866 by the Lancaster Locomotive Works.

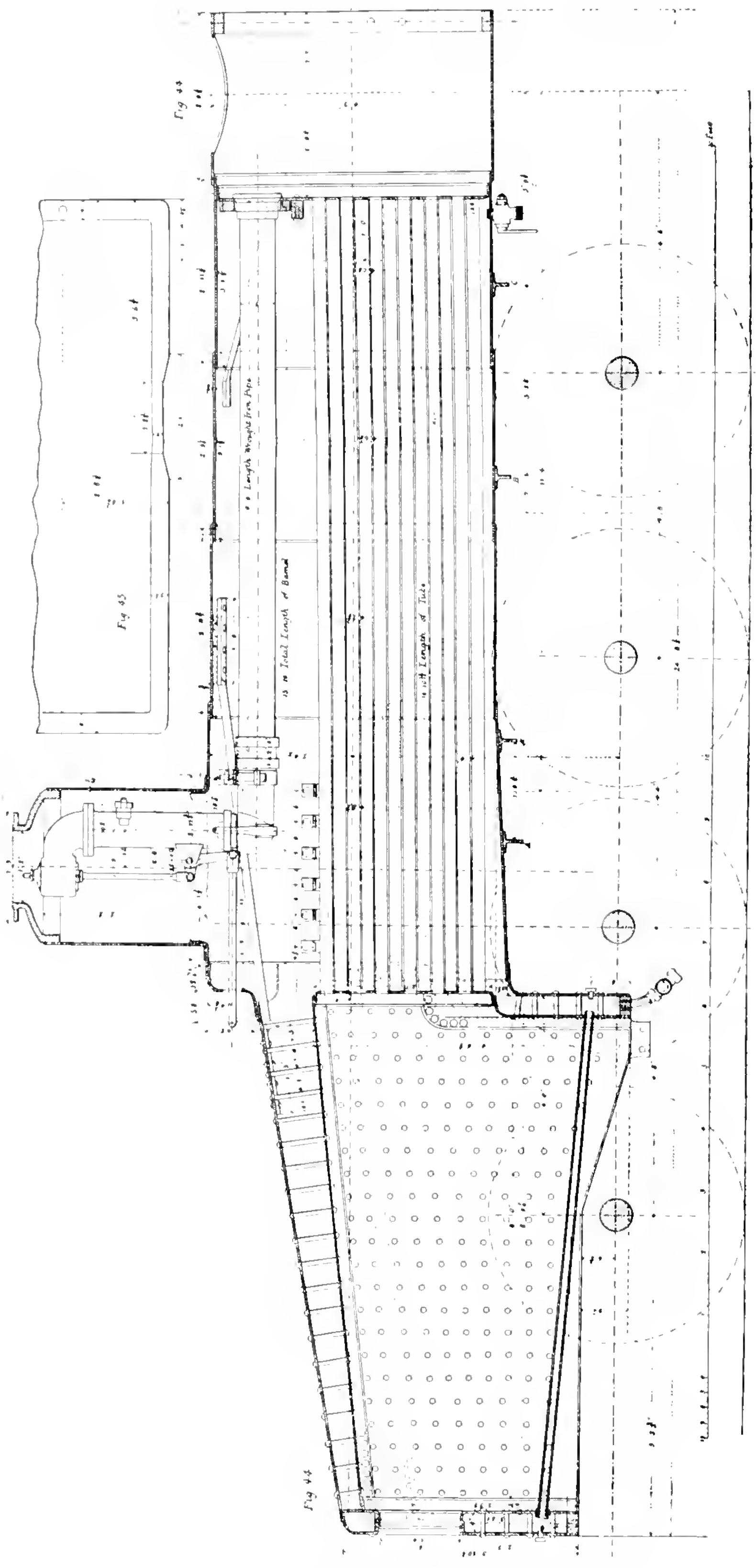

Figure 28.—THE SO-CALLED ALTOONA BOILER ON THIS 2-8-0 FREIGHT LOCOMOTIVE was patterned closely on Millholland's design. The Pennsylvania Railroad built or purchased over 350 locomotives with boilers of this design between 1875 and 1886. (*Engineering*, August 17, 1877.)

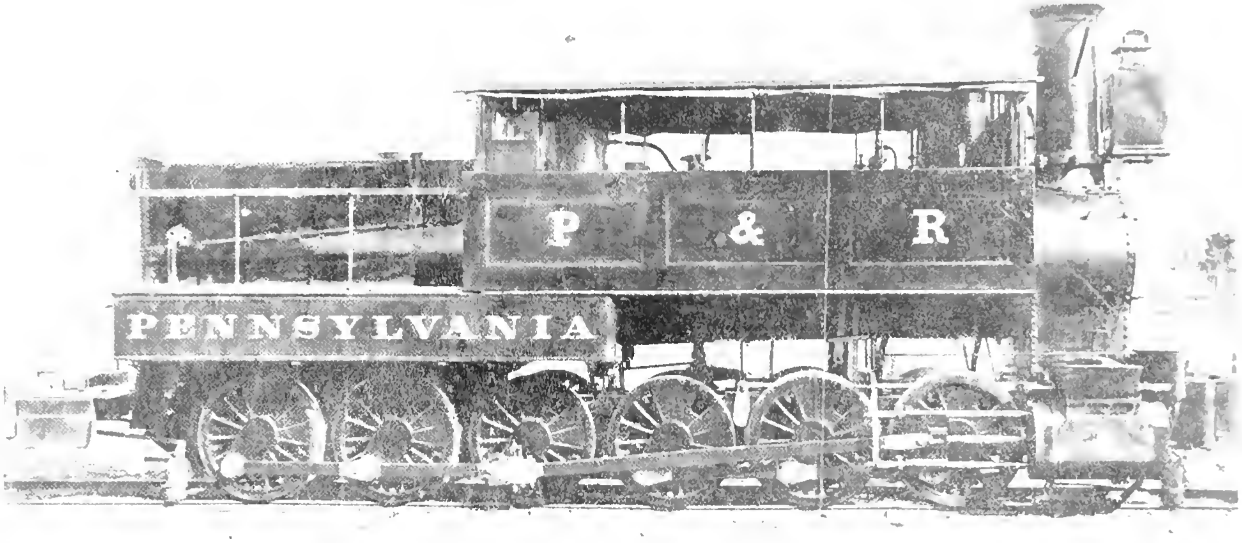

Figure 29.—The *Pennsylvania* was the largest steam locomotive in the world when constructed by Millholland in 1863; this 50-ton locomotive was in service until 1885. One pair of driving wheels was removed in 1870.

fireboxes. These were pronounced superior to any other coal burners tested on that road and were said to have saved 7 cents a mile over the road's wood burners.[35] The Erie purchased a large number of Mogul freight locomotives between 1862 and 1865, all of which were built with Millholland fireboxes. The New Jersey Railroad and Transportation Company also acquired three engines similarly equipped. The Lancaster Locomotive Works in 1865 advertised that it would build locomotives with the ". . . celebrated coal burning boiler of Mr. James Millholland." [36] Probably the most impressive testament to Millholland was the trial of his firebox by the Paris and Orleans Railway.[37] Millholland sent his chief assistant Levi B. Paxson to France to supervise the reconstruction of the French engines.

Incidental to the use of the boiler by other companies was Millholland's injector for supplying water to boilers. The injector had been invented by Henri Giffard of France and was introduced in this country about 1860.[38] While most master mechanics agreed that feedwater pumps were troublesome, early injectors were expensive and unreliable. Millholland sought to remedy these complaints with a simplified design. In his patent specification (No. 35,575) of June 10, 1862, the inventor claimed his injector could be made at $\frac{1}{20}$th the cost of an equal Giffard injector. Millholland's son James carried the argument even further by stating that an injector made by his father for $4 was equal to a $180 Giffard injector.[39] The actual cost and success of Millholland's injector remains a question, but the Reading was one of the first railroads to use injectors on its locomotives. The device did not gain universal acceptance in locomotives, however, for another 20 years.

In March 1863 Millholland completed a large 10-wheel freight locomotive called the *Nevada*. This machine was the first of the Reading's famous Gunboat class, of which 134 were constructed. The design was so sound that it was still being used many

[35] *American Railway Review* (February 28, 1861), vol. 4, p. 118.

[36] *American Railroad Journal* (August 12, 1865), vol. 18, p. 774.

[37] *Engineer* (February 8, 1861), vol. 11, p. 92.

[38] For a survey history of the injector, see Frank A. Taylor, *A Catalog of the Mechanical Collections of the Division of Engineering* (U.S. National Museum Bulletin 173, 1939), pp. 125-133.

[39] Letter from James A. Millholland to J. E. Watkins of the Smithsonian Institution, May 18, 1888.

years after Millholland's retirement. (The first locomotive with a Wootten boiler, built by Millholland's successor, John E. Wootten, in 1877, was essentially an elaboration of Millholland's plan for the Gunboat class, except for the very wide firebox which was made for burning waste anthracite coal.)

In September 1863 Millholland finished the *Pennsylvania* (fig. 28), a mammoth "pusher" engine. This giant 12-wheeled machine was for many years the largest locomotive in the world. Nearly twice the size of a standard eight-wheeler of the period, it weighed over 50 tons, had 20 x 26-inch cylinders and a grate area of 31½ square feet, and could pull 2500 tons on the level. The engine was built to assist heavy coal trains up the Falls Grade (0.9 percent) near Philadelphia. The *Pennsylvania* was followed by seven smaller sisters. The first of these, the *Kentucky*, weighing 41 tons, was completed in 1864; the last was built in 1872.

In 1866 James Millholland resigned as master machinist of the Philadelphia and Reading to devote himself to other business and community interests. After a long illness he died in Reading, Pennsylvania, in August 1875 at the age of 63. Although his later years were undistinguished by mechanical invention, he already had made outstanding contributions to railroad technology. His original works include the cast-iron crank axle, wooden spring, plate-girder bridge, poppet throttle, anthracite firebox, water grate, drop frame, and steel tires. He was also an early user and advocate of the superheater, the feedwater heater, and the injector. His general designs were followed by the Reading long after his retirement, and a number of his innovations were adopted as standard practice by the railroad industry.

James Millholland was an original mechanic whose designs were distinctive and different from those of his contemporaries. His locomotives were plain, practical machines; their simple lines favored European concepts rather than the gaudy and ornamental styles so typical of 19th-century American locomotives. One line in his obituary summarizes his career: "The science of mechanics was his lifelong study, and the locomotive the special object to which he devoted the energies of his constructive genius." [40]

[40] *Railroad Gazette* (August 28, 1875), vol. 7, p. 362.

Appendix

I

[From *Engineering News*, October 20, 1888, p. 305.]

The following letter, written by the designer to Mr. HERMAN HAUPT, soon after the erection of the bridge, gives many details which will be of interest:

READING, PA., May 1, 1849.

DEAR SIR: Enclosed I send you the drawings of the three bridges I constructed on the Baltimore & Susquehanna Railroad while engaged as Superintendent of machinery and road. The one marked *A* was built at the Bolton depot in the winter of 1846 and 1847, and was put in its place in April, 1847. This bridge is made of puddled boiler-iron ¼-in. in thickness. The sheets, standing vertical, are 38 ins. wide and 6 ft. high, and riveted together with ⅝ rivets, 2½ ins. from center to center of rivets. You will observe by reference to the drawing, that each truss frame is composed of two thicknesses of iron, 12 ins. distant from each other, and connected together by 5-16 iron bolts, passing through round cast-iron sockets at intervals of 12 ins.; which arrangement, together with the lateral bracing between the two trusses, ensured stability. The lateral bracing is composed of ¾ round iron, set diagonally and bound together at the crossing by two cast-iron plates about 4 ins. diameter, the sides next to the bracing being cut in such a manner, that when the two ⅝ bolts that pass through them were screwed up, it held them firmly together. There is also a bolt passing through both truss-frames and through the heels of the lateral bracing, at right angles with the bridge, which secured the heels of the lateral braces, and by means of a socket in the center made a lateral tie to the bridge, giving the bridge its lateral stability.

The lower chords were of hammered iron, there being some difficulty at that time to get rolled iron of the proper size, and are in one entire piece, being welded together from bars 12 ft. long. There are eight of them, 5 x ¾-ins., one on either side of each piece of boiler iron, and fastened to it with ¾-in. iron rivets 6 ins. distant from each other. There are but four top chords, and of the same size of the bottom, two on each truss near the top, the timber for the rail making up the deficiency for compression, and answering the purpose of chords. This bridge was built at the time Messers. STEPHENSON and BRUNEL were making their experiments with cylindrical tubes preparatory to constructing the Menai bridge; the cylindrical tubes failing, they adopted this plan of bridge.

The entire weight of the bridge is 14 gross tons, and cost $2,200; but as the same kind of iron of which the bridge is composed can be had for at least 15 per cent. less now, than it cost at the time, it would be but fair to estimate the cost of the bridge at $1,870, without any reference to the labor that is misapplied in all new structures of the kind, making the cost of a bridge 55 ft. long, $34 per ft. And I have no doubt where there would be a large quantity of iron required for such purposes, that it could be had at such prices as to bring down the cost of bridges of 55 ft. length to $30 per ft.

Very respectfully yours,

JAMES MILLHOLLAND.

II

[From Philadelphia and Reading annual report for 1859, pp. 55-61.]

READING, Dec. 13th, 1859.

R. D. CULLEN; Esq., President Philada. and Reading Railroad Co.

DEAR SIR: I have your letter of the 7th inst., and most cheerfully comply with your request mentioned therein.

We have been burning anthracite coal in some of our locomotives for the past twelve years, and for five years in all the engines employed in coal transportation, hauling with them trains of 500 tons, exclusive of the weight of cars, and are now burning anthracite coal in all the locomotives on passenger, freight, and coal trains, employed on the main line of the road, and in all the engines employed on the lateral roads, except the two passenger engines on Lebanon Valley Branch, and one running the Reading Accommodation Train, and one on the Chester Valley Railroad, burning wood.

There are now on the road,

4	First class	Anthracite coal burning	Passenger	Locomotives.
1	Second "	"	"	"
88	First "	"	Coal and Freight	"
3	Second "	"	"	"

These engines are much easier managed than wood-burners, and a much more uniform pressure of steam can be kept on them, as they are all provided with variable exhausts, under the control of the engineer, who can increase or diminish the draft at pleasure. To fire these engines requires much less labor than wood-burners, as it is not necessary to fire oftener than at intervals of forty minutes, and sometimes double that time may elapse without further attention than occasionally to clean out the cinder and ashes between the grate-bars. The best fireboxes for burning anthracite coal are those with the largest grate area. The first four large engines for burning this fuel, built by Ross Winans, Esq., of Baltimore, and placed on the road in 1847, had fireboxes six feet three inches long, by two feet ten inches wide, giving a grate area of 17·68 square feet; these engines did not make steam freely, and had to be run with a small exhaust, and in consequence produced a very strong draft, and threw a great deal of coal out of the chimney. The next five engines built by Mr. Winans for this Company, were placed upon the road in 1850 and 1851, and were different from the four built by him in 1847; they are what is commonly called the "Camel" engine, having a large dome and house on top of the boiler for the engineer, their fireboxes being five feet two inches long, by three feet six inches wide, giving a grate area of a little over eighteen square feet; they were also deficient in making steam, but gave much better results than the first four. The engines that have been placed on the road within the past seven years, also built by Mr. Winans, have fireboxes seven feet long and three and a half feet wide, making a grate area of 24.5 square feet, and perform very satisfactorily. One of the difficulties we have had to contend with in the use of anthracite coal as a fuel for locomotives has been the necessity of using an inferior quality of coal for the purpose of preventing the cast iron grate-bars from melting, as it makes a great deal of cinder and ashes, which, when once formed on the grate-bars, protects them from the immediate action of the fire, and the firemen have to be very careful

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in cleaning the grate-bars, that they do not get so much of it out as to bring the hot coals in contact with the bars and melt them down, and being compelled to use this inferior coal has made the consumption appear more than it really should be.

The best coal could not be used in our locomotives with any certainty of success, until water grate-bars were substituted for cast iron; in fact, it was looked upon as a bad article for the purpose, because it would melt the cast iron grate-bars; but the water grates have shown that it is far preferable, as it not only takes less of it to perform a trip, but there is less required on the grate at a time, and the fire being thinner, a larger exhaust can be used, and consequently a much milder draft is produced; no fire is thrown from the chimney, and the increased area of the exhaust relieves the back pressure on the pistons, and thereby increases the power of the engine.

In using the best anthracite coal in our passenger engines fitted with water-grates, I have seen the fire run down so low, when near the ends of the road, that a portion of the grate bars would be bare. And I have no hesitation in saying, that, with a properly constructed boiler, fitted with water-grates, and the use of good anthracite coal, all classes of locomotives, both passenger and freight, can be used with as much reliance as to their performances, both as to speed and power, as engines burning wood or any other fuel; and that a more uniform pressure of steam can be maintained on them, than any wood-burning passenger or freight engines that have been on our road for the past eleven years. It is, however, a matter of experiment with us now, to know what is the best material for a firebox, and the proper shape to put it in for service with anthracite coal. In the fireboxes of Winans' engines, having a grate seven and a half feet long, and three and a half feet wide, with *vertical* side-sheets, we have been using copper, three-eighths of an inch thick; this, however, would not last more than about eighteen months, running about 25,373 miles, when the boilers had the entire back end of the firebox open, with two upper and one lower door to close when in use, and cast iron grate-bars.

In this kind of a firebox, the side-sheets would be worn down in places to not more than a sixteenth of an inch thick; and in others, it would retain nearly its original thickness, but from what cause I am not able to say; but probably from mechanical action, as the thin places are generally found about where the coal would strike the side-sheets when thrown in with a shovel. To remedy this wearing away of the side-sheets, I put in a harder material, iron; but it does not last so long as copper placed in a vertical position, as it appears to become very much overheated, and cracks vertically, showing a crystalline fracture, which, I have no doubt, is caused by the absence of water on the opposite side of the sheet from the fire.

The steam generated on the side next to the water (in consequence of the sluggishness of the circulation, if any, in this part of the boiler), remains there in contact with it, and as it will not take up heat with as much facility as water, allows the iron to become too much overheated, and the first strain that comes upon it in the way of unequal expansion or contraction, causes it to crack; but copper being a more ductile material, is not affected in the same way, but becomes softer by the frequent heating and cooling, and therefore appears to be the best material of the two, for this kind of firebox.

I closed up one-half the open end firebox by putting a water back that took up one-quarter of the opening on each side of the firebox, leaving one-half the area of the end open from top to bottom; the lower half of the opening was closed by a grate door, which serves to admit air to the coal in that part of the furnace that would not be supplied with air if a solid door was used, and also for the purpose of inserting a slice-bar to break up the cinder on the grate. The upper half of the door is used for firing, and consists of two plates of cast iron, the inner one about two inches from the outer, leaving a space between, that was supplied with air through holes bored or cast in the outside plate; which air protects the inner plate to some extent from the heat, and also supplies air to ignite the gases, and not to allow them to pass from the furnace unconsumed.

This arrangement of doors increases the durability of the side-sheets, and engines whose boilers have been thus fitted, have run an average of 29,391 miles before the sheets required replacing.

To introduce the water-grates, I was compelled to close the back end of the firebox, leaving an oval door for firing, the same as in the ordinary wood-burning boilers, but with a number of small holes in the inner plate of the door, and larger in the outer; and in some of the boilers, I have put hollow stay bolts, with an opening about one-quarter inch in diameter, in the back end of the fire-box. The side-sheets in the first boiler fitted with water-grates and closed back end, run 39,254 miles; and as this is the only one that wants the side-sheets renewed, I have no

Statement of the Number and Names of Wood-burning Engines that have been changed to Anthracite Coal-burners; when done; the number of Miles run, and the Duty these Engines are doing

Names of Engines.	When altered to Coal-burners.		No. of Miles Run.	
Allegheny			168,588	Freight Train Main Road.
Gowen and Marx	January	1855	25,385	
Tuscarora	June	1855	28,708	Assorting at Reading.
Shamokin	November	1855	43,969	Running at Palo Alto.
Empire	February	1856	35,363	Pusher, Richmond Wharves.
Mahanoy	June	1856	56,045	Work on Lateral Roads, Coal Region (on grades over 100 feet to the mile).
Amazon	June	1856	54,182	" " " " "
Yorktown	November	1856	51,701	" " " " "
Columbus	November	1856	31,782	" " " " "
Rio Grande	June	1857	35,020	City Coal Trade, Philadelphia Branch.
Carolina	June	1857	41,626	Work on Lateral Roads, Coal Trade (on grades over 100 feet to the mile).
Missouri	July	1857	35,049	" " " " "
New York	August	1857	30,722	" " " " "
Manatawny	May	1858	27,011	Passenger Train, Valley Railroad.
Black Diamond	May	1858	32,590	Freight Train, Lebanon Valley Branch.
Texas	June	1858	38,457	Freight Train, Main Line.
New England	August	1858	30,540	" "
Warrior	October	1858	31,386	" "
Oregon	December	1858	14,098	Freight Train, &c.
Pacific	May	1859	7,364	" "
Ontario				Assorting Cars at Harrisburg.

doubt as good results will be had from others fitted in the same way. I have now on trial, in a boiler with vertical sides, and same sized firebox as before mentioned, with closed back, and side and end sheets five-sixteenths of an inch thick, made of Mr. Clay's homogeneous steel, which is doing well; it has run 14,381 miles. Most of the fireboxes of the boilers of engines we have built in our own shops, and of those we have made to take the place of wood-burning boilers, differ somewhat in shape from those I have mentioned, and have a combustion chamber attached, extending from eighteen to thirty-six inches into the cylindrical part of the boiler; and some of the fireboxes are much wider than they are long at the bottom, which makes the side-sheets incline towards the fire. Iron has been used in all these with one exception, which is five feet long and five feet wide, making a grate area of twenty-five square feet. In this I put copper side-sheets, to ascertain if the shape had any influence on the wear. The experiment showed that copper would last longer in this shape with cast iron grate-bars, and the back end partly open, as they lasted to run 38,292 miles, while those with back end partly open run but 29,391 miles.

The iron sheets, however, in other fireboxes, with inclined sides, show that this plan of constructing is much the best, as the side-sheets show little or no wear, and are not much thinner when taken out than they were originally, and the only cause for removing them arises from imperfect welding of the iron, which gives rise to blistering and cracking around the staybolts, so as to cause leaks; but they last much longer than the copper sheets in the vertical sides, and have run an average of 59,866 miles.

I think, from an experiment with an iron sheet in a firebox with vertical sides, that I have hit upon a plan that will prevent the radiating cracks around the staybolts. It is to indent the sheet at the hole the staybolt passes through, a little more than will receive the riveting of the end of the staybolt; this places the iron in such a shape in the sheet as to allow it to spring, when the expansion of the sheet and staybolt takes place. The experiment clearly shows an advantage from the indentation, as the opposite sheet, in the same firebox, is cracked and leaks, whilst the staybolts in this are as perfect as the day they were put in, never having leaked at all, after having been in operation since October, 1858, and ran 22,388 miles.

The most durable firebox for burning anthracite coal we have had on the road is of iron, in a small boiler of one of our light engines, built by the Company, about eight years since, and has been but a few months replaced with a new one. It is four feet five inches long, and three feet seven inches wide, making a grate area of 15.82 square feet. The sidesheets, being smaller than in the large engines now in use in our coal trade, were made direct from the bloom, and are consequently homogeneous; the flue sheet was also set back from the firebox about eight inches. It ran 168,588 miles, but I have not included it in the average number of miles ran by our engines with iron fireboxes.

RECAPITULATION

Average number of miles ran with iron firebox sheets,	59,866
Average number of miles ran with copper firebox sheets, open end,	25,373
Average number of miles ran with copper firebox sheets, half closed,	29,391
Average number of miles ran with copper side-sheets, closed end, and water-grates,	39,254

Cost of Renewing the Copper Firebox Sheets

Labor "per contract,"		$100 00
870 lbs. copper,		278 40
635 lbs. boiler iron,		31 75
165 lbs. rivets,		11 55
273 lbs. staybolts,		21 84
49 ft. hollow bolts,		10 87
Carried forward,		$454 41
Brought forward,		$454 41
Cr.		
By 530 lbs. old copper,	$106 00	
By 881 lbs. scrap iron,	11 75	
		$117 75
Balance,		$336 66

Cost of renewing Iron Firebox Sheets

Labor,	$100 00
1095 lbs. boiler iron,	54 75
165 lbs. rivets,	11 55
273 lbs. staybolts,	21 84
49 ft. hollow bolts,	10 87
	$199 01
Cr.	
By 1190 lbs. scrap iron,	15 87
Balance,	$183 14

The consumption of fuel by our coal train engines, with a train of 100 loaded cars, with five tons per car, and 110 empty cars up, is on an average in the round trip of 190 miles, 9 tons of coal.

The performance of our anthracite coal-burning passenger locomotives, I think, will compare favorably with locomotives using wood or bituminous coal on other roads.

Annexed please find a statement of the performance of one of them, and it may be as well to state, that the engineer and firemen of this engine never ran a coal-burner before, and had not been on this more than a month when the experiment was made, having been taken off a wood-burning passenger engine, and I have not the least doubt, but a better result can be shown under similar circumstances, in future.

I would also call your attention to the performance of the Phoenix, the pushing engine at the Falls grade. This engine burns anthracite coal, is an eight wheel connected engine, and weighs 70,700 lbs., and is doing the work that required two eight wheel connected wood-burning engines, weighing 52,192 lbs. each.

The number of engines that have been changed from wood to coal-burners, and the miles ran by each up to the 30th of Nov. 1859, will be found in the following statement.

None of these engines have had new fireboxes, or firebox sheets put in their boiler since they commenced burning coal.

Very respectfully,

James Millholland.

U.S. Government Printing Office: 1967

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Washington, D.C., 20402 - Price 30 cents

Contributions from

The Museum of History and Technology:

Paper 70

William Gunn Price and the Price Current Meters

Arthur H. Frazier

Figure 1.—William Gunn Price (1853–1928).

Arthur H. Frazier

William Gunn Price *and* The Price Current Meters

The development and use of current meters, which provide streamflow data by measuring the velocity and discharge of water flowing in rivers, has been an important factor in providing for municipal water supplies and in the construction of dams, bridges, and culverts, as well as contributing significant information toward the solution of territory litigations and public health problems resulting from stream pollution.

This paper traces the history and development of an outstanding family of current meters, the Price family, which is interrelated with the history of the United States Geological Survey. It also presents a biography of that remarkable 19th-century American inventor, William Gunn Price.

THE AUTHOR. *Arthur H. Frazier, as former chief of the Division of Field Equipment in the United States Geological Survey, had exceptional opportunities for accumulating technical and historical information on current meters, and he provided many of the meters now in the collections of the Smithsonian Institution.*

IN THIS MODERN AGE, the expression *current meter* tends to conjure up a mental image of an ammeter, which measures electrical currents, rather than an image of the device it originally was used to describe, namely, an instrument for measuring the velocity (in feet per second) and the discharge (in cubic feet per second) of the water flowing in rivers. The major purpose of this article is to discuss an important family—the Price family—of current meters of that old-fashioned type and to present some little-known information about the man whose portrait appears in figure 1, William Gunn Price. It was he who

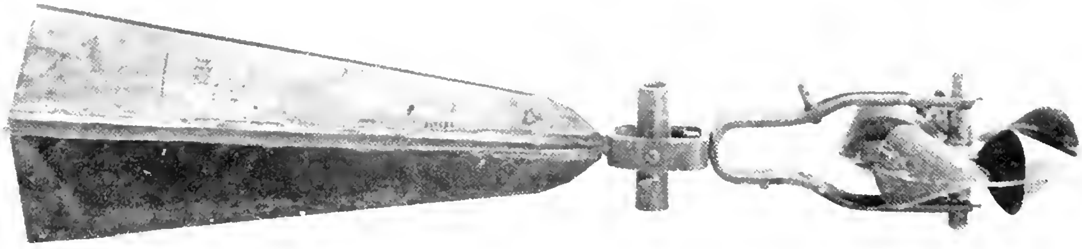

Figure 2.—The original Price current meter, now preserved in the Smithsonian Institution's Museum of History and Technology. (USNM cat. no. 289638; Smithsonian photo 44538 H.)

built the first model of those meters (fig. 2) while working on the Ohio River near Paducah, Kentucky, in 1882.

Price's current meter was by no means the first one built, but, as it is presently the most commonly used meter in the United States, it was selected for discussion in this paper. First, though, it seems appropriate to discuss some of the important uses for which streamflow data are obtained, daily records of which are maintained and published by U.S. Geological Survey for almost 8000 gaging stations on rivers throughout the United States. A partial list explaining the importance of streamflow records to modern engineering follows:

Dams.—Dams are built for water supplies, hydroelectric power, flood control, irrigation, navigation improvement, and recreation. In each instance, a careful study of all pertinent streamflow records must be made well in advance of any construction work to determine whether the drainage area above the selected site yields an adequate amount of water to accomplish the purpose for which the dam is intended, particularly when intended for irrigation or municipal water supplies. For hydroelectric power, *all* aspects of the streamflow characteristics must be considered before the economic feasibility of the venture can be determined. A common requirement concerning every proposed dam is that its spillway capacity be adequate to accommodate a maximum possible flood within the drainage area, because inadequate spillway capacity is one of the major causes of dam failure. Streamflow records, which are obtained by using current meters, provide the best possible basic data for designing proper spillways.

Litigations.—Litigations involving the uses of water have occurred since the beginning of written history. In *A History of Technology*,[1] one finds evidence that the words "rivals" and "rivers" stem from the same source. "That very word [rivals]," the book states, "in Roman law denoted those who shared the water of a rivus, or irrigation channel; it thus implies jealously guarded rights and frequent quarrels."

Perhaps the most equitable method yet devised for settling litigations concerning water rights has been by means of court decisions which allot certain amounts or proportions of the available water to each litigant who has a legitimate right to it. Water masters are appointed to carry out these court orders, and the masters base the distribution on data procured with current meters.

Public Health.—Today streams often are polluted by untreated sewage, by manufacturing wastes, and, more recently, by modern detergents, or by combinations of the three, with a consequent destruction of fish and wild life and withdrawal of attractive recreational waters and city water supplies from public use. Conservation officials and public health officers at all administrative levels—Federal, State, and local—are deeply concerned, particularly in periods of drought, when streams are

[1] Charles A. Singer, and others, eds. *From Early Times to Fall of Ancient Empires* (vol. 1 of *A History of Technology*, by Singer, and others, eds; Oxford: Oxford University Press, 1954), p. 521.

low and the percentage of pollution consequently high. Streamflow records—indicating the approach, presence, intensity, and passage of these periods—provide important information.

HIGHWAY BRIDGES AND CULVERTS.—The intelligent design of bridges and culverts for the vast network of highways across the nation depends on the availability and adequacy of streamflow records. Without such records, these structures might be built too large, resulting in excessive cost, or too small, endangering the road in times of severe floods. Although this list could be expanded, these examples are sufficient to explain the importance of such records in relation to modern engineering problems.

Current meters have provided the most expeditious and economical means for making acceptably accurate streamflow measurements. A current meter, combined with a graduated wading rod for making soundings in shallow streams or with a sounding weight for making soundings of deep streams from bridges, boats, or cableways, enables the hydrographer to determine quickly the cross-sectional area and velocity of a river at the place where its discharge is to be measured. This discharge is the product of the cross-sectional area (in square feet, as determined from the soundings) and the average velocity (in feet per second, as obtained with the current meter).[2] On the accuracy of streamflow records, Carter and Anderson conclude:[3]

> If single discharge measurements were made [with current meters] at a number of gaging sites by the usual 0.2 and 0.8 method (using 30 stations and 45-second observations) the errors of two-thirds of the measurements would be less than 2.2%.

There is little doubt that if measurements are made by a competent hydrographer, with good equipment, at a suitable site, and under favorable conditions, the maximum error occurring in any measurement of the entire lot would be well within five percent.

[2] For fuller information, consult the Water-Supply Paper series published by the U.S. Geological Survey. Number 888 deals with stream gaging; no. 868 with the performance of current meters in shallow water; and no. 95 with the accuracy of streamflow records.

[3] CARTER and ANDERSON, "Accuracy of Current Meter Measurements," Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers (July 1963).

William Gunn Price

William Gunn Price, the son of Dr. William Price and Tryphene Gunn Price, was born in Knoxville, Pennsylvania, on July 6, 1853, but moved when still a child to Chaseville, New York, two miles southwest of the picturesque village of Schenevus. Probably because William's father died before the boy's seventh birthday, William's early education was rather sketchy. There are reports that he attended high school in nearby Cooperstown, famous for James Fenimore Cooper's *Leatherstocking Tales* and for baseball. There are also reports that he attended Hartwick Seminary in New York State. Such reports tend to exaggerate Price's early education. Doubtlessly he attended both the high school and the seminary, but most likely not for the usual length of time. An article in the Yakima (Wash.) *Herald* for December 18, 1921, quotes him as saying:

> As a boy I was not much interested in school, and made very little progress. When not doing farm work, I was allowed to have tools, and learned to make things, many of them original. I also learned to repair clocks and watches, and to do blacksmith, tinsmith, and carpenter work.

When, however, Price was later faced with a special need for "book learning," he diligently studied the appropriate books and mastered the subjects.

His early disinterest in schools apparently was not inherited. Both his parents were well educated and had taught at the Knoxville Academy, which his father had established before he was married. William Price, Sr., taught mathematics and science, and Mrs. Price taught music, French, and art. During those teaching days William Sr. studied medicine, and finally was graduated from the University of Pennsylvania's medical college. Later, when a practicing physician at Chaseville, he often gave free lectures on scientific subjects.

As to young William's grandfather on his mother's side, these comments about him appear in the Price scrapbooks:

> Grandfather Gunn was an expert mechanic. He built and operated a sawmill on his farm, run by waterpower of a brook . . . . He sometimes made the shoes for his family . . . was the town gunsmith . . . designed and built churches. He was good, and had the gift of reason.

Looking back, it seems evident that William Gunn Price inherited much of the culture of his mother, the scientific insight of his father, and the craftsmanship together with the inventive genius of his grandfather. He, too, "was good, and had the gift of reason." There was an instinctive urge in him to design, construct, and invent—particularly to invent; the story of his inventions is truly the story of his life.

Price made the following statement to a friend in a letter dated July 15, 1926:

> When a boy I made several simple inventions, one of which was to enable my mother to shell peas by turning a crank. The pods came out of one hole, and the peas came out of another.

His first employment on work of an engineering nature began in 1871 or 1872, and lasted about four years. It was described in his scrapbook as "civil engineering, survey, sewer, and bridge work at New York city."

Possibly his association there with engineers made him aware of deficiencies in his knowledge of mathematics, because further notes in that scrapbook relating to the same period state in part:

> J. H. Serviss . . . taught me, for four years, higher mathematics and engineering, at Englewood, New Jersey. My cousin J. D. Probst paid him for doing it till I earned enough by my work to compensate him.

During the beginning of that four-year period he had invented an adding machine that was used for several years, probably at the engineering office where he was employed.

The training given Price by Mr. Serviss was no doubt responsible for his being able to qualify for his next three jobs as a land surveyor in the State of New York (1877), as an assistant engineer with the New York and Harlem Railroad (in 1878), and as an assistant engineer with the Mississippi River Commission (1879–96).

During the 17 years he spent with the Mississippi River Commission, his irrepressible talent for invention was continually in evidence. In 1882 he invented the Price current meter, which will be discussed later, and in subsequent years he invented many devices for building levees and for protecting the banks of the Mississippi from erosion.[4]

As though he felt remiss for not having invented anything of importance during the year in which he had worked for the New York and Harlem Railroad, he conceived and patented a "Street Car Fare Box." Patents for that device were awarded to him in 1885 (319,333 on June 2 and 326,778 on September 22). "That box," he later observed, "stopped horse-car drivers from stealing fares on many railroads." It was the first of his inventions to be patented, and modern streetcars and buses still use his fare boxes.

There can be little doubt but that Price's fare box produced a favorable impression on officials of the Chicago City Railway Company, because from 1896 to 1898 he held the position of chief engineer in that company. There, as one might expect, he brought forth a completely new series of inventions. Among them were his "momentum electric car brake" for streetcars, which has been used extensively, and his "automatic railway track-testing car" which, when moved at ordinary train speeds, produced a graph showing any defects that might be present in the tracks. In addition to the Chicago City Railway Company, the Northern Pacific and other railway companies have made much use of these inventions.

His next employment was with the Peckham Manufacturing Company. As chief engineer there between 1898 and 1903, he improved trucks for railway cars of all types. He also improved heavy-duty snow plows for clearing railroad tracks; these were manufactured under the name "Ruggles Rotary Snow Plow." The following advertising claims were made for the plow:

> Strong, durable, and always ready.
> Requires fifty percent less power.
> No brooms to keep in repair.
> Cost of maintenance ninety percent less than any other plow.
> Works equally well in light or heavy snow.
> The only snow plow capable of removing deep bodies of snow.

Patents, however, did not absorb all of Price's attention. He was gifted with a spirit of adventure that occasionally refused to be suppressed; back in the 1880's, while working among the bayous of the lower Mississippi, stories were rampant about gold and other treasures that supposedly were buried there by the well-known pirate, Jean Lafitte. With the aid of an Indian guide who boasted of having a map that showed the location of Lafitte's $10,000,000 buried gold cache, Price took part in one of the numerous, fruitless searches for that treasure.

When he was 50 the lure of gold again beckoned him, but this time to a more sophisticated adventure. To prepare for it, he attended classes in metallurgy, chemistry, and assaying at Columbia College in New

[4] An example of the latter is found in U.S. patent 528,891, dated November 6, 1894, which Price received for inventing a "machine for building embankments."

York. Thus prepared, he undertook the adventurous job of equipping the old Fentress gold and copper mine about nine miles due south of Greensboro, North Carolina, with operating machinery. That mine, sometimes called the North Carolina mine, was the first one in that State to have been worked for copper. Although the mine is known to have been reopened in 1903, 1904, and again in 1906, the newspaper article which described Price's venture did not reveal what success was achieved through his efforts.

Before the end of 1903, Price's fame as an inventor had reached the attention of officials in the Standard Steel Car Company of Pittsburgh, and he was appointed designing engineer for one of their special subsidiaries. Regarding that experience Price later wrote:

> I was employed during a period of ten years in the interest of Andrew Mellon, now Secretary of the U.S. Treasury, under a salary and royalty contract, to invent improvements in railway equipment. He incorporated the Standard Motor Truck Co., especially to manufacture and sell my inventions. I placed with that Company, on royalty, 34 patents,—and the resulting royalties have been coming to me during the past 23 years.

Many of the motor trucks which Price designed were of the type used on streetcars. His scrapbook contains a photograph of one of them with the following note, in his handwriting, below it:

> Car at Niagara Falls equipped with W. G. Price's power brake. President McKinley looking out of the window.

By 1913, the condition of Price's heart caused him considerable worry, and he yearned for the smell of clean, fresh air. Moreover, he missed the companionship of his only living son, William Kelley Price, whose inventive talents almost equaled his own and who then lived at Selah, a few miles north of Yakima, Washington. Price joined his son there and had hardly settled down when the old urge to invent seized him. Among the problems that intrigued him first were those related to packing dried apples into shipping boxes. Dried apples, being spongelike in nature, were hard to keep compressed within a 50-pound box while the workman tried to nail the cover onto it. An unidentified newspaper clipping in his scrapbook contained the following report on that subject:

> Dried apples were shoveled into a 50-pound box and then tramped down by the feet of the workmen, who wore clean rubber boots. More apples were then forced into the box by a hand press having a lever ten feet long. Evaporated apples are like rubber, and when the hand press was removed, they followed it like a "jack-out-of-the-box," and quick work was required to get the cover in place . . . .
>
> In the interest of efficiency and cleanliness, Mr. Price devised an electrically-operated power press which eliminates the foot tamping and which forces the apples into the box with a pressure of twelve tons. So great a pressure forces out much of the expansive air, making it easier to lid the box, and making it possible for one man to do all the boxing for a good sized plant.

Another invention pertaining to the fruit industry on which he and his son collaborated was a "Fruit Sizer." In one version of these sizers, apples were fed in a single row into a pocket at the end of a spring-actuated lever. Upon coming to rest in the pocket, a tripping device released the lever and the apples catapulted into one of a series of cloth bins, where they were caught gently and rolled without damage into separate wooden troughs, from which workers transferred them into shipping boxes. The smallest apples, being lightest, would be catapulted into the farthest bins; medium-sized apples would fall into the intermediate bins; and the largest apples would drop into the closer bins.[5] This apple sizer received a Highest Award for fruit-grading machines at the Panama Exposition in San Francisco in 1915.

In about 1754 Horace Walpole coined the word "serendipity"—an aptitude for making discoveries accidentally—which might well apply to the invention of Price's apple sizer. The circumstance was described in an article entitled "Latest in Apple Sizing Devices" in a September 1913 issue of the Yakima *Daily Republican*. It stated in effect that apples are sometimes plagued with a self-explanatory condition called water core. Because of excessive water, apples so afflicted are heavier than healthy apples of the same size. When graded with the Price apple sizer, those apples afflicted with water core fell into one of the closer bins intended for the larger apples. Their noticeably smaller size made it easy for packers to identify them and cull them out. Fortunate, indeed, are inventors like the Prices who are gifted with "serendipity."

At the age of 70, Price was still maintaining a consulting-engineer office in Yakima and supervising the Price Manufacturing Company, where he gave his

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[5] See U.S. patent 1,288,184, dated December 17, 1918.

attention to inventions as modern as drift-evaluating devices for airplanes.

Price obtained over 100 patents on his inventions during his career. At least two of them were awarded after his death. Perhaps the most eloquent testimony to the excellence and practicality of his inventions is that contained in the following telegram, preserved in one of his scrapbooks:

Webster, Mass. Nov. 8, 1904

Mr. W. G. Price, Mgr. Elec. Truck Dept.,
Standard Steel Car Company, Pittsburg, Pa.

Dear sir:

We have operated for six months your truck 0 50; can find no defects in same; it rides perfectly. Cost of maintenance nothing. Braking attachments superior to any we ever had in operation. You may write any testimonial you desire and sign my name to same, also same for Mr. Meller.

Yours truly,
Signed: J. D. Potter, Supt.
[The Consolidated Railway Company]

Price's success at improving street cars led him and his son to play with the idea of designing a complete automobile. They did not go ahead with that idea, however, because Price had a strong belief that automobiles would never be more than "just a rich man's plaything." "Too bad," his grandson wrote 40 years later. "Between the two of them, they could have built quite a car!"

Large Price Current Meters

Of all Price's inventions, those that most held his interest and attention throughout his long engineering career pertained to his current meters. Four patents on such meters, scattered over a period of 41 years, were issued to him. He wrote numerous articles about them for trade and scientific magazines and took an active part in discussing them at such meetings as those of the American Society of Civil Engineers, the Western Society of Engineers, and the American Association for the Advancement of Science, in all of which he held membership.

The year 1879 was an especially eventful one for Price. That was the year when the Mississippi River Commission was established, when he found employment with that Commission, and when he married Mary R. Kelley. His first station of duty under the Commission was at Plum Point, Tennessee, a loop in the Mississippi River opposite Osceola, Arkansas. There, under the general supervision of the famous engineer, James B. Eads, Price assisted in transferring

Figure 3.—Rod floats similar to those used by Price at Clayton, Iowa, in 1881. (From Frederick Yancy Parker, "Mississippi River Gagings by Rod Floats," *Professional Memoirs, Corps of Engineers, United States Army*—1913, vol. 5.)

the configurations of the Mississippi River onto a map of the United States. He also helped to determine the height, up to 10 feet, of sand waves which moved along the bottom of the river at a rate of "many feet per day." But most important of all, he helped to measure the discharge of the river. Those were probably the first river-discharge measurements in which he ever participated.

Those early investigations at Plum Point did not last very long. Before the end of 1879, the entire party was forced to evacuate the area and flee to St. Louis because an epidemic of yellow fever had broken out in Memphis. In an old syndicated newspaper article, Dr. W. A. Evans mentioned that epidemic in the form of a conversation between an old man and his grandson:

> I lived in Memphis in 1879. I saw the people stampede in wild flight when yellow fever comes. There were less than 10,000 left in the city, and they stayed only because they could not get away . . . guards shot down refugees trying to escape the plague-stricken city . . . wagons stacked high with bodies of victims were driven to the

Figure 4.—Ellis current meter of the earliest type such as that used by Price at Clayton, Iowa, in 1881 and Paducah, Kentucky, in 1882. (USNM cat. no. 317669; photo taken by author.)

> cemetery . . . no trains and no business . . . hungry men and women went into abandoned stores and took what they wanted. All of this in the latter half of the last century.

From St. Louis the fleeing survey party proceeded to Mound City, Illinois, on the Ohio River, close to its confluence with the Mississippi. There it remained until the yellow fever epidemic subsided.

By October 12, 1880, Price was placed in charge of a stream-gaging party with headquarters at Clayton, Iowa, on the Mississippi River. His was one of several such parties the Commission organized for obtaining records of discharge, slope, and sediment movement in the upper Mississippi River. The other parties were located at Prescott, Wisconsin; Winona, Minnesota; Hannibal and St. Louis, Missouri; and Grafton, Illinois.

The devices then available to Price's party for measuring stream velocities were rod floats similar to those shown in figure 3 and an Ellis current meter similar to that shown in figure 4. In his official report of May 10, 1883, to the Mississippi River Commission, Price described the work he and his party had performed with these devices as follows:

> During the entire (1880–1881) season, 222 velocity observations [i.e., discharge measurements] were made, of which 85 were with the meter, and 137 with rod-floats. Besides the regular velocity observations for discharge, there were taken 36 sets of vertical observations . . . . Until the breaking up of the ice on March 29, 1881, all of the velocity observations were measured with the meter. After the ice stopped running, April 12, 1881, all of the velocity observations were taken with the rod-floats, used in connection with the plant.

Price's party remained at Clayton, making streamflow measurements on the average of about one in every two days from December 7, 1880, to October 24, 1881.[6]

During the winter months of 1880–81, Price rated his Ellis current meter six times. The expression "rating a current meter" refers to the operation whereby the meter is moved through still water at many different speeds with simultaneous observations made of the rate at which its impeller (sometimes called the meter's rotor—the instrument's primary moving part) revolves. An electrical contact, which occurs at each revolution or in some instances at every fifth revolution, actuates a counting device which facilitates counting those revolutions. From the data thus obtained, rating tables are prepared which show how many revolutions are made by the impeller within a selected period of time when the meter is moved through water at *any* velocity. Although such data are usually obtained while moving the meter through still water, the same results would be produced if the meter was held still and the water was moving, under which conditions the meter is used in the field.

[6] The results of those measurements are published on pp. 2243–2248, vol. 2, part 3, of the Report of the Secretary of War, 48th Congress, 1st Session, House of Representatives Executive Document no. 1, part 2, 1883 (serial 2185).

To measure the velocity of water flowing at any point in a stream, the hydrographer need only position his meter at the desired point and count the number of revolutions the impeller makes during whatever period of time is provided for in the table—usually 40 to 70 seconds. He can accomplish that operation either by making an actual count of the clicks he hears in a headphone connected to the meter or by the method used by Price, namely, using an electric register, the early expression used to describe an electrical counter. After determining that figure, he would consult the rating table to determine the magnitude in feet per second of the water's velocity at the point where his meter was positioned. Many velocity observations are needed because of the variations in velocity which prevail throughout the cross section of every stream. The velocity is usually highest near the surface at midstream; from that point, it gradually becomes slower and slower as the bottom and sides of the streambed are approached.

During the past 40 or 50 years, most of the Government-owned current meters have been rated at the National Bureau of Standards. Such service was not available to Price in 1880, so the method he used under exceptionally trying circumstances is of considerable interest. Here is the description he wrote for the *Journal of the Western Society of Engineers*[7] on how six ratings of his Ellis meter were made on cold days during the winter of 1880–1881:

> The meter was first rated in a lake of still water, through the ice. To do this successfully, an opening should be cut in the ice one foot wide and 250 feet long. The meter should be attached to its rod and weight, and suspended two or three feet below the ice from a sled which straddles the opening, and which carries the observer with his battery, register, and stop watch. The ice must be made level where the sled runners are to pass, so the meter will be carried without any up and down movement. A base line of 200 feet should be measured along the opening, and each end should be marked by a range made by two flags at right angles with it. The sled should be drawn back and forth at low, medium, and high velocities, the stop watch and register being started on the first range line and stopped on the second. Several ratings like this were made by the writer during the winter of 1880–1881.

In the same article, Price also described how he had made his measurements of streamflow when the river was covered with ice:

> [A house was built] just large enough for one man to sit inside, leaving room at the end for a very small stove,—and room at the other end to lower the meter into the water through a trap door. The sled had board runners, curved to run forward and back, and had a rope at each end to draw it by. The house consisted of a light wood frame, which was covered on sides and top with heavy canvas, and had a canvas door, all of which was given a coat of linseed oil. A reel near the roof, at one end, carried the steel meter-suspending rope and insulated wire. The shaft of the reel passed through the side of the house, and there was a crank-ratchet and pawl on the outside. The suspending rope and insulating wire were connected with copper rings on the reel, and springs made contact with these rings and completed the electric circuit to the meter, register, and battery. Two men were required to measure the discharge, one to sit inside and record the soundings, registrations, and time,—and the other to cut holes in the ice, draw the sled, feed the fire, and turn the outside crank when the meter was to be raised or lowered. Holes were cut in the ice in a line across the river, and measurements were taken at mid-depth, for the discharge. Many vertical velocity measurements were also taken, so as to determine the correction required to reduce the observed mid-depth velocity to the mean velocity.

Soon after October 24, 1881, Price's party of stream gagers left Clayton for similar work on the Ohio River at Paducah, Kentucky. By December 22 he had established a gage there and had selected a suitable section in the river for making discharge measurements. During the following month, January 1882, Price conceived the design of his first current meter. The circumstances relating to his invention were described in a letter he wrote on April 20, 1927, to Nathan C. Grover, then chief hydraulic engineer of the United States Geological Survey:

> In January, 1882, I began measuring the discharge of the Ohio, at Paducah, Kentucky, under orders of Captain Smith S. Leach, Corps of Engineers, U.S.A., who was Secretary of the Mississippi River Commission. My equipment included a meter which was designed by General Ellis and another which was designed by Clemens Herschel.
>
> The Herschel meter was of the propeller type, having a horizontal shaft,—and there were no means for excluding water from its bearings.
>
> The Ellis meter had a cupped wheel which revolved in a horizontal plane,—and there was no provision for excluding water from its vertical-shaft bearings.
>
> I rated these meters in clear, still water, and the plotted ratings indicated that they would give accurate measurements.

[7] William G. Price, "Gauging of Streams," *Journal of the Western Society of Engineers* (1898), vol. 3, p. 1026.

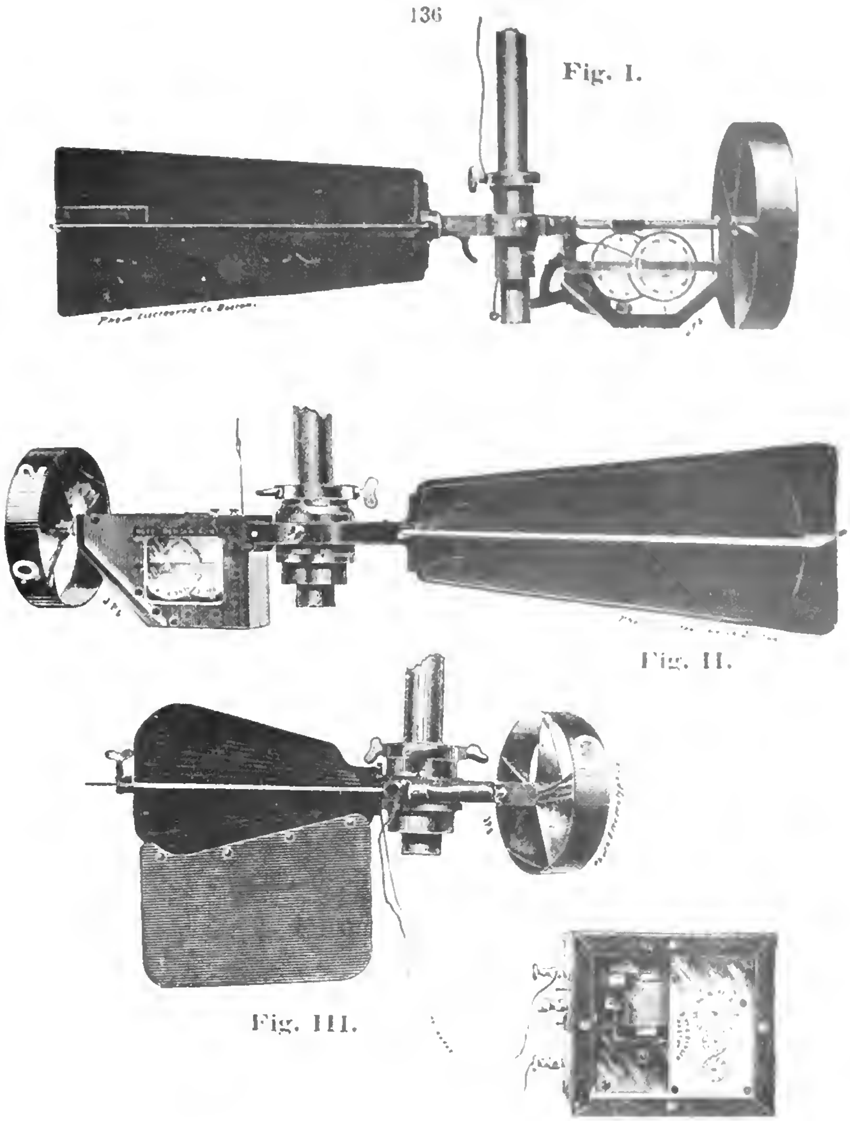


Figure 5.—HERSCHEL CURRENT METERS as illustrated in the 1879 edition of Buff and Berger's catalog.

I then began using them for river measurements. The water was very muddy, and boils in the swift current carried fine sand to the surface which I caught in my drinking cup. Neither would give discharge measurements which corresponded with the gradual increase in gage.

I then rated both meters in a bayou which had been recently filled with muddy water from the river, and the rating dots were irregular in location. Some dots indicated an increase of friction in the wheel bearings.

I then rated the meters in a smooth-flowing chute, carrying sand and fine silt from the river. The meters were moved alternatively upstream and downstream. These ratings were very inaccurate, indicating the effect of grit in the bearings.

I then wrote to Captain Leach that using these meters, I was unable to secure discharge measurements which at all corresponded with the daily increase in stage. The river was having a slow continuous rise. I asked Captain Leach to send me a meter which would give accurate measurements. The next day at 5 p.m. I received the following telegram: "Have no meter to send you. Do the best you can."

Almost immediately the idea occurred to me that by

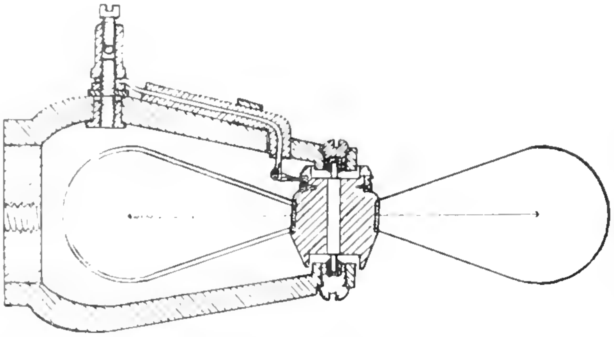


Figure 6.—CROSS-SECTIONAL VIEW of the original Ellis current meter. (USNM cat. no. 317669.)

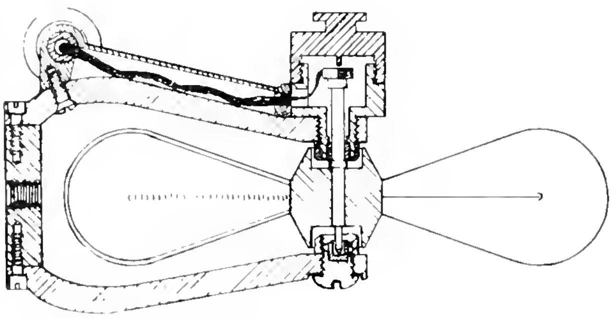


Figure 7.—CROSS-SECTIONAL VIEW of later Ellis current meter. (USNM cat. no. 289637.)

using inverted cup bearings, which would trap air, I could exclude the water and grit. I made drawings for such a meter that night, and by employing four mechanics, the meter was completed the next day at 3 p.m.

This meter was used for measuring the great flood of that year, 1882.

In other documents, Price revealed that in the group of mechanics he had hired, one was a tinsmith, another a blacksmith, and a third a locksmith. They were "the best mechanics in town." The actual current meter constructed on that occasion is shown in figure 2.

Price's criticism of the Herschel current meter was thoroughly justified. Three types of these meters are shown in figure 5. The impellers, which consist of four fan-shaped blades surrounded by a circular metal band, are likely to catch submerged grasses and leaves which inevitably impede its normal rotating action, and this, together with the troubles created by the silt and grit which add friction to the bearings, overrules any otherwise excellent features that such meters might possess.

Price's criticism of the Ellis meter was also valid. Cross-sectional views of the heads of the two earliest versions of the Ellis meters are shown in figures 6 and 7. It will be noted that in both of these figures the lower bearing is shown to consist of a pivot pointing downward into a cup-shaped receptacle that is in an ideal position to collect silt. Figure 7, illustrating a meter provided with a contact chamber, shows a further unsatisfactory condition. As the meters are lowered into water, the consequent increase in pressure causes the air within the chamber to compress, and silty water is forced upward through the bearing into the chamber. Once inside, the water becomes quiet, and the sediment settles out and lodges around the upper end of the bearing. When the meter is raised out of the water, as is frequently the case during the course of a streamflow measurement, the water drains out of the contact chamber, but the sediment tends to cling to and remain on the bearing. Every time the meter moves vertically downward while in a river, more silt-bearing water enters the chamber, adding in turn an additional load of silt in the area from which it should be excluded.

The drawing in figure 8 shows how Price managed to cause the open ends of both cup-shaped bearings to point downward. When this meter moves downward

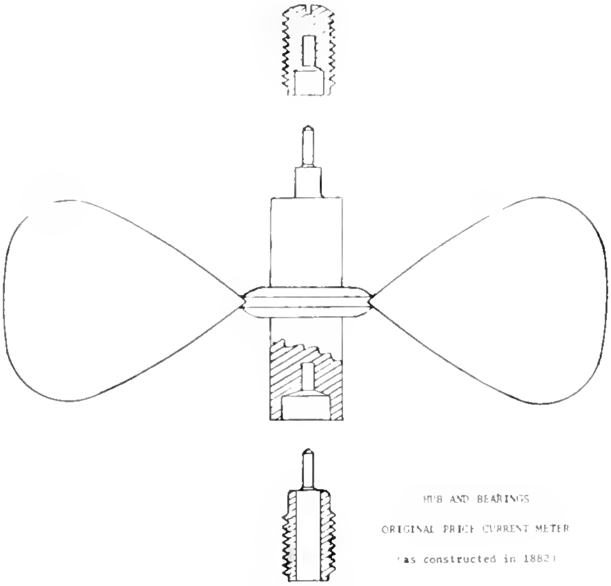


Figure 8.—CROSS-SECTIONAL VIEW OF HUB of the original Price current meter showing the arrangement by which the air was trapped in the bearing areas when the meter was submerged.

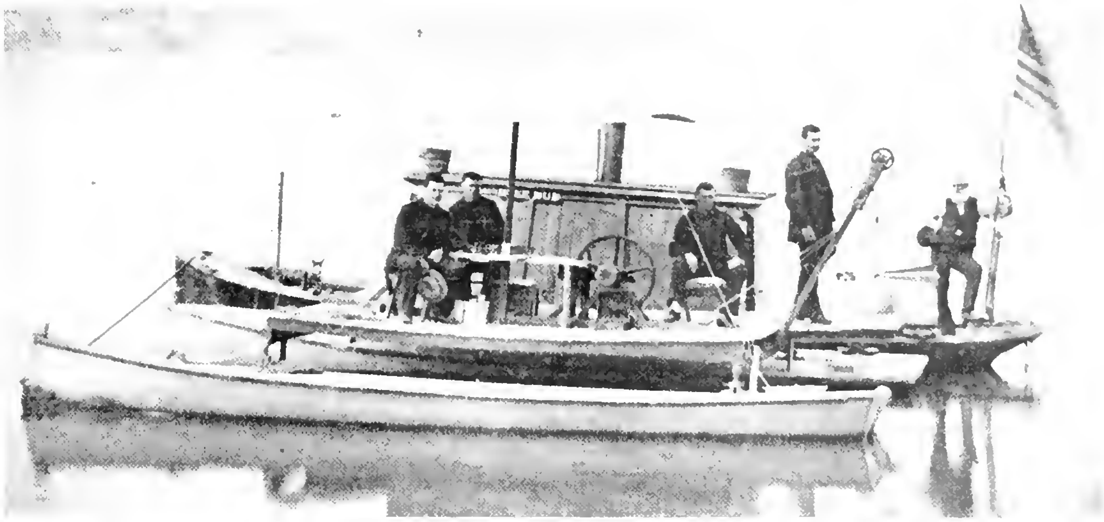


Figure 9.—Price's stream-gaging plant at Paducah, Kentucky, in 1882. Crew, from left to right: Dorst, Hoyt, McDonald, Price, and Hill. Note meter between Price and Hill. (Photo from scrapbook of W. G. Price.)

in water, air becomes trapped in the cavities which surround the pivots, preventing silt-laden water from reaching the bearing areas. The drawing in this figure was based on the earliest model of Price's meters; his later models contained even larger air traps, the particular feature that characterizes all Price-type current meters. The provision of such air traps was the specific idea for which his first current-meter patent (325,011) was granted on August 25, 1885.

Price's original current meter, identified as Price No. A, was first placed in service at Paducah, Kentucky, on the Ohio River, between two and three miles below the mouth of the Tennessee River, on January 24, 1882. The plant, a catamaran which was towed from one position to another by the launch *Rose Bud*, which Price had used at Clayton, Iowa, for handling rod floats, was outfitted with reels for handling the new current meter (fig. 9). News about Price's current meter spread quickly among the stream gagers who worked for the Mississippi River Commission, and they seemed to have been favorably impressed by it. By February 1883, Price had built a second model, No. B, which was placed in service during that same month at Carrollton, Louisiana, near New Orleans, and was exhibited at the United States World's Industrial and Cotton Centennial Exposition (December 16, 1884, to June 1, 1885) in New Orleans.

After finishing the construction of current meter No. B, Price began building additional meters for sale on a commercial basis to the Corps of Engineers and others. These he started to number consecutively, beginning with no. 1. By July 1885 he had sold 11 of them, mostly to the Corps of Engineers. In Price's letter of January 14, 1885, to W. & L. E. Gurley, he tried to induce that firm to take over the manufacture of his current meters. The letter stated in part:

> It is a great trouble to me to find a machinist who can make them, and I have been obliged to do all of the fine work myself. I wish you would undertake the manufacture of these instruments and furnish them to the U.S. Government at a reasonable price. The instruments cost $40.00 to make, which is the value of material and cost of machinist's labor at $5.00 per day. You can make them for less money.
>
> I want a royalty of $25.00 on each, and would require you to sell them for not more than $100. If you accept this offer, I will have the instruments patented . . . and any orders I receive for them I will send to you.

Subsequent events show that the firm of W. & L. E.

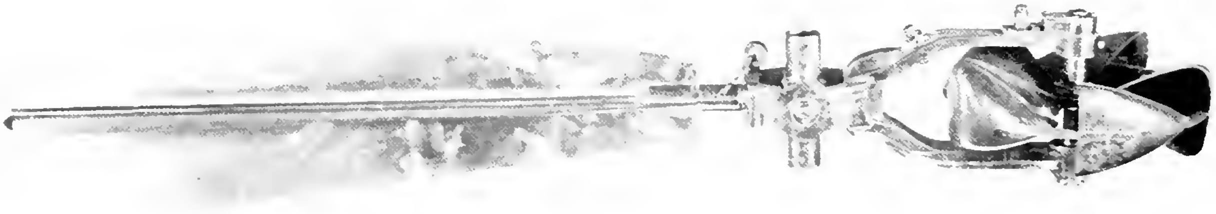


Figure 10.—Large Price current meter (35 inches long), model no. 375 in Gurley's early catalogs. (USNM cat. no. 311708; Smithsonian photo 44538-D.)

Figure 11.—Large Price current meter (24 inches long), model no. 376 in Gurley's early catalogs but no. 600 in later ones. (USNM cat. no. 289642; Smithsonian photo 44538-G.)

Gurley accepted the offer and that by July 1885 they had begun handling whatever orders for meters Price received. In fact, they seem to have taken over the remaining supply (about 4 or 5) of the 16 meters that Price had manufactured up to that time and sold them for him.

A common criticism of the early Ellis meters was that they were too fragile for use on large rivers. In his meters Price had attempted to combat that criticism by making them much larger and far more rugged than the 18-inch Ellis meters. His original meter was a little over 32 inches long. Gurley's first production model (their catalog no. 375) was even longer—35 inches. Both were made of much heavier materials than were the Ellis meters. Price's theory seems to have been that large rivers required large current meters, and the first models built by both Price and Gurley complied with that theory.

Before Gurley's first production lot of the no. 375 current meters was completed, Price decided that a smaller meter might be easier to handle when measuring small streams. When, therefore, the Gurley firm introduced its new line of Price meters in 1887, that line consisted of two models (figs. 10 and 11)—the 35-inch model with a 7½-inch-diameter impeller (catalog no. 375) and a 24-inch model with a 6-inch-diameter impeller (catalog no. 376). In both instances, the impellers had five cups.

Between the years 1887 and 1896, when a change in Gurley's model-numbering system went into effect, that firm sold 45 Price current meters, 19 of which were of the larger size (catalog no. 375), and 26 of which were of the smaller size. Of the large meters, 14 were sold to the Corps of Engineers, 1 to Columbia College School of Mines, New York City, and 4 were sold in Canada.

Influences of Irrigation and of The U.S. Geological Survey

Two circumstances appear to have had a strong influence on the design and construction of Price's next current meter, his Acoustic model: the intense interest in irrigation that had arisen, particularly in Colorado, Nebraska, and California, and the advent of stream gaging as one of the functions of the United States Geological Survey.

Edwin S. Nettleton, a graduate of Oberlin College, Ohio, who was serving his apprenticeship as a civil engineer under Zacharia Dane, was among those who heeded Horace Greeley's slogan, "Go West, young man, and grow up with the country." Nettleton born on October 22, 1831, joined Greeley's Union Colony when it migrated to the Cache la Poudre Valley and founded the town of Greeley, Colorado. As the colony's engineer-in-chief, Nettleton laid out the town, surveyed the farms, and planned the irrigation system. In March 1883 he was appointed state engineer of Colorado, an office he held for four years. During his first year in office, he designed a current meter. In his biennial report for 1883–84 he remarked:

> At first the Fteley current meter was used for measuring current velocity, but it was soon apparent that this instrument was entirely too delicate for the rough torrents, filled with drift of all sorts, in which it was necessary to use it. *An instrument was designed by me more suitable to the work (named the "Colorado" current meter)*[8] a description of which is given elsewhere. The main object kept in view in designing this instrument, was to make it self-clearing, the great defect of the Fteley meter being its liability to error from clogging with grass, weeds, etc. which at times would vitiate many hours' work . . . . Three "Colorado" meters, having been made for this department by W. E. Scott & Co. of Denver; these instruments have since been in continuous use in gauging rivers and ditches giving entire satisfaction.

Photographs of Nettleton and of one of the current meters built by W. E. Scott & Co. are shown in figures 12 and 13 respectively. In addition to having been referred to as the Colorado and the Scott current meter, these or very similar meters also have been called the Nettleton meter, after their designer; the Lallie meter, named after one of its later manufacturers; and the Bailey meter, which was named after an associate of Lallie's who worked out the design wherein the exposed counting wheels were placed within a glass-covered enclosure. One of the Bailey meters, from the collection of the Museum of History and Technology, is shown in figure 14.

The early irrigation work performed in Colorado, Nebraska, and California demonstrated that there was a considerable need for a small current meter like Nettleton's that could be carried about easily and that was convenient to handle when used for measuring the flow of shallow streams. Moreover, beginning in 1888, when extensive stream-gaging programs were undertaken by the United States Geological Survey, the need for such meters became greatly enhanced. As a matter of fact, the impact of that Federal agency

Figure 12.—Edwin S. Nettleton, State engineer of Colorado who designed the Colorado current meter in 1883. (From "Eleventh Biennial Report of the State Engineer to the Governor of Colorado," 1901–02.)

on the design and general use of current meters was so great that a full discussion seems warranted here.

Although the Geological Survey was organized in 1879, with its first office provided by and situated in the Smithsonian Institution, stream gaging did not become one of its activities until President Cleveland approved a Sundry Civil Appropriations Act on October 2, 1888. That act provided $100,000 for the establishment of an Irrigation Survey. Within that Irrigation Survey was a sub-unit called the Hydrographic Survey, the main purpose of which was to obtain streamflow measurements in areas where the practicability of irrigation was likely to depend upon the quantity of available water.

Neither John Wesley Powell, then director of the Geological Survey, nor Clarence E. Dutton, chief of Powell's new Hydrographic Survey, were acquainted with suitable means for measuring such water supplies. Under Captain Dutton's orders, therefore, a party of young engineers was quickly organized and rushed to the tiny village of Embudo, New Mexico, on the Rio Grande about 45 miles north of Santa Fe, to determine the best manner in which to make such measurements

[8] Italics are the author's.

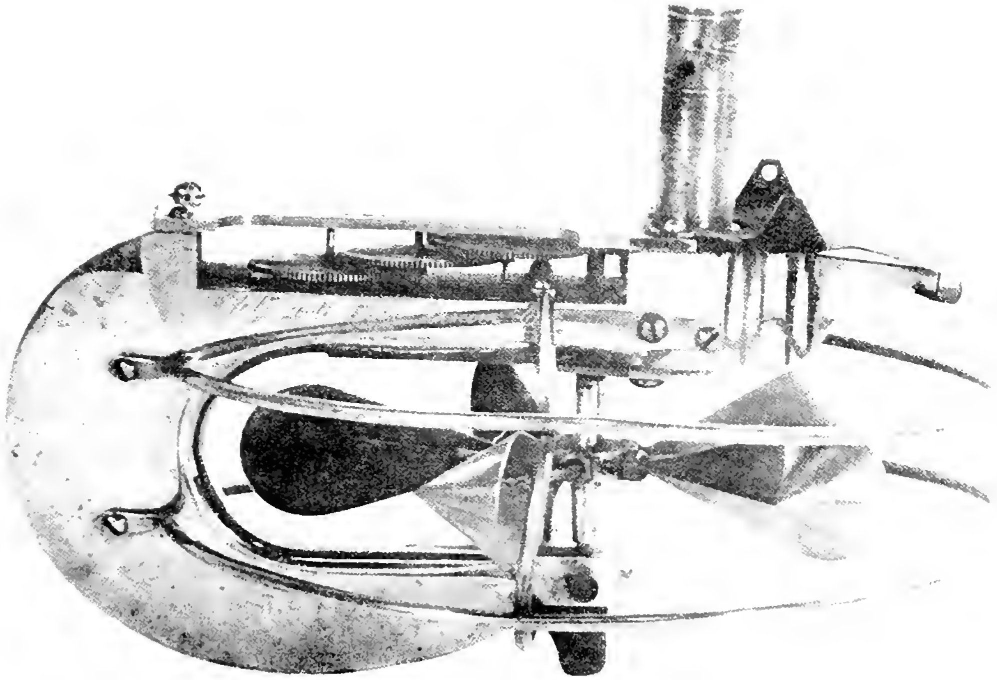


Figure 13.—Nettleton's Colorado current meter as made by W. E. Scott & Co., Denver, Colorado. (USNM cat. no. 289641; Smithsonian photo 44537–H.)

and to ascertain what instruments would be best for that purpose. Embudo is reported to have been selected by Powell because of his acquaintance with it from studies he had made of the Pueblo Indians in that area and because the river was a western stream, accessible by railroad, and situated in a canyon which was assumed to have a mild winter climate. The engineer placed in charge of that group of potential hydrographers was Frederick Haynes Newell, a graduate student from the Massachusetts Institute of Technology.

Arriving at Embudo during the early part of December 1888 and remaining there until late in April 1889, the party tried out all the known stream-gaging methods and tested practically all the different types of floats, current meters, and other streamflow measuring devices that they could build, borrow, or otherwise acquire within the allotted time. The Price models 375 and 376 meters apparently were either too scarce at that time or too large for use on the then-shallow Rio Grande to have been included in those trials. In fact, most of the actual discharge measurements made on that occasion were accomplished with Nettleton's Colorado meter (fig. 15).

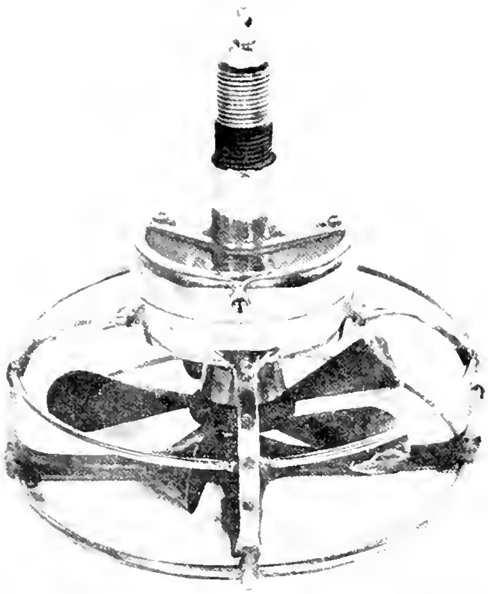


Figure 14.—Nettleton's Colorado current meter as improved by Bailey of Lallie & Bailey, Denver, Colorado, now in the Smithsonian's Museum of History and Technology. (USNM cat. no. 248696; Smithsonian photo 44538–A.)

Figure 15.—U.S. Geological Survey camp at Embudo, N. Mex., from 1888–89. Note Colorado-type current meter held at center of group. Frederick H. Newell, the chief of the party, stands, profile to camera, in the back row, holding a leveling rod. *(Photo courtesy of U.S. Geological Survey.)*

The act of Congress under which the Irrigation Survey had been created was interpreted by Major Powell as calling for a relatively quick reconnaissance of a huge area (some 1,300,000 square miles) of arid public lands and a subsequent report to Congress on the extent and location of the particular parcels on which irrigation appeared to be practicable and economical. As soon as the report was delivered, the purpose of the act was to have been accomplished, and any stream-gaging programs started under it would terminate automatically. Such being the circumstances, Newell found it necessary to write the following advice to all of the hydrographers in the Irrigation Survey on August 22, 1890:

> The Conference Committee finally came to an agreement yesterday. The bill provides (only) $325,000 for topography, one-half of which is to be expended west of the 101st meridian. By this, the Irrigation Survey is brought to a close as far as the engineering and hydrographic divisions are concerned.

The hydrographers then turned over their equipment, mules, and horses to the nearest topographic field parties and either sought new employment or were assigned to other duties in the Survey. Newell was one of those retained in the Survey's employ.

Except for a few special incidents, no stream-gaging activities were carried on by the Geological Survey for several years. Newell's salary was paid out of topographic funds, but his major activities appear to have been associated with exploiting as many of such special incidents as he was able to bring to light. A crisis occurred when Major Powell announced that he would resign as director of the Geological Survey on June 30, 1894. Charles Doolittle Walcott, who in 1907 became Secretary of the Smithsonian Institution, succeeded him. He found no justification for continuing hydrographic work out of the meager funds then available to the Survey and regretfully informed Newell to that effect. Newell, faced with the prospect of seeking a new job, made a determined effort to preserve his old job by promoting the enactment by Congress of a special appropriation of funds solely for stream-gaging purposes, a difficult undertaking since the nation was then in the second year of a financial depression. Despite the obstacles, he induced Senator William V. Allen of Nebraska, a state which then was keenly interested in stream gaging as an aid to irrigation, to offer an amendment to the pending Sundry Civil Appropriations Act (already passed by the House) providing a special item for stream-gaging operations in the amount of $25,000. The amendment was accepted by the Senate, but before approval the amount was reduced to $12,500. Newell, nevertheless, had accomplished his purpose and the funds—the first appropriation for the specific purpose of stream gaging granted by Congress—became available to the Geological Survey on August 18, 1894. With those funds, the Geological Survey reestablished its Division of Hydrography and appointed Newell, who in his career in the fields of hydrography and irrigation rose to such eminence that he has often been referred to as the father of systematic stream gaging, as its hydrographer-in-charge. From this small beginning has grown one of the world's largest organizations devoted to stream gaging. During the course of its existence, it has, incidentally, made use of several thousands of current meters.

The passage of the appropriation bill created a further renewal of interest in the design of current meters. Nettleton's Colorado meters, which had ranked high in popularity during the period when the old Irrigation Survey was in operation, were found subsequently to be "so delicate that the cost of repairs has become a serious matter, and on the score of economy it has seemed advisable to condemn them as they became worn."[9] When the Survey's newly established division of hydrography purchased additional current meters, the small Haskell type manufactured by E. S. Ritchie & Sons, of Brookline, Massachusetts, was most frequently selected. But that screw-type meter enjoyed only a brief period of popularity. The turning point occurred in March 1895 when Professor O. V. P. Stout of the University of Nebraska borrowed his University's model 376 Large Price current meter (Gurley's no. 37) and made a streamflow measurement with it—the first measurement ever to have been made with a Price meter in behalf of the Geological Survey. Stout, one of the Survey's per diem employees, seemed very much pleased with the meter's performance, and two months later the Survey acquired its first Large Price current meter. It was a second-hand model 376, Gurley's no. 55. It originally had been sold to the Montana College of Agriculture and Mechanical Arts on March 24, 1894, and the college sold it to the Geological Survey. It was rated May 27, 1895, at the Survey's rating flume at Denver, Colorado.

It is of interest to note that whereas the firm of W. & L. E. Gurley sold only 45 Large Price meters during the first nine years of their manufacture (1887 to 1895 inclusive) and those mostly to the Corps of Engineers, during the next nine years they sold 104. Of that number, 47 went to the U.S. Geological Survey and only 3 to the Corps of Engineers. This preponderance of sales to the Survey is likely to explain the special attention that Gurley subsequently gave to the Survey's suggestions for current-meter improvements.

Price "Acoustic" Current Meters

Price was the nation's foremost authority on current meters for probably a longer period than anyone before or after his time. Beginning in 1883, one year after inventing his first model, and continuing for ten years thereafter, he directed the discharge-measuring operations of the Mississippi River Commission. As part of those duties, he wrote the official instructions for making such measurements, for rating current meters, and for taking proper care of the equipment used for such purposes. One set of those instructions, which he personally prepared, is shown in figure 16. He also made special studies on subjects such as determining the shape of the vertical-velocity curve and the relationship between the velocity of the water at mid-depth in a stream to the average velocity throughout the entire depth at the same spot.

Another type of study which Price was especially qualified to perform is expressed in the following order, a copy of which was preserved in his scrapbook:

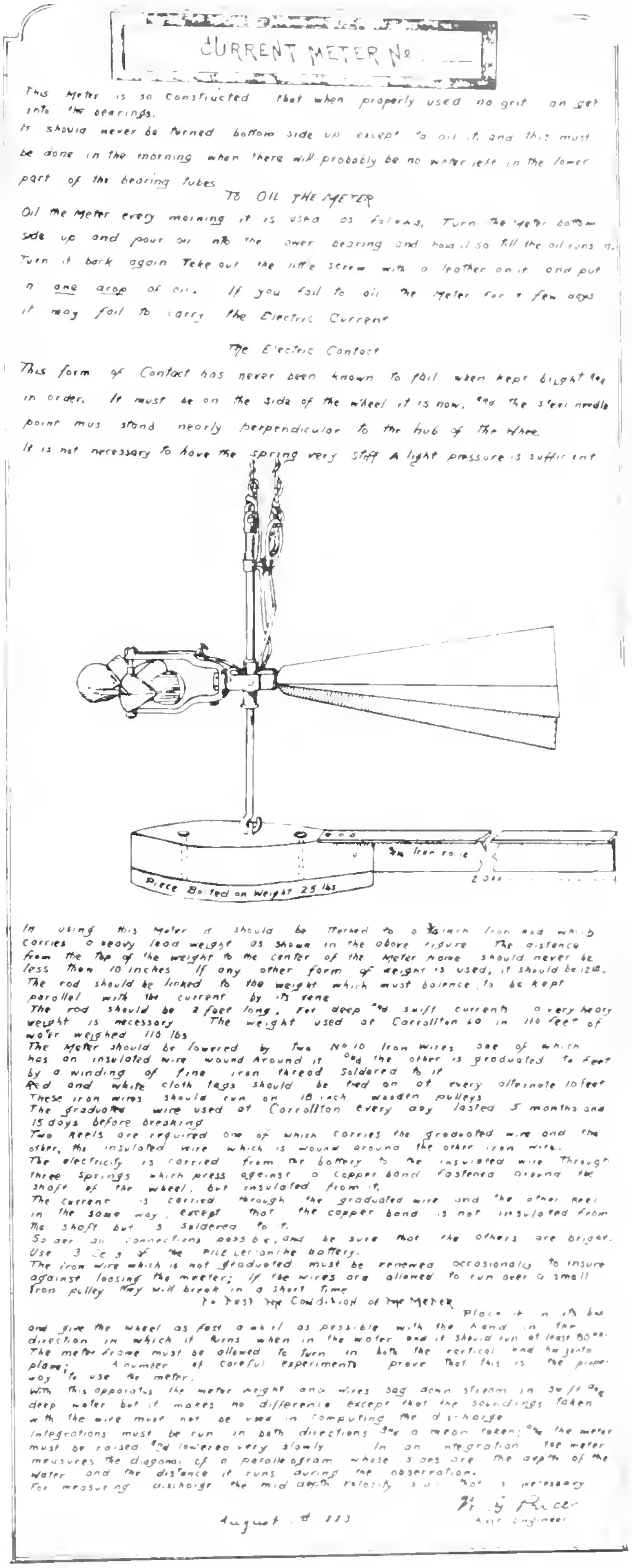
> It has been reported to me that there is probably a leak in the Missouri, near Great Falls, Montana. You will take the necessary instruments and assistants and go to Great Falls and determine if there is a leak, and if so, report on how to plug it.

Price's comment many years later (1927) was:

> I found the leak where the water seeps into the upturned edge of the Dakota sandstone, fifty miles long, through the canyon from Great Falls to Fort Benton. At extreme low water the leak was about 600 second feet. It probably is one source of supply for the artesian wells of South Dakota.

[9] Frederick Haynes Newell, *U.S. Geological Survey Bulletin 140* (1896), p. 15.

Figure 16.—Price's instructions on care of current meters. (*Photo courtesy of U.S. Geological Survey.*)


CURRENT METER No. ___

This Meter is so constructed that when properly used no grit can get into the bearings.
It should never be turned bottom side up except to oil it and this must be done in the morning when there will probably be no water left in the lower part of the bearing tubes

TO OIL THE METER

Oil the Meter every morning it is used as follows, Turn the Meter bottom side up and pour oil into the lower bearing and hold it so till the oil runs in. Turn it back again Take out the little screw with a leather on it and put in one drop of oil. If you fail to oil the Meter for a few days it may fail to carry the Electric Current

The Electric Contact

This form of Contact has never been known to fail when kept bright and in order. It must be on the side of the wheel it is now, and the steel needle point must stand nearly perpendicular to the hub of the wheel.
It is not necessary to have the spring very stiff A light pressure is sufficient

In using this Meter it should be fastened to a ¾ inch iron rod which carries a heavy lead weight as shown in the above figure The distance from the top of the weight to the center of the Meter frame should never be less than 10 inches If any other form of weight is used, it should be 12 in.
The rod should be linked to the weight which must balance, to be kept parallel with the current by its vane
The rod should be 2 feet long, For deep and swift currents a very heavy weight is necessary The weight used at Carrollton La in 110 feet of water weighed 110 lbs
The Meter should be lowered by two No 10 Iron wires one of which has an insulated wire wound around it and the other is graduated to feet by a winding of fine iron thread soldered to it
Red and white cloth tags should be tied on at every alternate 10 feet
These iron wires should run on 18 inch wooden pulleys
The graduated wire used at Carrollton every day lasted 5 months and 15 days before breaking
Two Reels are required one of which carries the graduated wire and the other, the insulated wire which is wound around the other iron wire.
The electricity is carried from the battery to the insulated wire through three springs which press against a copper band fastened around the shaft of the wheel, but insulated from it.
The current is carried through the graduated wire and the other reel in the same way, except that the copper band is not insulated from the shaft but is soldered to it.
Solder all connections possible, and be sure that the others are bright.
Use 3 cells of the Pile Leclanche battery.
The iron wire which is not graduated must be renewed occasionally to insure against loosing the meeter; if the wires are allowed to run over a small iron pulley they will break in a short time

To test the Condition of the Meter

Place it in its box and give the wheel as fast a whirl as possible with the hand in the direction in which it turns when in the water and it should run at least 80 sec.
The meter frame must be allowed to turn in both the vertical and horizontal plane; A number of careful experiments prove that this is the proper way to use the meter.
With this apparatus the meter weight and wires sag down stream in swift and deep water but it makes no difference except that the soundings taken with the wire must not be used in computing the discharge
Integrations must be run in both directions and a mean taken; and the meter must be raised and lowered very slowly In an integration the meter measures the diagonal of a parallelogram whose sides are the depth of the water and the distance it runs during the observation.
For measuring discharge the mid depth velocity is all that is necessary

W. G. Price
Asst. Engineer

August . . . 1893

While working on the Missouri River when still employed by the Mississippi River Commission, Price was selected to deliver a speech as a delegate from Iowa to an irrigation conference held on January 30–31, 1894, at O'Neill, Nebraska. The newspaper accounts of that event described him as an enthusiastic irrigationist.

With such a background and in such an environment, Price was quick to recognize the need for a meter, similar to that designed by Nettleton, with which to measure the discharge of shallow streams and irrigation ditches. According to his notes, he had conceived of a design for such a new meter as early as 1893, the year before the irrigation meeting took place at O'Neill. It was not publicly announced, however, until his article entitled "A New Current Meter, and a New Method of Rating Meters" appeared in the January 10, 1895, issue of *Engineering News*.

The Geological Survey was one of the earliest purchasers of the new meter. Its first purchase is recorded as follows:[10]

> No. 19. Small Price acoustic meter. Maker's No. 3. Purchased in June, 1895, and issued to W. G. Russell, Kansas.

On page 16 of the same document are the following comments:

> The little Price acoustic meter, lately introduced, has also been successfully used, even under unusual difficulties. The instrument has commended itself by its extreme lightness and its sensitiveness, and it has been found possible to employ it from bridges by suspension from the end of long rods made of gas pipe.

Although records show that Price had conceived its design in 1893 and that sales of this meter had already been made in 1895, he did not file an application for a patent on it until August 4, 1896. Patent 582,874 was issued to him as of May 18, 1897.

[10] Frederick Haynes Newell, "Report of Progress of the Division of Hydrography for the Calendar Year 1895," ibid., p. 339.

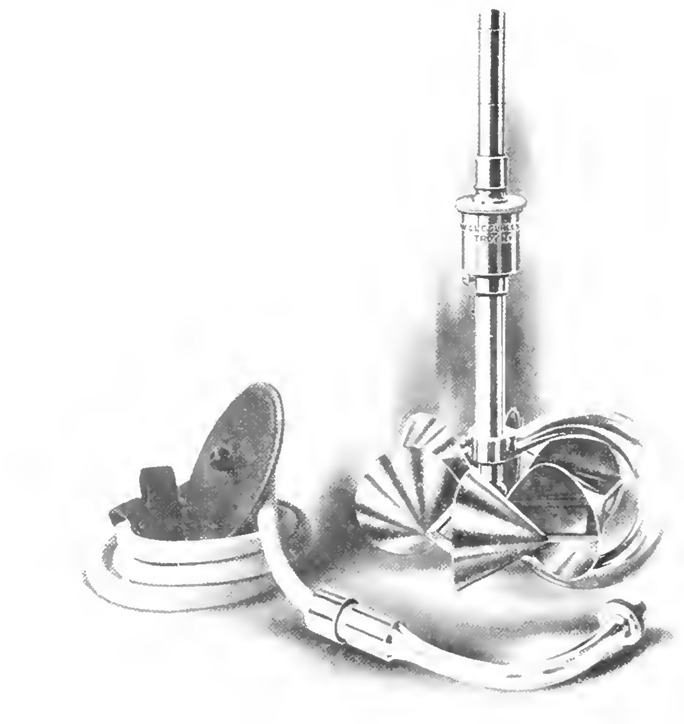


Figure 17.—The Price Acoustic current meter. (*Photo courtesy of W. and L. E. Gurley.*)

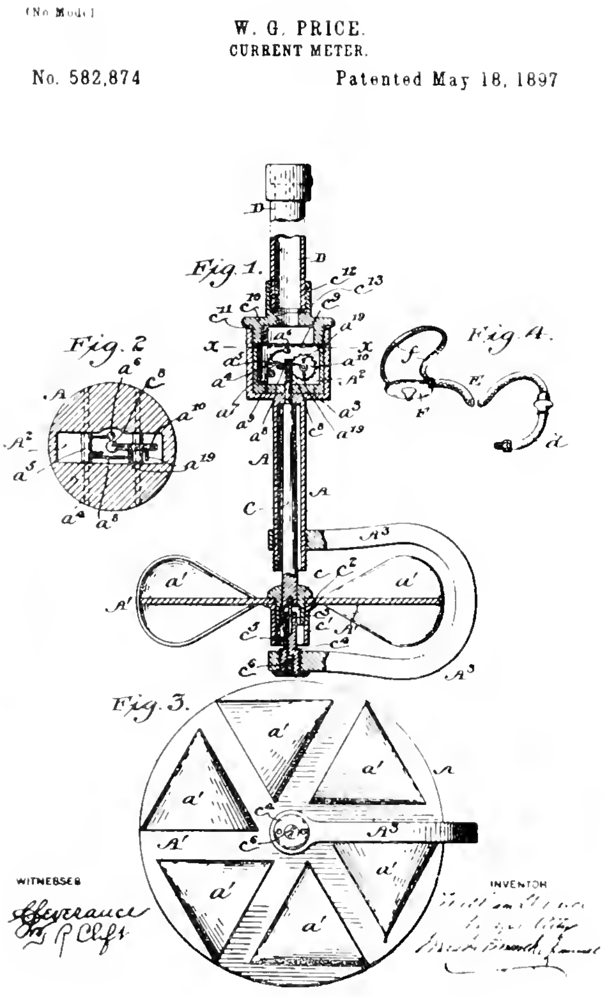


Figure 18.—Patent drawing for Price Acoustic current meter.

A photograph of a Price Acoustic current meter is shown in figure 17 and a copy of the patent drawing in figure 18. Its name was derived from the manner in which sound was conducted from the meter to the ear of the hydrographer. As the impeller revolved, a worm gear located within the enlarged section of the suspension rod caused its associated worm wheel to make 1 revolution for every 20 revolutions of the impeller (see figure 18). Projecting from one side of the worm wheel were two short pins, 180 degrees apart. Each pin, in its turn, caused a small, spring-actuated hammer to be pushed downward against the spring during 10 revolutions of the impeller. At the tenth revolution, the pin automatically disengaged itself from the hammer mechanism. The hammer then flew up and struck a diaphragm situated across the top of the chamber, thus creating a sharp sound. Then the second pin started depressing the hammer, and the process repeated itself over and over again as long as the impeller continued to revolve. The sound caused by the hammer striking the diaphragm every tenth revolution traveled upward through the hollow rod, then through a rubber tube to the earpiece worn by the hydrographer. The hydrographer thus could count by tens the number of revolutions made by the impeller during a certain period of time and convert the data, by means of a previous rating of the meter, into figures representing the velocity of the water in feet per second.

At the time when the Gurley firm started manufacturing this new meter, they adopted an entirely new numbering system for cataloging such instruments. On that occasion they announced that (1) the new acoustic meters were to be listed as their catalog no. 616; (2) the 24-inch Price meters (model 376) were

Figure 19.—Gaging car provided with blocks and tackles to facilitate using the Acoustic meter. (From U.S. Geological Survey Water-Supply Paper 56, pl. 9.)

to be renumbered as catalog no. 600; and (3) the manufacture of the 35-inch Price meters (model 375) was to be discontinued.

The Acoustic meter soon achieved a considerable degree of popularity, but either a Large Price or a Haskell meter had to be taken along on stream-gaging trips by field parties of the Geological Survey in order to enable them to measure the deep as well as the shallow rivers. Many attempts were made to adapt the Acoustic meter for deep-water observations so as to avoid that nuisance. In at least two instances, one of which is shown in figure 19, gaging cars were provided with blocks and tackles for lowering the entire car and its occupants almost to the water's surface. With such a facility it was possible to shorten the length of the gas pipe required for positioning the meter at the proper depth in the river, but this never proved to be wholly satisfactory.

First Small Price Current Meters

The division of hydrography of the Geological Survey had started early in its existence the practice of holding periodic conferences at which the problems of the field men were discussed and new ideas exchanged. Prior to the conference held in 1896, Newell requested that the resident hydrographers be prepared to submit suggestions for improving current meters. The suggestions received on that occasion led Edwin Geary Paul, the mechanician of the division, to design the first Small Price electric current meter. That design contemplated using a 6-cup impeller identical to those furnished on Acoustic current meters, in combination with a yoke, tailpiece, and electric contact facilities resembling the corresponding parts of the Large Price meters but built on a much smaller scale.

W. & L. E. Gurley collaborated with E. G. Paul in manufacturing a meter conforming with his specifications (fig. 20). Figure 21 shows Mr. Paul rating a later version of such a meter at the Survey's rating facility at Chevy Chase Lake, Maryland. Records in the Geological Survey's Water-Supply Paper 11 (1897) show that the new meter (Gurley's no. 1) had been assigned no. 91 in the Survey's meter-numbering system and that this meter had been purchased from Gurley as of November 12, 1896. E. G. Paul and C. C. Babb rated it on December 10 of that same year. The overall length of this new, custom-built, experimental meter was a mere 12 inches. Several improvements were suggested before a production lot was manufactured, and about six months later (June 28, 1897) the Survey made its first purchase. A drawing and a photograph of a meter from that lot (Gurley catalog no. 617) are shown in figures 22 and 23 respectively. This model soon became very popular. Within a short time its sales far exceeded the combined previous sales of both the early types of Large Price current meters.

Throughout all of the period during which the model 617 current meters were in vogue, the task of

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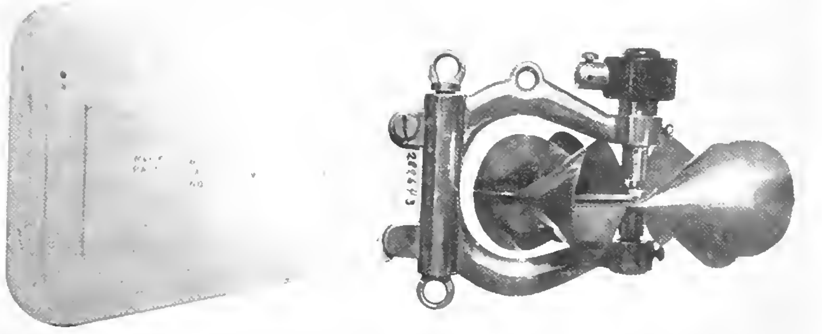

Figure 20.—ORIGINAL SMALL PRICE current meter designed by Edwin Geary Paul and constructed by W. & L. E. Gurley; now in the Smithsonian's Museum of History and Technology. (USNM cat. no. 289643; Smithsonian photo 44538–E.)

carrying two meters, one for wading measurements and the other for cable measurements, was accepted as a necessary evil. That circumstance was demonstrated by the decision to manufacture a new model (no. 618) exclusively for wading measurements as a companion to model no. 617 for cable measurements. The new model no. 618 had no tailpiece. In its earliest version (fig. 24) it was suspended by means of a wading rod screwed into the top of the contact chamber, in the place normally occupied by the contact-chamber cap. In a later version (fig. 25) the wading rods were screwed into a boss on the yoke. In both instances the electrical contact facilities were identical to those furnished in the 617 models.

Small Price "Combination Type" Current Meters

With the advent of the model nos. 617 and 618 Small Price current meters, the Geological Survey assumed practically all responsibility for any changes in the design of such meters. This was not strange or arbitrary because the Survey had become a world pioneer in conducting stream gaging on a systematic basis, and such an organization inevitably must take charge of the improvement of its own working tools. In any event, that was the prevailing attitude when John Clayton Hoyt of the Survey began to make his influence felt on the improvement of current meters and their accessories. Although Hoyt was not noted for possessing any particularly outstanding mechanical ability, he was quick to recognize and to act on good ideas when he saw or heard of them.

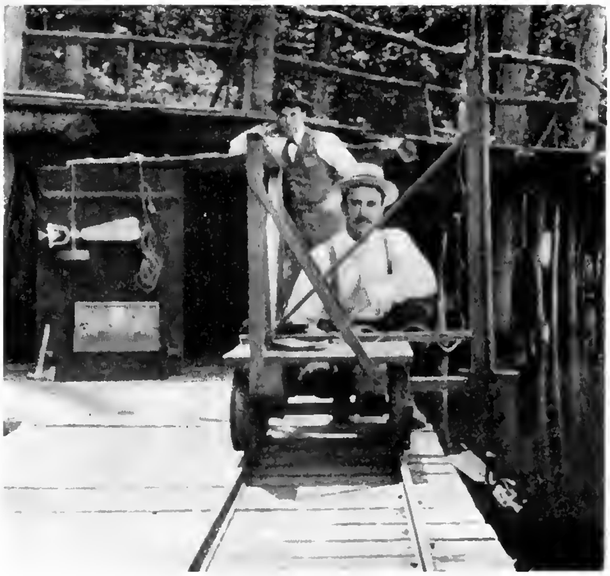

Figure 21.—E. G. PAUL (seated) rating a later model 617 Small Price current meter. (From U.S. Geological Survey Water-Supply Paper 56, pl. 12A.)

About the same time the Geological Survey sponsored the new-model no. 617 Small Price current meters, the use of electrical counters for evaluating the number of revolutions of the impellers began to lose favor. Newell reported that circumstance as follows:[11]

> The more experienced men . . . prefer to reduce their equipment to the simplest form, and, instead of reading

[11] U.S. Geological Survey, *19th Annual Report* (1897–98), p. 23.

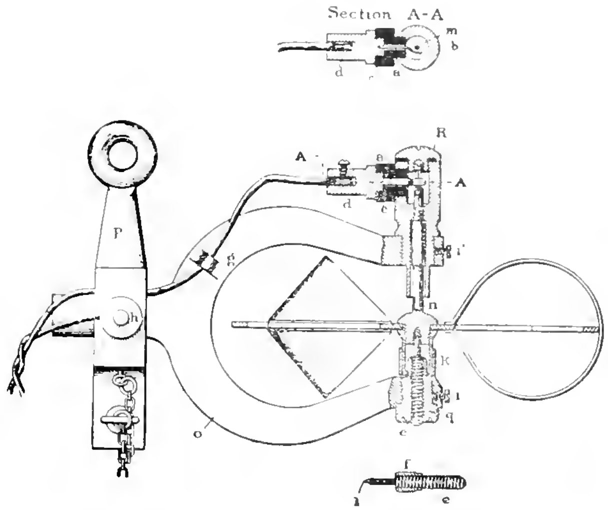

Figure 22.—Cross-sectional view of model 617 Small Price current meter. (From U.S. Geological Survey Water-Supply Paper 56, fig. 3.)

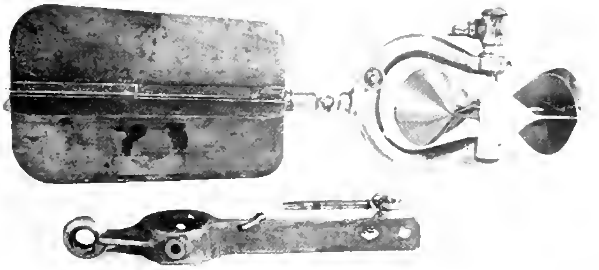

Figure 23.—Model 617 Small Price current meter, now in the Smithsonian's Museum of History and Technology. (USNM cat. no. 289644; Smithsonian photo 44538-F.)

dials, count the clicks made by the miniature sounder, keeping the time by watching the second hand of an ordinary watch while it marks off fifty seconds.

These two innovations—the adoption of the new meter and the abandonment of the electrical counters—brought about an unexpected difficulty, the solution of which fell on Hoyt's capable shoulders. In explanation of that difficulty, it should be mentioned that large-diameter cup-wheels on current meters, "much like large-diameter wheels on a wheelbarrow," to use a favorite expression of Hoyt's, revolve at a slower rate than small wheels. Hydrographers frequently found that during flood periods they were barely able to keep up with the count of the clicks

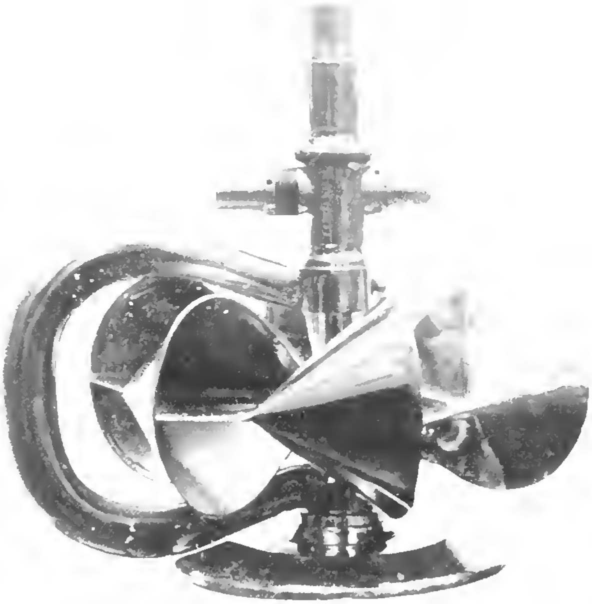

Figure 24.—Earliest version of model 618 Small Price current meter. (*Photo courtesy of U.S. Geological Survey.*)

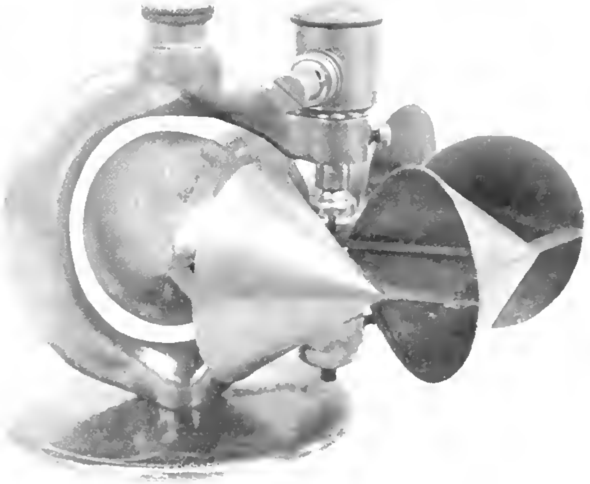

Figure 25.—Later version of model 618 Small Price current meter. (Photo taken by author.)

produced by even the large-diameter impellers of the Large Price meters. When, therefore, the smaller impellers were introduced on the new Small Price meters, their rate of rotation was so much faster that it was utterly impossible for the hydrographer to keep

Figure 26.—ORIGINAL MODEL of the 621-type yoke- and penta-contact chamber for use on Small Price current meters. Details of the inner parts of the contact chamber are the same as those in figure 27. The instrument is now in the Smithsonian's Museum of History and Technology. (USNM cat. no. 289645; Smithsonian photo 44538-B.)

up with them without an electric counter. That situation reached a climax at the second annual conference of the Survey's eastern hydrographers in January 1905. The minutes of that conference show that a recommendation was made to the effect that a current meter should be constructed for use in flood measurements that will record once every 5, 10, or 20 revolutions.

It may be remembered at this point that Price's Acoustic meter had an impeller with the same dimensions as those of the Small Price meter. No fault was found with it in this respect, because, as previously explained, that meter produced one click for every 10 revolutions of its impeller. With it, the hydrographer easily could count those revolutions by tens, even under the most severe velocity conditions. Its greatest fault, if any, lay in the opposite direction. While measuring extremely low velocities, the clicks were widely separated in time, and the hydrographer might have to wait several minutes before the first one occurred. Since many observations are needed during the course of a measurement, an unwarranted amount of his time would thereby be wasted.

Such circumstances prevailed when John Hoyt returned to Washington, D.C., in the fall of 1906 from Alaska, where he had just inaugurated the Territory's first stream-gaging program. The events which then took place are best described in the following extract of a letter dated April 5, 1932, which Hoyt wrote to Willard G. Steward:

> As I remember, when I returned from Alaska in the fall of 1906, you were engaged in designing a penta head [one which produced a "click" at the completion of every fifth revolution of the impeller] for the Small Price current meter. In discussing this matter with you shortly after I returned, it occurred to me that gearing similar to that used in the acoustic meter would give the desired results. The idea came from having used the acoustic meter in Alaska during the previous season. Following this suggestion, you made a model of a contact chamber in which you used a set of gears from an acoustic meter [and] provided [it] with contact points so as to indicate electrically. This arrangement gave satisfactory results, and a meter was equipped with this contact chamber and sent to W. & L. E. Gurley, who adopted the idea. In the meter which was sent to Gurley several other changes were made, including the substitution of sliding connections in the place of screw connections. The meter was designed so as to use either a single point contact chamber or the penta contact chamber, and was known as the combination meter.

Mr. Steward's reply contained a few suggested corrections to Hoyt's statement, namely that the model of the contact chamber actually had not been built by him but rather by "an old German model maker, Haverbach(?)." It also indicated that he and Hoyt had "designed the balancing weights for the tailpiece, and revised the locking mechanism [which had been designed originally by Maxie R. Hall of the Geological Survey] on the tailpiece so as not to lose half of the tail."

Both Steward and Hoyt overlooked mentioning two other important features that either of them might have been responsible for on this occasion. The first was a slot through the stem of the yoke, through which a flat hanger bar could be passed and used to support both the meter and one or more sounding weights. That facility reduced the cost and complexity of the hangers and greatly improved the streamlining of the assembly. The second feature was that of a sliding hanger used in connection with wading rods. It enabled the meter to be positioned conveniently at the desired depth below the surface when it was used for making wading measurements. Such sliding hangers made it possible, for the first time, for the same Small Price current meter to be used for making wad-

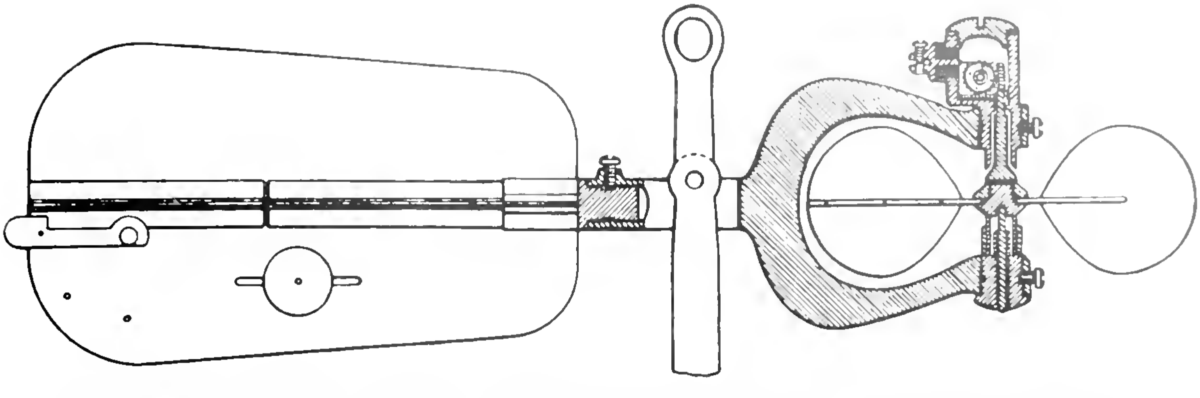

Figure 27.—Cross-sectional view of a model 621 Small Price current meter with its penta-contact chamber (From *Engineering News*, July 2, 1908.)

ing measurements in shallow streams as well as for making cable-suspension measurements in deep streams. The need for hydrographers to carry two current meters into the field was finally eliminated.

The original model of the meter having the new penta-contact chamber (and a new yoke) has been preserved in the Smithsonian Institution (fig. 26). Its penta-contact facility may not have been the first to have been installed in a Price current meter, since Michael C. Hinderlider of the Geological Survey's Denver office is known to have previously installed a number of them in Large Price meters, but this is the first Small Price current meter to have been so furnished. And it was from this model that the idea has been carried into the present.

The method used to produce single-point and penta contacts can be explained best by referring to figures 22 and 27. The cross-sectional drawing marked AA in the first of those two figures shows the construction of a single-point contact chamber. The upper end of the hub of the impeller has been shaped into an eccentric which touches the contact wire every time the impeller makes one complete revolution, producing a click in the hydrographer's headphones. A penta-contact chamber is shown on the meter illustrated in figure 27, where the upper end of the hub of the impeller terminates in a worm-gear arrangement, the larger gear of which revolves only once while the meter's impeller makes 20 revolutions. Four pins, spaced 90 degrees (or five revolutions) apart, protrude from one side of that large gear. These pins touch the contact wire as they go past it, thereby making an electrical contact (and a corresponding click in the headphones) for every fifth or penta revolution of the impeller. The hydrographer chooses whichever of those two facilities is best for the conditions with which he is faced. If the water is flowing rapidly, he would select the penta facility for greater ease in counting the clicks. If it is flowing slowly, he would select the single-point facility because less time is wasted while waiting for the first click of each observation to occur.

For W. & L. E. Gurley to manufacture a current meter containing all of those new ideas involved their changing the pattern for casting the yoke and making a completely new set of drilling fixtures and jigs. Nevertheless, in response to the persuasive enthusiasm of J. C. Hoyt, that firm undertook the manufacture of the new model. It was assigned their catalog no. 621 and was generally identified by that number. In a circular letter that Hoyt sent to field offices of the Survey, he reported that as of May 1, 1908, the first two experimental models were in use and that two additional experimental models were then being manufactured.

Despite the statement in Hoyt's letter to Steward that the meter "was designed so as to use either a singlepoint contact chamber or the penta contact chamber," the idea of providing such interchangeability was not conceived of as early as he seems to have thought. In fact, several documents written by him during the period in question contain strong implications that he had considered the penta head as being suitable for measuring both high and low velocities, and there was no intention of providing any single-contact facility with any of the 621-type meters (see figs. 27 and 28).

At the time of their introduction, therefore, each of the 621-type Small Price current meters was equipped with only a penta-contact chamber, but, because the time lost while waiting for that first

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Figure 28.—MODEL 621 SMALL PRICE current meter. Only one contact chamber of the penta type was furnished with these meters when orders specified the 621 model. (Smithsonian photo 44537 E.)

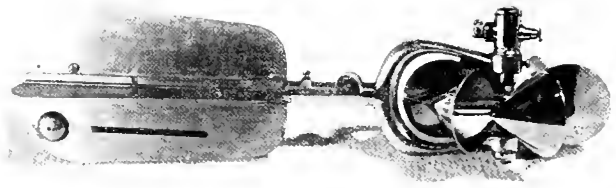

Figure 29.—MODEL 624 SMALL PRICE current meter showing the earliest type of single-point contact chambers. On later models both the single- and penta-contact chambers had the same outward appearance as is seen in figures 28 and 30. (Smithsonian photo 44537–C.)

click to occur annoyed the men who used them on field work, the meters soon were provided with two interchangeable contact chambers, the extra one providing an electrical contact at each revolution. At first, these extra contact chambers were constructed like those on the early 618 models, with two binding posts, one for the insulated wire and the other for the ground (see figures 24 and 29). On later models, however, the single-point chamber was made to correspond with the penta chamber in its outward appearance. In Gurley's catalog, the number 624 was assigned to meters that had been furnished with the two contact chambers.

All model 624 meters used by the Survey were rated twice—a low-velocity rating for use with the contact chamber that produced one electrical contact per revolution and a high-velocity rating for use with the penta-contact chamber. For field purposes, both ratings usually were combined in a single rating table.

To introduce the 621 model, J. C. Hoyt prepared an article for the *Engineering News* entitled "Recent Changes of Methods and Equipment in the Water Resources Work of the U.S. Geological Survey," which was published on July 2, 1908. In that article Hoyt wrote that it was:

> . . . a meter that can be readily carried in the field and manipulated by one man under all conditions of velocity, depth, and width of a stream and with the various facilities for making measurements, which can be either a bridge, a boat, a cable and car, or by wading.

A further description of the meter was contained in a paper entitled "The Use and Care of the Current Meter as Practiced by the U.S. Geological Survey" that Hoyt presented before the American Society of Civil Engineers on September 15, 1909.[12] Illustrations accompanying that article—considered a classic on the subject—show that an additional, although soon discarded, feature was being explored in connection with the 621 models. It consisted of an acoustic head which could be used interchangeably with the other two contact chambers, thus enabling the same instrument to be operated either as an acoustic meter producing a click at every tenth revolution of the impeller, a penta electric Small Price current meter producing a click at every fifth revolution, or a single-point meter producing a click for each revolution. Of these three facilities, only the second and third continued in use for some time.

The next variation in the design of Small Price meters resulted from a suggestion offered by Clermont Calvert Covert, the Geological Survey's district engineer in New York State. A boss was added to the upper limb of the yoke of the meter and was tapped to accommodate the lower section of a wading rod. Through its use, the meter could be suspended from a rod without resorting to the sliding hanger previously mentioned. This yoke became known as the Covert yoke. Meters on which it was furnished were identified by no. 623 in Gurley's 46th (May 1912) manual and in subsequent manuals. All 623 meters, like the 624 models, were furnished with both single- and penta-contact chambers. Representative models of the 621 and 624 meters are shown in figures 28 and 29; a 623 meter, with a Covert yoke, is shown in figure 30.

Because of a desire to have each improvement made applicable to previous models, most of the important dimensions on the Small Price meters have remained the same since the first model 617 was designed. All of the impellers, called bucket wheels, beginning, for example, with those placed on the earliest Acoustic

[12] See the Transactions, vol. 66.

Figure 30.—MODEL 623 SMALL PRICE current meter showing the Covert yoke. Except for the yoke, the 623 and 624 models are identical. Each was provided with both single and penta interchangeable contact chambers. (USNM cat. no. 323836; Smithsonian photo 44537 D.)

current meters, are interchangeable with the modern models. Except for a short time when the tailpiece was screwed into the early 617 yokes, any tailpiece will fit any yoke. Covert yokes can be substituted for any 621 or 624 yokes. So, whenever it became necessary to replace a part on a meter, it usually was replaced by its most modern counterpart. As a consequence, meters which had begun their existence as 617 models frequently became either partly or completely converted to 623 or 624 models. This practice has continued, enabling the U.S. Geological Survey to keep its thousands of meters up to modern standards and in good repair at minimum cost.

With the introduction of the Covert yoke, both the Geological Survey, as represented by J. C. Hoyt, and the firm of W. & L. E. Gurley seemed satisfied with the meter's design, and no further changes were made for several years.

W. G. Price's Final Design

In the summer of 1920, W. G. Price, then in Yakima, Washington, examined the changes that had been made in his current meters and was displeased. The change that most irritated him was that which had been made in the upper bearing of the Small Price meter. In every talk or article he had presented on the subject, he had emphasized the importance of *both* bearings operating in *air pockets* which would exclude water, silt, and grit. Despite his admonitions, the design adopted for the upper bearings on all the Small Price meters thus far manufactured was identical to that which he had condemned on the Ellis meters as far back as 1882.

His first step toward combating that condition was to apply on August 19, 1920, for a new patent which had for its objective "the *effective* protection of the bearings from contact with water, dirt, or other foreign substances." Patent 1,413,355 was granted him on April 18, 1922. During the almost two years while he was waiting for the application to be processed, another idea occurred to him. This was to use the same contact chamber to house both the single- and penta-contact facilities. That contact chamber was to be provided with two binding posts, one pointing forward, the other pointing rearward. The one pointing forward was for use in measuring low velocities (the single-point contact); the one pointing toward the rear was for use when high velocities were to be measured (the penta contact). Price filed an application for a patent covering those features on November 21, 1922, but patent 1,571,433 was not granted to him until February 2, 1926. A reproduction of the patent drawing is shown in figure 31.

While Price was waiting for his patent to be awarded, W. & L. E. Gurley and the Geological Survey were collaborating on the development of still another new model, probably without any knowledge of the renewed interest Price had taken in the subject. On this occasion it was Carl H. Au, the Survey's instrument specialist, who provided the major ideas for their new design.

"Improved" Small Price Current Meters

Carl Au (1876–1958), after having taught mechanical-engineering subjects for eight years at Worcester Polytechnic Institute, established an instrument shop in Washington, D.C. On one occasion his services were employed by the Geological Survey in connection with the design and construction of the Survey's stage-discharge integrator, an instrument used to convert graphical records of the stages in rivers into figures representing their average daily discharges. Officials were so impressed with his work on that instrument that in 1916 they invited him to become a senior engineer in charge of the Survey's stream-gaging equipment—an invitation which he promptly accepted. During the earlier period of Au's employment, he devoted most of his time and energy to

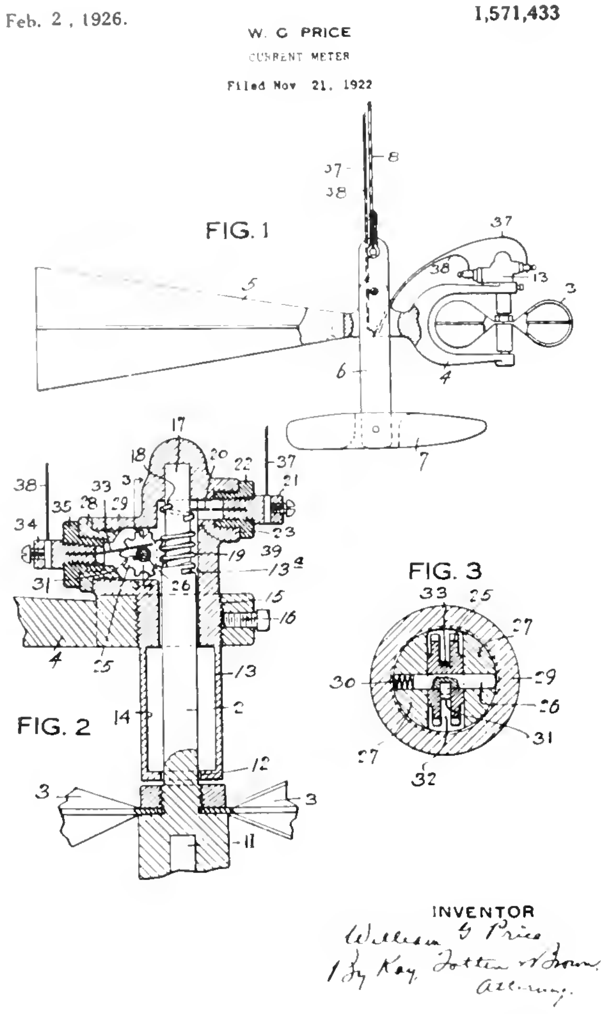

Figure 31.—PRICE'S PATENT NO. 1,571,433, showing both the single- and penta-contact facilities provided within one contact chamber. Note the upper bearing at the extreme top of the chamber.

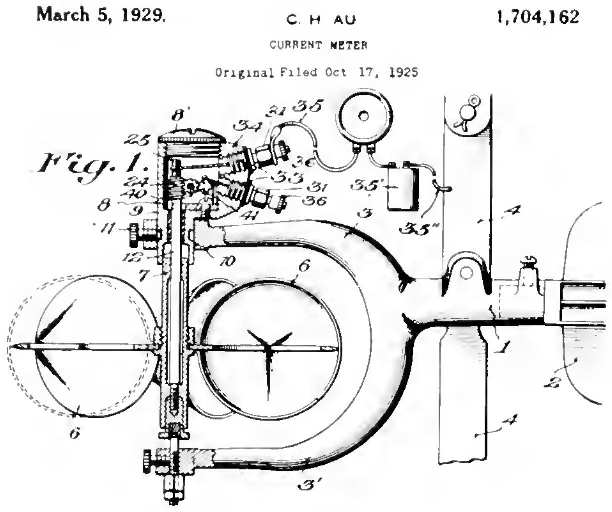

Figure 32.—AU'S DRAWING for patent 1,704,162 showing the single- and penta-contact facilities both within the same chamber. Price's patent (fig. 31) appears to have covered this identical feature.

improving water-stage recorders. Five patents were awarded to him for such improvements.

In 1925, Au turned his attention toward improving current meters, and by October of that year he had applied for a patent on a design which satisfied him. Two patents were eventually awarded: patent 1,644,005 dated October 4, 1927, and patent 1,704,162 dated March 5, 1929. It was during the same year in which Au had applied for these patents that he and J. C. Hoyt appealed to the W. & L. E. Gurley firm to revise the design of the Small Price meters to correspond with Au's latest ideas. As usual, Gurley agreed. They assigned catalog no. 622 to the new model and manufactured a small lot for field trial. The new models were referred to in Hoyt's writings as the "Small Price 'Improved' Current Meter."

One of Au's patent drawings of this meter is shown in figure 32. It reveals that his design still contained the feature that Price had objected to so strongly, namely that the upper bearing was located *below* rather than *above* a substantial air pocket. Moreover, Au's new design for the *lower* bearing eliminated practically all of the beneficial air pocket in that area. In fact, the improvements which Price had so diligently worked for in current meter design were seemingly ignored in Au's design. Apparently neither Au, nor Hoyt, nor Gurley's design engineers were aware of that circumstance.

The first lot of experimental models built in accordance with Au's design was completed in March 1926 and distributed for trial purposes among selected field offices of the Survey. W. & L. E. Gurley also sent one to W. G. Price in Yakima with a suggestion that he exhibit it among those of his friends who were employed on neighboring irrigation projects. Price was then away from home for a long period, but about a year later he exhibited the model as requested. His report to Gurley (with a copy to the U.S. Geological Survey) dated March 29, 1927, was both frank and discouraging, as shown by the following extracts:

I have been away from Yakima, except for an occasional day, for a year, and arrived here two weeks ago. Last Saturday, March 26th, I exhibited your new type meter at a meeting of Engineers here, most of whom are engaged in Reclamation work. They were much interested, but criticised the meter severely . . . .

I cannot comprehend how an engineer, who must have known the conditions under which a meter has to operate, could have designed such a device.

The upper bearing in my first meters was not worn or cut by grit; the lower pintle bearing was not cut or worn; and the hardened steel pintle and its hardened steel bearing did not rust . . . . The water with the grit it contained was kept out by the air which was compressed in the inverted cups.

The upper bearing of *this* meter has no air trap to keep out water and grit, and the lower bearing is nearly as inefficient. The upper bearing housing is, I believe, four times larger than necessary. The large housing produces eddy currents, which may cause some inaccuracy in measurements.

If I can go East next summer, I would like to have you build a meter for me, at my expense, that I would not be ashamed to bear my name.

I will express your meter to you today.

That letter might have created considerable consternation, especially in the Geological Survey where the new design had been sponsored, had it not been that prior to May 18, 1926—several months before the letter arrived—someone had already conceived of the idea of moving the upper bearing from the stem of the contact chamber to a much higher position within the chamber. The air trap in that area was thereby provided for the first time on Small Price current meters. That change first appeared in Gurley's drawing no. 8250BS, dated May 18, 1926. The first production lot of the 622 meters was manufactured on the basis of that drawing so that only the small experimental lot contained the fault Price criticized most severely. The fault of having no air pocket for the lower bearing still remained, however. A cross-sectional view of the 622 model is shown in figure 33.

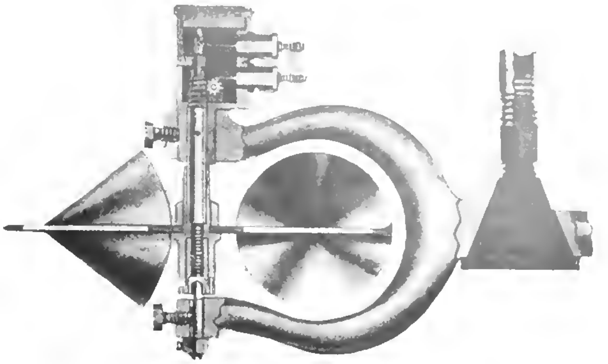

FIGURE 33.—CROSS-SECTIONAL VIEW of 622-type Small Price meter. (From W. & L. E. Gurley, Bulletin no. 700, April 1928.)

The penultimate paragraph of Price's letter of March 29, 1927, tells of his plan to visit the W. & L. E. Gurley plant in Troy, N.Y., the following year to get them to build, at his own expense, a special current meter that would fulfill all of his desires. That visit never took place, although Price and his wife left Yakima in June 1928 with every intention of making it. Their first stopover was at the Sanitarium in Battle Creek, Michigan, where Price underwent a physical examination to see what, if anything, could be done for his heart condition. Their next stop was to have been at Schenevus, New York, where some of Price's relatives still lived and where he planned to revisit the scenes of his childhood. As their train was drawing near Detroit, however, he suffered a severe heart attack. He was taken to the Fort Shelby Hotel in Detroit, where he died on July 6, 1928, on his 75th birthday, in the city where the world's first cup-type current meter—Daniel Farrand Henry's cup-type "Telegraphic" current meter, the forerunner of all four of Price's current-meter inventions—was built. No doubt, if he could have made the visit to Gurley's, the results might well have produced a change in the subsequent history of current meters.

Price was buried among the scenic hills of his childhood at Schenevus, New York. The inscription on his tombstone reads:

WILLIAM GUNN PRICE
1853 1928
SCIENTIST ENGINEER
AND INVENTOR
ADORED HUSBAND OF
MARY KELLEY PRICE

The model 622 "Improved" Small Price current meters enjoyed the status of being the Geological Survey's standard meter for about three years after Price's death. Toward the end of that period, the supervision of the repair and improvement of current

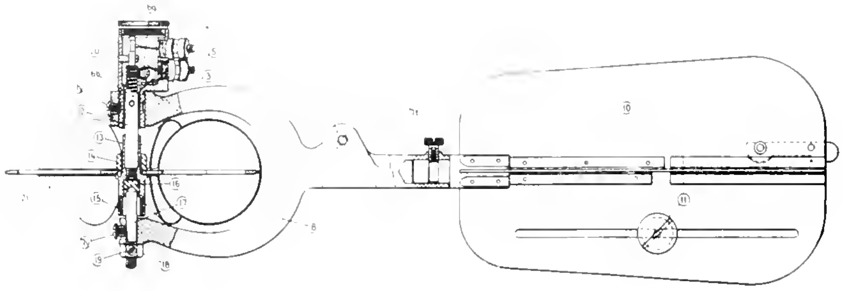

Figure 34.—Cross-sectional drawing of type-A Small Price current meter. (From "Water Measurement Manual," Bureau of Reclamation, 1953.)

meters was shifted from Au to the Survey's section of field equipment, the chief of which was Rha L. Atkinson.

Although Price was no longer present to criticize the design of the lower bearings on 622-type current meters, his earlier criticism was still valid and was recognized as such by many Survey officials. Atkinson accordingly took steps toward correcting the fault by redesigning the lower end of the hub assembly. In his modification, the lower bearing was set within a fairly deep cavity that was drilled into the lower end of the axle, thus reestablishing the type of air pocket that Price had prescribed. At the same time Atkinson improved upon and standardized the hardness of the metal used for the pivot and lower bearing. The following is an extract from an announcement about these alterations which was sent to field offices of the Survey on September 10, 1931:

> We now have seven meters with redesigned shaft assembly and pivot in the field. It is hoped that the field tests will have sufficiently progressed so that the results may be presented at the [forthcoming] conference.

The field tests reported at the 1932 Water Resources Branch Conference were generally favorable, and Atkinson's design was accordingly approved. It was identified by the Survey as the Type-A Small Price Current Meter and later by Gurley as their catalog no. 622 A. A drawing showing the details

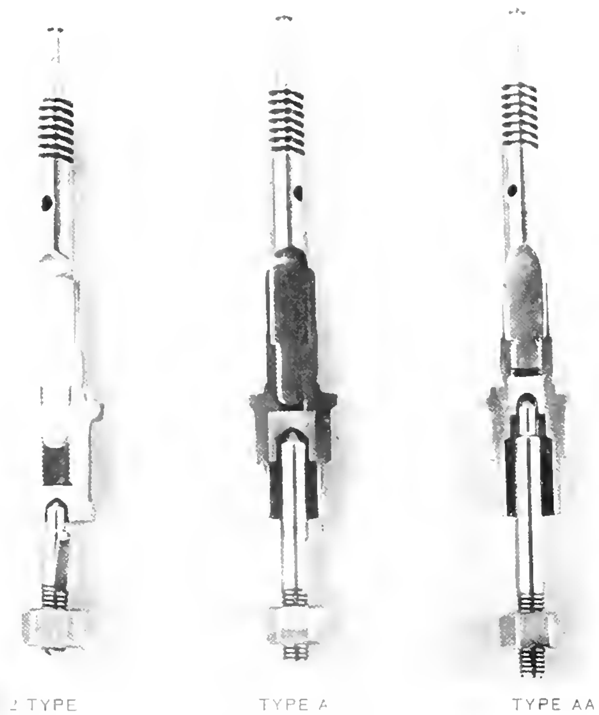

Figure 35.—Hub assemblies for the three types of Small Price current meters, showing their differences. (Photo taken by author.)

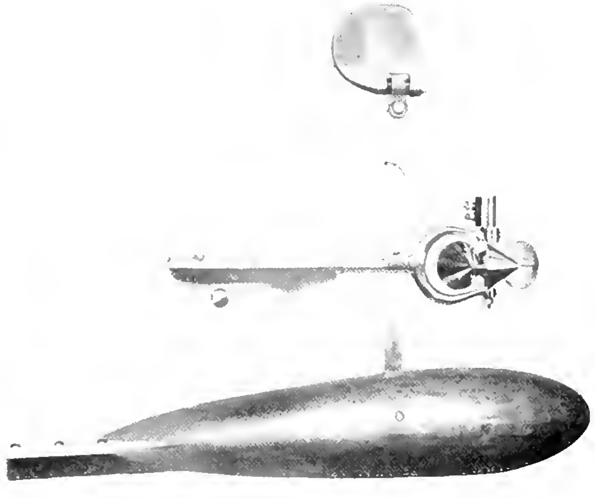

Figure 36.—Small Price current meter with sounding weight such as used with cable suspension. Type-AA, Type-A, and 622 type all have the same outward appearance as the meter shown here. (Photo taken by author.)

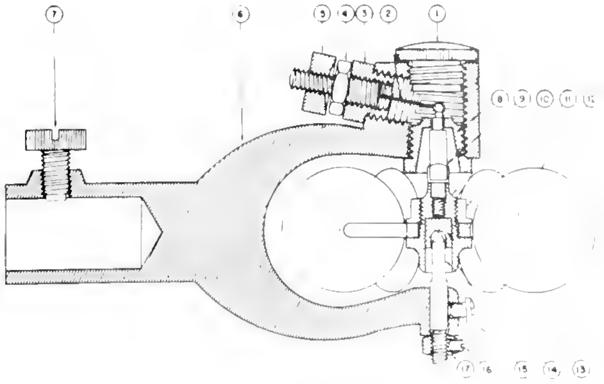

Figure 37.—Cross-sectional view of the Pygmy current meter. (From *Water Measurement Manual*, Bureau of Reclamation, 1953 ed., fig. 68.)

Figure 38.—Type-AA current meter with a Pygmy meter on a carrying bracket in the foreground. (Photo taken by author.)

of its construction is shown in figure 34. This design prevailed for about six years. In September 1937 Atkinson made another change in the lower bearing by reducing its diameter and moving it into a still deeper cavity within the hub assembly. This change further increased the volume and depth of the air pocket. Price's major objectives in that respect were thereby fully reinstated. Meters containing that latest change by Atkinson have been identified in the Survey as Type-AA Small Price Current Meters and by Gurley as their catalog no. 622 AA.

Except for a subsequent change by the author in the materials used for the pivot and lower bearing—stainless steel for the pivot and tungsten carbide for the lower bearing—the AA design has continued in effect up to the present (1965). A photograph showing the shaft details in the 622, the A, and the AA models is shown in figure 35. The external appearances (fig. 36) of all three of these models are practically identical. The Survey's policy of making each new design change apply as much as possible to the preceding models has been followed. Few, if any of the 622 and Type-A models remain in the Survey's possession, all of them having been converted to the latest Type-AA models.

As might have been surmised from the foregoing, W. & L. E. Gurley was the only firm that manufactured Price meters as long as their rights to Price's patents remained in effect. Not long after those rights expired, however, several other instrument makers started manufacturing Price meters. Among them were the Lallie Manufacturing Company of Denver, Colorado; the A. Lietz Company of San Francisco, California; and Hilger and Watts, Ltd., of London, England. It was copied even in Russia. Evidence of such construction and use of a Russian Price meter in Central Asia is contained in the following excerpt from Professor Steponas Kolupaila's *Bibliography of Hydrometry* (1961):

> V. I. Vladychanskii, "O vertushkakh Praisa" [On Price current meters]. *Izvestiia Nauchno-Issledovatel'skogo Instituta Gidrotekhniki*, 8 (1932), pp. 161-164, Leningrad. [An imitation of the Price meter made in Russia is described and evaluated.]

Prior to June 1930, the Geological Survey customarily purchased its current meters completely assembled from W. & L. E. Gurley. After that it became necessary to fill its needs through contracts negotiated annually by the Government's General Services Administration. R. L. Atkinson accordingly prepared the complete written specifications required for obtaining bids. As subsequent improvements developed, these specifications were modified appropriately by Atkinson's successors in the Survey. As a means for assuring that all parts purchased under such contracts would be interchangeable on all Survey meters of the corresponding type, Atkinson made use of a set of gages for checking each critical dimension—a practice that has been followed to the present by the Survey. Contracts for individual parts or complete meters have since been awarded to the following manufacturers: Arline Precision Instruments, Inc. and the W. L. Lawrence Company, both in Baltimore, Maryland; David White Company, Loma Corporation, Modern Screw Products Inc., and the Scientific Instruments of Wisconsin, Inc., all in Milwaukee, Wisconsin. Beginning in 1958, current meters were dropped from the Federal Supply Schedule. Since then, Federal agencies have obtained them through their individual purchasing

Figure 39.—THE WES MIDGET VELOCITY meter designed for use on model studies by the Corps of Engineers, U.S. Army. (*Photo courtesy of the Mississippi River Commission.*)

facilities. Meanwhile, W. & L. E. Gurley has continued to manufacture them in accordance with the Survey's latest specifications.

Pygmy Small Price Current Meters

Just as the Large Price current meters were found to be too large for use in shallow streams, so the Small Price current meters were found to be too large for use in still shallower streams. Even normally large rivers can become so shallow during periods of drought that the Small Price meters will not produce accurate results. To attempt to measure them by building weirs is usually a highly expensive and time-consuming procedure. A Pygmy Small Price current meter, the advantages of which are described in the Geological Survey's Water-Supply Paper 868, accordingly was designed by the author in 1936. Several variations in its design were tried experimentally during the succeeding two or three years, but the final design as it emerged in February 1939 is that shown in figures 37 and 38. The impellers on such Pygmy meters are two inches in overall diameter (two-fifths the size of those used on the Small Price meters). The meter is designed to fit onto the wading-rod facilities used with all Small Price meters. Because it is intended only for use with rod suspension, it has not been provided with a tailpiece. Pygmy meters enable a hydrographer to make fast and accurate measurements of streams that are too shallow for the Small Price meters to be used, yet too large for the use of weirs or volumetric methods.

In 1944, a still smaller cup-type current meter was designed, constructed, and used by the Corps of Engineers at the U.S. Waterways Experiment Station at Vicksburg, Mississippi, for measuring the currents in scale models of river channels. It still serves that purpose. The impeller of the so-called WES Midget Velocity meter is about $1\frac{3}{16}$ inches in diameter—only a little over one-half the diameter of the impeller on the Pygmy meter. Thus, the Corps of Engineers, the organization that sponsored the design of the earliest and largest of the Price meters, also sponsored the design of the latest and smallest of the cup-type meters. A photograph of that Midget meter is shown in figure 39.

Conclusion

The cup-type current meter, conceived in America in 1867 by Daniel Farrand Henry and improved upon by Ellis and Price in 1874 and 1882, respectively, rapidly became one of the most frequently used current meters in the world. Among all of the changes that have been made in its design, the principle of the cup-type impeller, borrowed from the Robinson anemometer, has been steadfastly adhered to, but the principle introduced by Price of excluding silty water from its bearings through the use of trapped air has undergone numerous changes. At one time, as has been shown, that principle was threatened with extinction, largely because the history of its conception and its purpose seemed temporarily to have been forgotten. The Smithsonian's fine collection—the largest in the world—and such papers as this explaining the important design details concerning these meters will ensure that their importance is not overlooked.

U.S. Government Printing Office: 1967

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 Price 35 cents

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Sir William Congreve and his Compound-Plate Printing

Elizabeth M. Harris

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1967

Sir William Congreve
James Lonsdale 1772 1828
The National Portrait Gallery, London

Elizabeth M. Harris

Sir William Congreve and his Compound-Plate Printing

The chronic problem of counterfeit bank notes in England in the early 19th century led the Bank of England to sponsor a public competition for a printing process that would deter forgers. Among those answering the appeal was Sir William Congreve, a colorful and controversial figure, who was a governor of the Bank and an engineer by profession. During his temporary excursion into the printing trade he developed a process which he felt could not be imitated. This became known as "compound-plate printing." The process was never accepted by the Bank, but it was used with success for many years by one of London's private printing firms and by Somerset House, a government office.

The illustrations used in this paper are reproduced from photographs in the collection of the University of Reading, and were kindly made available by Dr. Michael Twyman of the Department of Fine Arts.

THE AUTHOR: *Elizabeth M. Harris received her doctorate at the University of Reading, England, and is consultant to the division of graphic arts in the Smithsonian Institution's Museum of History and Technology.*

Sir William Congreve (1772–1828) was a soldier, engineer and inventor. Most of his inventions had to do with ships and fighting machines, and he is chiefly remembered now for a military rocket which he invented in 1808 and used successfully in several battles of the Napoleonic Wars. He was interested in mechanical problems of all kinds, and his fertile imagination occasionally went beyond the laws of mechanics. Among his contemporaries Congreve was notorious as a tireless inventor of perpetual-motion machines. Journals were apt to treat his public activities with amused forbearance and his inventions with caution, for some seemed no more than rearrangements of the work of other inventors. Congreve filed eighteen British patents between 1808 and 1827.

Congreve's connection with the printing trade was a temporary excursion from his main fields of interest. An appeal for inventions to defeat forgery—a chronic problem in England at the time—kindled his imagination. In 1818 a public competition was opened, with the winning entry to be put into operation by the Bank of England. Although Congreve was appointed one of the judges, this did not deter him from submitting his own entries. One of these was the process he called "compound plate printing."

The following five years were eventful for Congreve. He developed the idea of compound-plate printing and took out a series of three patents connected with it. He saw the process established with a private firm of printers, Branston and Whiting, and Somerset House, a government office. He wrote pamphlets and letters in defense of the method, published specimens, and was involved in several quarrels with other inventors. Then in about 1824, when the new trade was flourishing, Congreve turned over the patent rights to Branston and Whiting and returned to his other interests. He had nothing more to do with the process. Compound printing survived until late in the century at Whiting's firm and until 1920 or later at Somerset House. But its history after 1824 formed a second chapter of steady application, quite different in character from the first colorful years of its invention and establishment under Congreve's management.

Compound-plate printing was a method of making relief prints in several colors, the colors all being printed at once with a single pull of the press. By the ordinary method of color-relief printing, different blocks were used for the different colors and they were printed in succession. It was always difficult to print the colors so that they coincided exactly. Congreve's compound plates, on the other hand, were composed of several interlocking parts like the pieces of a jigsaw puzzle. To print a plate the parts were separated, inked in their different colors, fitted together again and printed as a single plate. In the resulting print the colors registered with a precision that could not be achieved by any other method. At the same time it was impossible, from the nature of the plates, to print one color over another to product a third color. This precise registration between adjacent simple colors gave the print a peculiar character and made it quite easy to tell a true compound print from a copy, however carefully made, by some other method. This, and the fact that the equipment needed to set up a compound-printing shop was cumbersome and expensive, made the process a potentially useful protection against forgery.

The endemic problem of forgery was intensified with the coming of the Industrial Revolution. The volume of bank notes increased to meet the demands of an expanding commercial activity for which the specie circulation was inadequate. Moreover, the growing labor force needed notes in smaller denominations. The notes were issued by many independent banks of which the Bank of England was the most important. The Bank soon became the chief target of forgers, whose efforts would easily pass among a new group in society unused to the currency and incapable of recognizing forgeries.

In 1797 the Bank of England invited suggestions from the public for improvements that would safeguard its notes. In 1802 a "Committee to examine plans for the improvement of bank notes" was set up by the Bank to consider these suggestions, but it found none worth recommending. Over the next fifteen years more suggestions were made, but many were worthless and others repeated ideas that the Bank had already rejected. Meanwhile the recognized forged notes increased from about 3,000 in the year 1803 to 31,000 in 1817.[1] During the Napoleonic Wars the problem had been shelved. With Europe at peace again it was no longer to be ignored.

At this time forgery or the passing of forged notes was a crime which brought the death penalty or life transportation, but the forgers themselves were rarely caught. Most of the executed criminals were the passers, often ignorant and illiterate men and women who did not understand their crime. Public sympathy was more with the convicted criminals than with the law. Juries were unwilling to convict and private banks would not prosecute if they could avoid it. Public feeling was strong. Pamphleteers and journalists demanded some action to improve the situation. As a result three separate committees were established in 1817 and 1818 to investigate the matter: the Bank's "Committee to examine plans for the improvement of bank notes" was revived; a Royal Commission was set up by the government; and the Society of Arts held its own inquiry. Sir William Congreve, who was a governor of the Bank, was one of the seven Royal Commissioners.

[1] A. D. Mackenzie, *The Bank of England note* (Cambridge: Cambridge University Press, 1953), pp. 55, 58.

The three committees were told of ideas concerning all aspects of the Bank's activity and the production of its notes, but they were principally looking for a new technique by which currency could be produced in very large quantities, with each piece virtually identical and inimitable. In particular they considered printing, papermaking and ink-making techniques.

From these inquiries several facts emerged to explain why Bank of England notes were forged more often than those of private bankers. Private banks promised to redeem forgeries of their own notes which were accordingly handed in promptly and were thus easier to trace to their source. The Bank of England, on the other hand, refused to redeem forged notes, so people who suspected that they held forgeries would try to pass them on rather than hand them in to the Bank. The Bank of England was handicapped, too, by the size of its circulation for there were technical difficulties in the production of such a large number of notes, and consequently there was some variation even between genuine notes.

The Bank's notes were printed from copper plates. Engraved copper will provide only a limited number of prints before it becomes worn and the quality of the prints deteriorates. The number may range from a few hundred to several thousand, depending on the kind of engraving, the kind of copper, and the way the plate is handled in printing. There was no known way of duplicating plates mechanically. A team of engravers was employed continuously at the Bank to engrave new plates which were put into service as soon as they were ready, but the plates deviated more and more from the prototypes. The Bank had various devices, but none satisfactory, for increasing the number of impressions from each plate. It was customary for engravers to touch up worn plates by deepening and sharpening the lines, though this was not considered among engravers to be a reputable practice as prints from retouched plates were never as fine as the originals. Bank of England plates were retouched several times over, to increase the life-span of a plate two- or three-fold. Another trick was that of taking two prints from a plate with only a single inking. The inked plate was printed the first time with light pressure so only half the ink was taken from the lines. This print was removed, a second paper put in its place and the plate printed again, this time with extra pressure to take the remaining ink from the lines. Thus two imperfect prints were taken for the price of a single good one, and the plate was saved from the wear of the extra inking operation.[2]

The quality of Bank of England notes was so low that there was said to be more variety among its genuine notes than among forgeries. The genuineness of any note, however bad, could be discerned from secret marks on the print, such as apparently accidental scratches or faults in the engraving. These marks, however, known only to Bank officials, gave no protection to the public. The effect was that the Bank of England offered both the greatest temptation and the harshest penalty to the forger.

Sir William Congreve submitted three suggestions to the Bank committee. They were a metal coin, a paper, and the compound-printing process. All three had in common the idea of compound construction. He patented only the coin and the printing process. The coin[3] was to be composed of two elaborate separable metal parts. The inner piece or "token" was made of a hard metal like steel, and the outer piece or "gauge" was made of a more fusible metal which was cast around the first. This "gauge" was of no value except in testing the genuineness of any "token" by the exactness of the fit. Congreve maintained that the token was inimitable without the original die with which it was stamped, since no forged copy could be made to fit perfectly into the gauge. He suggested, too, that a compound gold ingot could be made in the same way from interlocking pieces of gold and another metal. The words "Bank of England" and "Ingot" were to be stamped on the sides, crossing the different metals. The ingot would be tested by the precision of the fit and the coincidence of the stamped letters on the different parts.

The compound coin and ingot were rejected by the Bank Committee and Congreve made his second suggestion, a method of making bank-note paper. The paper, which he called "triple-paper," was to be made of three thin layers couched together so that they fused. The outer two were white and plain and the center layer colored and strongly watermarked so the watermark showed very clear and bright. This, too, was turned down by the Committee.

Congreve next adapted the idea of the compound

[2] *Report of the Society of Arts relating to forgery* (London 1819). This report contains a full and interesting account of the state of engraving in England at the time, particularly at the Bank of England.

[3] British patent 4404 (November 1819).

coin to make a printing plate. This was his final "compound plate printing," later sometimes known as "Congreve's" or "Whiting's process." The process was patented in 1820.[4] By this time, however, the Bank Committee had already chosen Applegath and Cowper's plan.

Congreve's compound plate was made by first cutting or stamping a design through a plate of fairly strong metal, such as brass or copper, to make a stencil. The stencil was then put on a flat surface and another more fusible metal was melted and poured over it. This formed a second detachable plate covering the back and filling the holes of the first. Next the face of the entire plate was engraved with lettering and mechanical patterns in a continuous design over both metals. Commonly the stamped holes were in wormlike shapes as in Branston's specimen bank note (figures 1 and 2) or roughly circular (figures 3 and 4). The linear engraving on the surface was not governed by the pattern of the stencil: in both of these examples the engraving formed a more or less independent design laid over the two colors. For printing, the two interlocked plates were separated, inked in different colors, fitted together again and printed at one pull. A special machine was built to ink and print the plates.[5] In his patent specification Congreve claimed that other materials such as wood or ivory could be used as well as metal, and that three, four or more colors could be combined and printed by the same machine with a slight adjustment.

In 1819 Congreve introduced his compound coin to the public in a pamphlet, *Principles upon which it appears that a more perfect system of currency may be formed.* The pamphlet had three pages of illustrations. Two of these consisted of ordinary hand-colored engravings showing coins. The third illustrated the gold ingot, with two compound prints in blue and yellow. These two prints are particularly interesting as they predate Congreve's patent for compound printing. They must have been his first published compound prints though they were not mentioned as such in the text of the pamphlet. Congreve himself still hardly recognized the promise that the process held: he argued in the pamphlet that no printed money could be quite as satisfactory or as inimitable as hard coin. He had claimed in the 1819 patent for the coin, however, that his method of casting one metal within another might be useful for ornamenting furniture, and for printing. In the case of printing it would "tend to throw great difficulty in the way of forgery of bank-notes and other documents which it is desirable to protect."[6]

In these two first compound prints the colors, blue and yellow, were divided very simply into rectangular forms, unlike Congreve's later more complex plates. The words "Bank of England" and "Ingot" were engraved with the letters crossing both parts. It is obvious, by applying the same procedure recommended by Congreve for testing his patent ingots, that these prints were made from compound plates and the colors printed simultaneously: the broken edges of the letters coincide exactly and the colors meet but do not overlap.

Other renowned people besides Congreve made suggestions to the various committees. Among them was Rudolf Ackermann, an influential London publisher who, with Charles Hullmandel, was largely responsible for the successful introduction of lithography into England. Ackermann recommended the new lithography for bank-note printing, but the Bank Committee regarded it as a "discovery as applied to the subject of forgery infinitely more to be dreaded than encouraged."[7] Other suggestions were made by John Landseer, the first of a famous family of painters; Alexander Tilloch, a Scottish printer and pioneer of stereotyping; and Anthony Bessemer, father of the engineer Sir Henry Bessemer. Thomas Hansard proposed a note printed entirely from type in minute sizes. Hansard was the founder of the publication *Hansard's Parliamentary Debates* which continues to this day. Thomas Bewick, the famous wood engraver, submitted some of his engravings. Jacob Perkins, an outstanding American engineer, came over to London with his "siderography," a process for mechanically duplicating engraved steel plates. The London firm of printing engineers, Applegath and Cowper, was responsible for several important innovations in presses and color printing. They proposed a method of printing in several colors

[4] British patent 4521 (December 1820).

[5] According to Timperley the credit for this machine went to an engineer, Wilks, of the firm of Donkin and Company. C. H. Timperley, *Dictionary of printers and printing* (London, 1839) p. 885.

[6] British patent 4404 (November 1819).

[7] Quoted in A. D. Mackenzie's *The Bank of England note* (Cambridge University Press, 1953), p. 61.

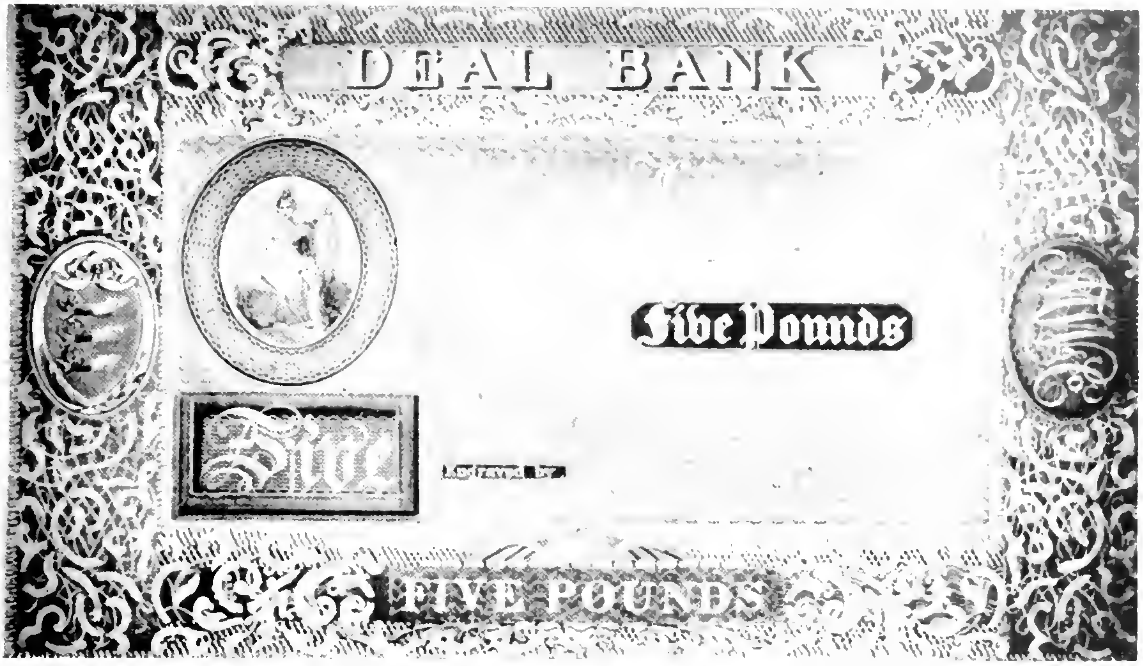

Figure 1.—Specimen bank note engraved by Robert Branston on Congreve's compound plates, about 1820. Reduced from $4\frac{1}{4} \times 8\frac{1}{4}$ inches. (Original in St. Bride Library, London.)

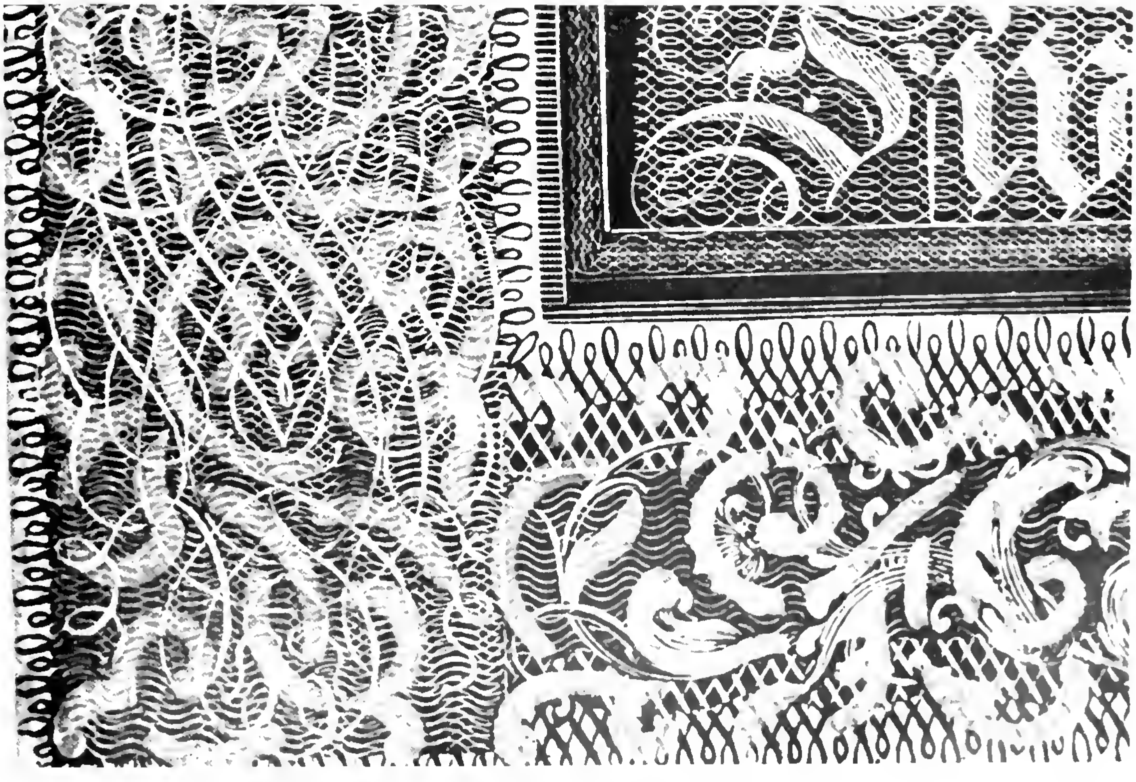

Figure 2.—Detail from figure 1. Enlarged from 1[illegible] x 2[illegible] inches.

with a reverse impression on the back of each note in exact register with the one on the front, and this was the plan that was finally chosen by the Bank Committee. Printed specimens were sent on to the Royal Commission and approved. Applegath and Cowper were installed in the Bank where they carried out their work in strict secrecy.

The new bank note was relief printed from stereotyped plates. The method of making the plates was a guarded secret. It apparently involved some casting system similar to Congreve's, though the colors were printed at separate impressions. The note was described in the "Bill for protection against forgery" of the 10th of July 1820:

> The ground work will be black or coloured, or black or coloured line work, and the words, Bank of England, will be placed at the top of each bank-note, in white letters, upon a black, sable or dark ground, such ground containing white lines intersecting each other.[8]

For two years the Bank's chief engraver, William Bawtree, tested the security of the new note by making copies, using the ordinary means a forger would have at hand. The design of the note was made more and more complicated to defeat Bawtree's efforts, until in 1821 Bawtree finally succeeded in imitating a five-color version. After failing on the basis of Bawtree's test, the Applegath and Cowper note was abandoned by the Bank. The old method of copper engraving was readopted.

In 1819 a pamphlet had been issued by another competitor, John Holt Ibbetson. This was *A practical view of an invention for better protecting bank-notes.* Ibbetson described his own process, "dissected plate printing," through its stages of evolution and he pointed out that it had much in common with Congreve's compound-plate printing. He hinted that Congreve's process might be derived from his, for Congreve, as commissioner, had "had the opportunity of perusing the various plans which were submitted to his board." [9] Ibbetson's submissions had been made between November 1818 and January 1819, ten months before Congreve's first patent was taken out. His ideas, as they were described in the *Practical view*, were broad and vague. Originally Ibbetson simply took relief prints from wood blocks engraved by his improved model of the rose-engine engraving machine. Later he thought of cutting up the engraved blocks and separating the parts with type. Finally he inked the several parts in different colors, clamped them together and printed them as one block. Specimens of the process in this final form were shown to the Bank Commission in January 1819. It was these specimens that Ibbetson suggested were the basis of Congreve's compound process.

Some illustrations in the *Practical view* demonstrated Ibbetson's two-color printing (figures 5 and 6). The designs were bold and attractive, with the blocks divided into relatively simple geometrical shapes for the two colors. But this very simplicity worked against the process as an acceptable means of preventing forgery. Ibbetson's method of cutting the blocks, which he kept secret, was evidently not capable of producing the complicated filigree of Congreve's plates.

Congreve was probably referring to Ibbetson's prints in a note in his next pamphlet, *Analysis of the true principles of security against forgery* published in 1820:

> We have seen such printing [as the compound prints] produced from blocks; but the form in which the colour was introduced was extremely simple, not at all like the work here described.[10]

But Congreve made no public reply to Ibbetson's pamphlet. The Bank competition had led to a number of similar charges, chiefly suggesting that the Commission had shown unfair favor to Applegath and Cowper, whose method was said to be the same as other suggestions made and rejected over the previous fifteen years.

While Ibbetson was making his barely concealed accusations, Congreve himself was involved in a quarrel with the American contestant, Jacob Perkins. Perkins had been as persistent as Congreve in submitting his "siderographic" notes to the Bank (figure 17). Siderography was a mechanical method of making faithful copies of engraved steel plates in almost unlimited numbers. A single steel engraving could provide as many duplicate plates as were needed. The plates were printed by the intaglio rather than the relief process, that is, the ink-holding lines were grooves sunk below the surface of the steel. The original engraving, usually measuring only one or two inches square, was made on a plate of mild steel, and the surface of the steel was then hardened

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[8] Quoted in J. H. IBBETSON'S *A practical view of an invention for better protecting bank-notes* (London, 1820), p. 67.

[9] Ibid., p. 62.

[10] SIR W. CONGREVE, *Analysis of the true principles of security against forgery* (London, 1820), p. 10.

Figure 3.—Ticket to the Coronation of George IV printed from Congreve's compound plates, 1821. The border was embossed by Dobbs. Reduced from 5¼ x 8 inches. (Original in Constance Meade Collection, Oxford University Press.)

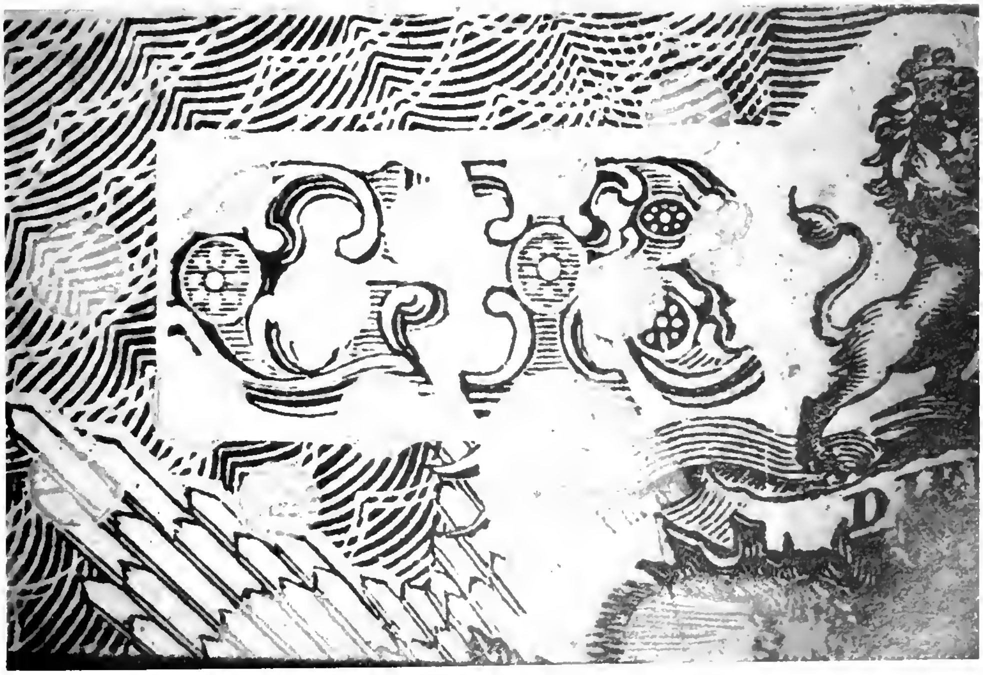


Figure 4.—Detail From Figure 3. Enlarged from 1 x 1½ inches.

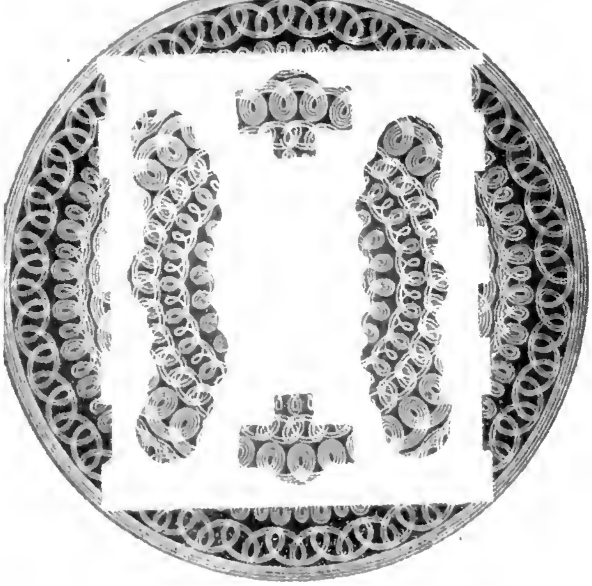


Figure 5.—COMPOUND print from Ibbetson's dissected plates, 1820. Enlarged from $2\frac{5}{8}$ inches diameter. (Ibbetson, *A Practical View*, 1820. St. Bride Library, London, copy.)

Figure 6.—COMPOUND print from Ibbetson's dissected plates, 1820. Enlarged from $2\frac{1}{2}$ inches diameter. (Ibbetson, *A Practical View*, 1820.)

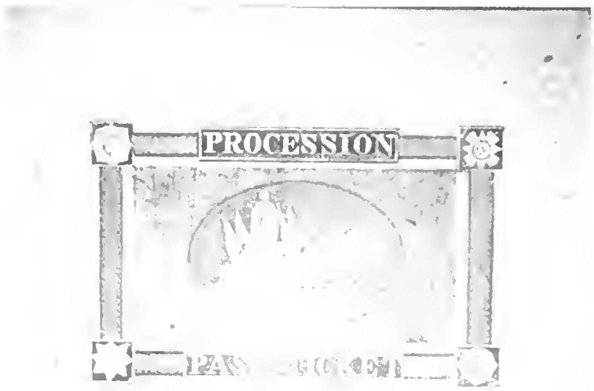
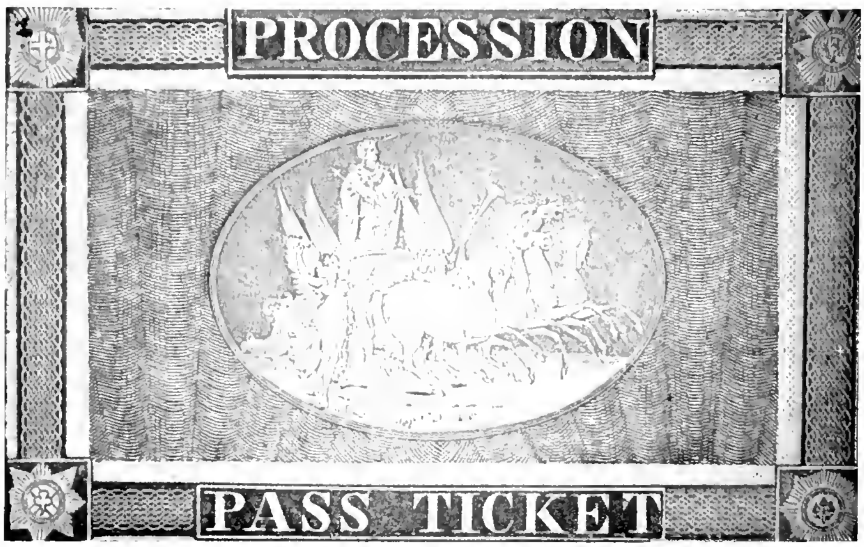


Figure 7.—TICKET TO THE CORONATION OF GEORGE IV, at left, produced by Whiting and Branston by conventional means with two impressions. Reduced from $8\frac{1}{2}$ x $6\frac{3}{4}$ inches, 1820. See the corresponding compound-plate printed ticket, figure 3. (Original in Constance Meade Collection, Oxford University Press.)

Figure 8.—DETAIL, BELOW, FROM FIGURE 7. Actual size. The border was embossed by Dobbs.



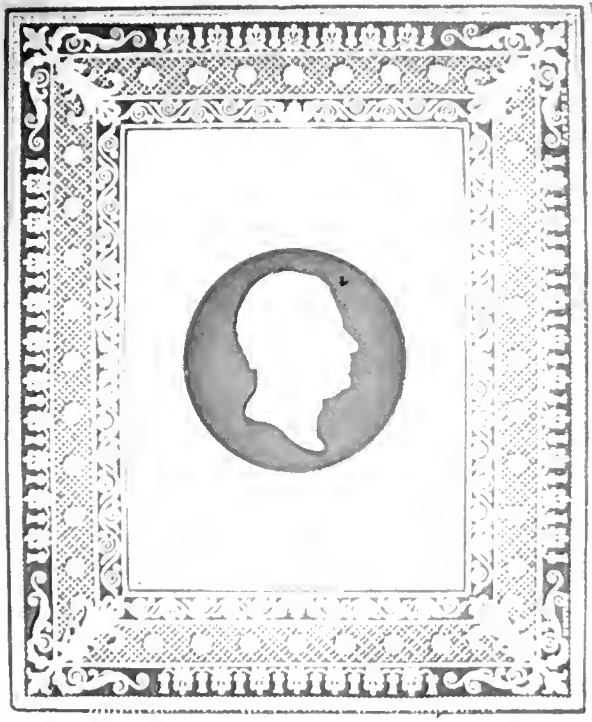


Figure 9.—Embossed Print made by Whiting using Congreve's print-embossing process. Reduced from 7 x 6 inches. (Original in Constance Meade Collection, Oxford University Press.)

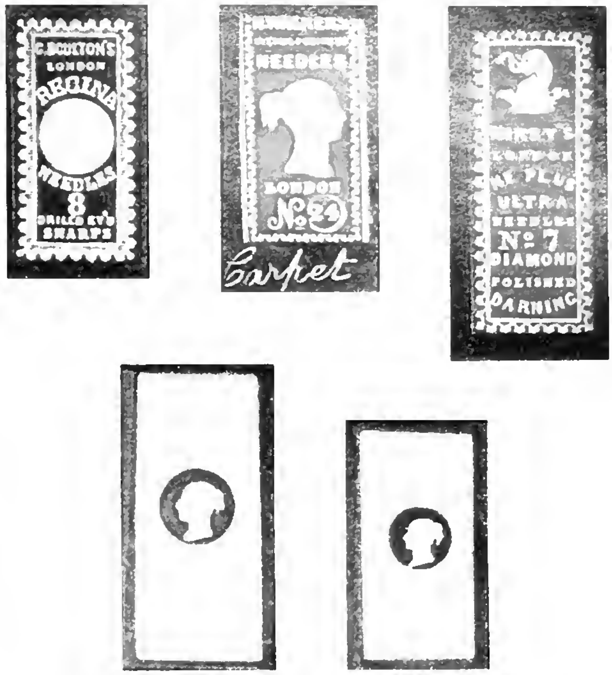


Figure 10.—Needle Cases printed by a process similar to Congreve's printing-embossing process. The contrasting color on three of the labels was printed separately. Unsigned, undated. Actual size. (Originals in Constance Meade Collection, Oxford University Press.)

Figure 11.—Label Printed from Congreve's compound plates and signed "Whiting Patentee." Undated. Reduced from 4 x 5 inches. (Original in Constance Meade Collection, Oxford University Press.)

Figure 12.—Government Duty Seal for medicine, printed from Congreve's compound plates. Late 19th century. Enlarged from $2\frac{1}{2}$ x 4 inches. (Original in Constance Meade Collection, Oxford University Press.)

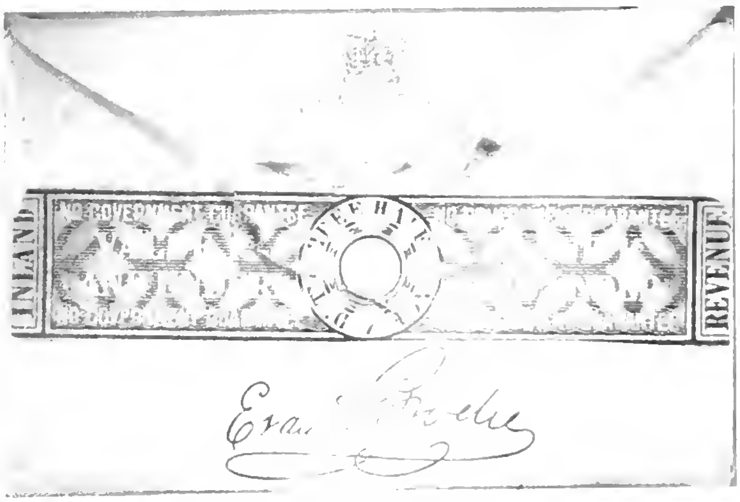


Figure 13.—Compound-Printed blacking label.

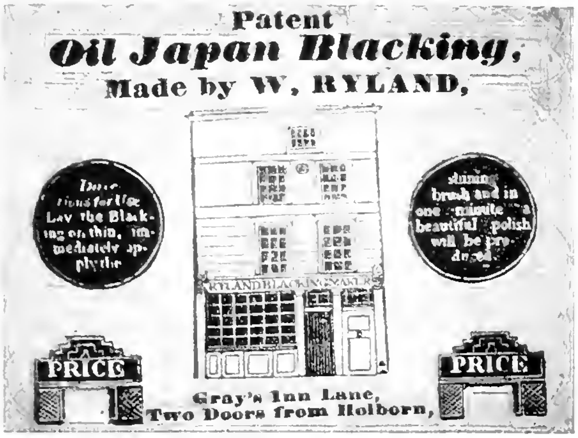


Figure 14.—Blacking Label in the style of a compound print, but made with two impressions.

Figure 15.—Poster for Stephens' Inks, printed from Congreve's compound plates. Three separate labels are pasted down onto a brown printed ground. Reduced from 11 x 7 inches. (Original in Constance Meade Collection, Oxford University Press.)

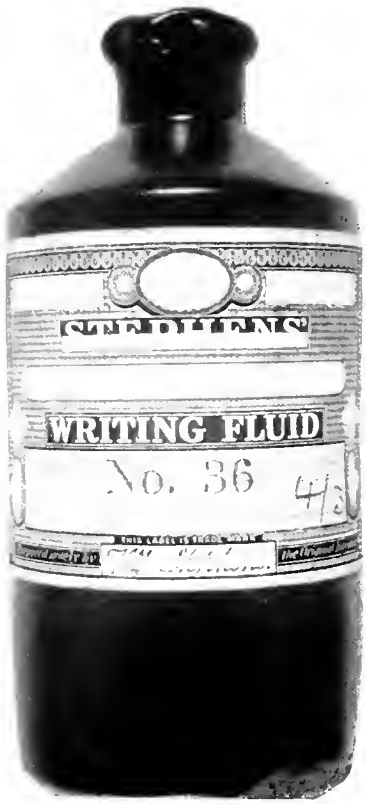


Figure 16.—Modern Bottle of Stephens' Ink with a label printed in imitation of the old compound prints. Height 7¼ inches.

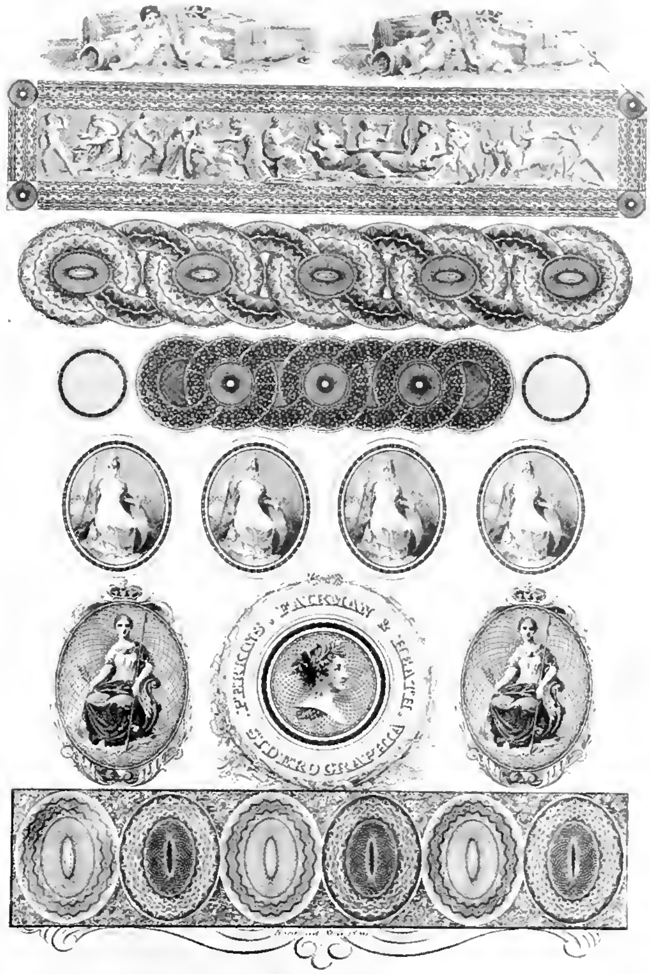


Figure 17.—Siderography specimen plate, 1819. Reduced from 8 x 6 inches. (Original in Constance Meade Collection, Oxford University Press.)

by the old case-hardening method. Next a small cylinder of mild steel was rolled and pressed repeatedly over the engraving, by means of a special machine, forcing the softer metal into the engraving until the image was transferred in raised lines to the cylinder surface. The cylinder was then hardened and used in its turn to impress the image into any number of mild steel plates, this time once again in sunken lines. These plates were then hardened for printing. Thus a single engraving, however complex, could be copied exactly on to any number of plates, or the engraving could be repeated several times on the same plate. The blacks and whites of an image could be reversed by a change in the order of transferring: if an extra cylinder was introduced, or if the initial engraving was made on a cylinder rather than on the flat plate then the final printing plate would hold the image in raised rather than sunken lines, and the printed result would be a white line design on a black ground.

The siderography process had enormous advantages for bank-note printing. Since the plates were copied mechanically, not by hand, there was no variation between them. The questionable devices for stretching the output of each worn plate were avoided, for there was an endless supply of fresh plates. It was feasible once more to employ only the most skilled of engravers to make the original engraving. By repeating high-class engraving several times on the plate, combining this with complex machine-engraved patterns, and reversing the blacks and whites in parts of the design, a composite plate could be built up which was well beyond the copying skill of the ordinary engraver.

Perkins' siderography was already well tried before he submitted it to the Bank Committee in 1818. He had worked it out in America over the previous twenty years, from a much simpler idea. By 1804 the developing process already involved the transfer by pressure to mild steel and subsequent hardening of the steel. It was adopted at its different stages by a considerable number of American banks. In 1810 the process was patented in England[11] and demonstrated, unsuccessfully, to the Bank of England on Perkins' behalf by his agent, J. C. Dyer.[12] The process in its perfected form of 1818 was undoubtedly the most important suggestion that was made to the Bank, and it was short-listed with the Applegath and Cowper process for the final choice. William Congreve, however, was determined to oppose the American plan and to further his own at the same time. Perkins and his friends believed that Congreve's hostility had caused their failure. In December 1819 Perkins wrote to a friend:

> We were told yesterday from the best authority that one of Sir Willm. Congreave's workman had said, that Sir Willm. had been as cross as a bear, ever since our specimens were exhibited to the commissioners, that he had said that he expected the American plan would be adopted, altho it was not any better than *his own*.[13]

According to an Irish banker, Thomas Joplin, Congreve behaved as though:

> the competition lay between Messrs. Perkins and Heath and himself; and he wrote a pamphlet to prove that his plan was a good plan, and theirs good for nothing.[14]

The full title of this pamphlet of Congreve's explains his thesis:

> An analysis of the true principles of security against forgery; exemplified by an enquiry into the sufficiency of the American plan for a new bank note; with imitations of the most difficult specimens of those bank notes made by ordinary means, by which it is proved that there is no adequate security to be achieved in one colour, in the present state of the arts, and that the true basis of security is in the due application of relief engraving, and printing in two or more colours.

A copy of this rare pamphlet is in the Patent Office Library in London. Ten of its twelve pages of illustrations are imitations of Perkins' siderographic notes or parts of them. One shows a clumsily engraved and printed compound plate and one is a very beautiful specimen of Congreve's "triple paper." The siderography imitations were the work of Congreve's friend Robert Branston, and Branston's son. Robert Branston was one of the greatest English wood engravers of the time and a leader of the London school of engravers, the rival to Thomas Bewick's pioneer school in Newcastle.

The Perkins claim for siderography rested on the fact that it was virtually impossible to make by hand a number of identical engravings like the repeated designs on his notes. A forgery would give itself away immediately by the slightest variation between the designs. Branston got around this difficulty in a very simple way. He engraved only one copy of each design and printed this onto the paper as many times as necessary. Thus a note which, in the original, was composed of five designs appearing nineteen times altogether was copied by making five engravings and putting the paper through the press as many as nineteen times. Branston engraved on wood and on metal, and used both intaglio and relief methods of printing. A trained eye could spot that his copies were printed part relief and part intaglio, but the man in the street would notice only that the repeated designs were the same, line for line. Branston's method was ingenious and his results were remarkable, but there were serious weaknesses to his case. No ordinary paper could take the punishment of so many impressions. Branston pointed out that the relief blocks could be duplicated and united into one block by stereotyping, to reduce the number of impressions. But the task of making and printing the blocks was so great that it would have been easier and more profitable for the forger to earn a living as an honest engraver. Perkins and his company re-

[11] J. C. Dyer, British patent 3385 (1810).

[12] A. D. Mackenzie, op. cit. (footnote 1), p. 56.

[13] From a letter quoted in G. & D. Bathe's *Jacob Perkins* (Philadelphia: Historical Society of Pennsylvania, 1943), p. 81.

[14] T. Joplin, *An essay on the general principles and present practice of banking in England and Scotland*, 6th ed. (London, 1827), p. 118.

garded Branston's copies as the best possible advertisement for their siderography and they offered

> to furnish every purchaser of Sir William Congreve's work with the original note, free of charge, and are desirous of giving the greatest possible publicity to Sir William's published imitations.[15]

Congreve was known as a troublemaker and in his dispute with Perkins public sympathy was on the side of the American. But the skirmish had no practical effect as the Bank competition had already been judged and closed by 1820, and both Perkins and Congreve soon found other applications for their processes.

The single compound print in Congreve's *Analysis* consisted of a short chain of interlocking rings in a red and black pattern with delicate white line engraving through the two colors. The engraving was so fine that it became almost scratchy, and the relatively large gap between the two metals disturbed the course of the engraving tool. The result was less satisfactory than later coarser engravings. In the final "Notice" at the end of the book Congreve apologized for this bad example of his process and promised better ones to follow:

> A variety of Specimens of the work of the Compound Plate illustrative of the foregoing principles, and formed on the test of inimitability except by original means, are in preparation, and will be published, with due explanations, as a sequel to this volume, containing both partial and complete Designs for Bank Notes, and all other public documents, the security of which against Forgery is important. The Specimens hitherto produced are to be considered merely as progressive Experiments.

So far as I know, the promised sample prints never appeared.

Congreve had a compound-printing press already established in the government offices at Somerset House, London, by the time he took out his patent of 1820. The patent specification refers to the use of this press for printing government stamps on the backs of private bankers' notes as an extra precaution against counterfeit.[16] In 1822 Congreve issued a notice to draw the attention of private bankers to these government stamps, and to the fact that his "triple paper" was obtainable from his office, "The New Bank Paper Office for the Prevention of Forgery" at Somerset House.[17] The bank-note stamps continued in use for some years, often on the backs of notes printed from Perkins' siderographic plates. They must have been the earliest important application of Congreve's process. But bank notes were not often dated, and it is difficult to know which of those that survive were the earliest. The first dated compound prints that I have seen (apart from those in the *Principles* of 1819 and the *Analysis* of 1820) were tickets to the coronation of George IV in 1821. From about this time compound prints became quite common on tickets, labels, bank bills, and posters. Most of the blocks were engraved by Robert Branston, the wood engraver, and they were printed either by the Somerset House press or by James Whiting. Whiting had been associated with Congreve as early as 1804 when they were involved in a libel action together[18] and had printed most of Congreve's numerous pamphlets since then.

The coronation tickets of 1821 were the joint production of Branston and Whiting along with Charles Dobbs, one of the great 19th-century masters of embossing. In the ticket illustrated in figure 3 there is a red and black compound pattern of roses and circles surrounding a blue centerpiece which was apparently printed at the same time. The blue ticket numbers in the top corners were printed separately. The print is surrounded by a border richly embossed by Dobbs. The enlarged detail from this ticket in figure 4 shows how the red printing plate fitted into the black, and how the combined surface was cut away in some places and engraved in others. Branston and Whiting made at least two other designs of tickets for the same event. Their "Procession Pass Ticket" (figure 7) was produced by conventional means with two engraved plates printed separately to give a moiré effect in the overprinting. The general design echoes the style of the compound

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[15] *London Journal* (London, 1820), p. 209.

[16] In his *Memoir*, Thomas Bewick, the wood engraver, claimed that the idea of printing stamps on the backs of country bank notes was his, and that the credit had been unjustly taken by Congreve. Bewick wrote a letter to the *Monthly Magazine* to this effect and made the same accusations as Ibbetson against Congreve as Bank Commissioner. Congreve gave no public reply, though he sent a "very impudently written" reply by hand. *Memoir of Thomas Bewick* (London, 1862), p. 171.

[17] A. D. Mackenzie, op. cit. (footnote 1), p. 73.

[18] The action was brought by the Hon. G. C. Berkeley against William Congreve, John Parsons, and James Whiting who were the proprietor, publisher, and printer of the newspaper, *Royal Standard*, in which Admiral Berkeley was accused of cowardice in battle. Congreve asked that the fine of £1000 be imposed entirely on him, as the others were young men who would be ruined by it. *[illegible] Whiting, Parsons and Congreve* (Buckingham, 1804).

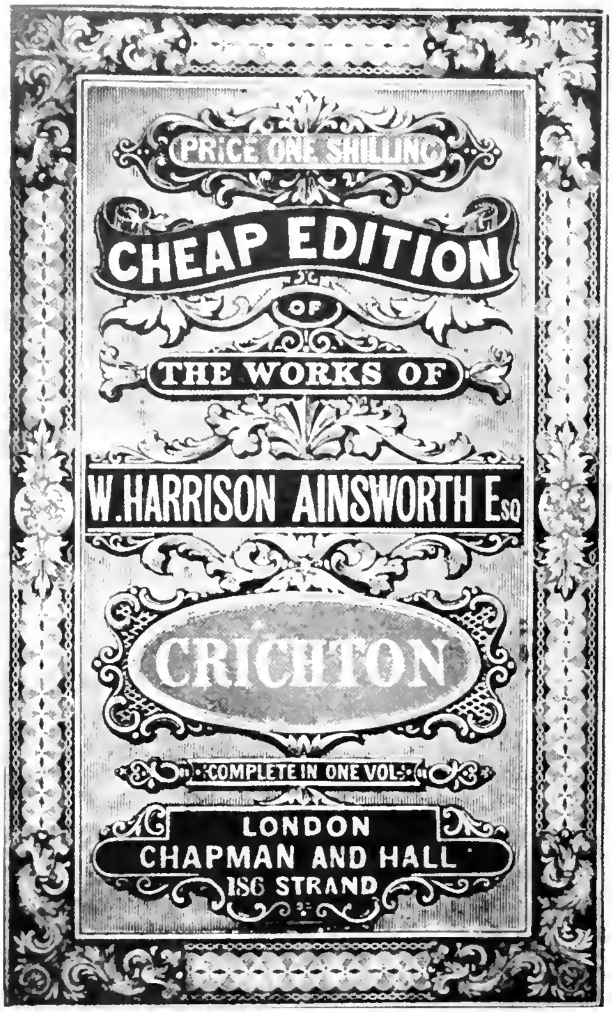

Figure 18.—Compound-printed book cover. About 1850. (From the Constance Meade Collection, Oxford University Press.)

printed tickets, and the borders were again embossed by Dobbs.

Other compound prints dating from the 1820s are to be found on the ream labels that sealed bales of paper on leaving the makers. These were probably the work of the Somerset House press. Branston and Whiting printed compound-plate lottery tickets and bills for various betting houses until private lotteries were made illegal in 1827. From about 1830 the process was used on labels of manufactured goods, paper wrappers for series of books, government duty seals for patent medicines (figure 12) and the decorative borders of official documents. The process probably survived longest at Somerset House where it was still being used for government medicine seals in 1920.[19]

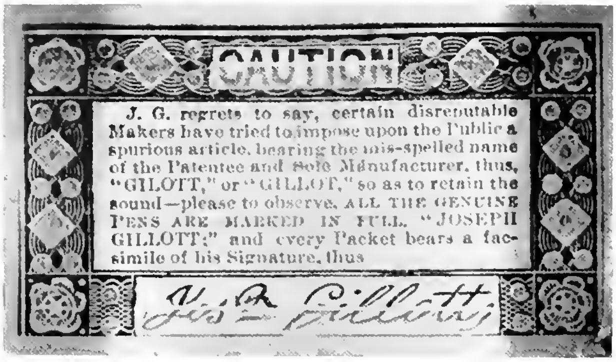

Figure 19.—Compound print from a pen nib box. Mid-19th century. (From the Constance Meade Collection, Oxford University Press.)

In about 1824 Whiting and Branston acquired the patent rights for compound printing from Congreve.[20] Congreve returned to his other interests and from this time he played no active part in connection with the process, though he continued to have Whiting print his pamphlets. The association between Whiting and Branston continued until Branston's death in 1827.[21] Branston's son broke with Whiting to go into partnership with Henry Vizetelly, another wood engraver. For a time the new firm, Branston and Vizetelly, used the separate elements of compound plates for page ornaments, but they never made true compound prints. Congreve died in 1828 and his widow married James Whiting [22] who moved to Beaufort House, in the Strand in London. There James, and later

[19] Sir E. D. Bacon, *The line engraved postage stamps printed by Perkins, Bacon and Company* (London: C. Nissen, 1920), p. 5.

[20] R. M. Burch, *Colour printing and colour printers* (London: Sir Isaac Pitman & Sons, Ltd., 1910), p. 122. The dates Burch gives for these transactions are inaccurate.

[21] A unique album, probably the firm's record, was preserved until recently in London. It consisted of hand-painted designs, progressive proofs showing engravings at different stages, prints from blocks separated and united, and test pieces of machine engraving and lettering, all pasted into a guard book. The original is lost, but a photostatic copy survives in the Constance Meade Collection in Oxford.

[22] Sir E. D. Bacon, loc. cit. (footnote 19).

Figure 20.—MANUFACTURER'S LABEL of the late 19th century, printed lithographically. (From the Constance Meade Collection, Oxford University Press.)

Figure 21.—PAPER-REAM LABEL of about 1825, printed from compound plates. (From the Constance Meade Collection, Oxford University Press.)

his son Charles Whiting, continued in business with the process until well into the second half of the century.

In addition to compound-plate printing, Whiting practiced another process patented by Sir William Congreve in 1824.[23] His idea was a simple method for making a printed and embossed impression. A single embossing die, in which the image was sunk, served as a printing plate: the flat surface surrounding the intaglio image was inked with a roller and then printed with great pressure to produce a white embossed (or raised) design against a colored ground (figures 9 and 10). The process was sometimes known by the French name *gaufrage*. It was not as original as compound printing, nor was the equipment as unusual, and consequently it was practiced by other London printers, notably Charles Dobbs and Thomas De La Rue, as well as Whiting. Nevertheless, Whiting lettered his *gaufrage* prints, like his compound prints, "Whiting Patentee" until long after the patent rights had expired.

In 1839 a competitive prize of £200 was offered by the British Treasury for suggestions for new postage stamps. Whiting entered both his processes. His suggested adhesive stamps were printed from compound plates, and the embossing process was to be used for stamping paper sent in by the public.[24] None of the competitors' entries was judged good enough to be adopted, but nevertheless the prize was increased to £400 and divided equally between four outstanding competitors. Charles Whiting was one of these four, and the specimens of another, Henry Cole, were also said to have been made by Whiting.[25] The contract for producing the first penny postage stamps was eventually given to Perkins' company—Perkins, Bacon and Petch—which had not taken part in the competition. The stamps were printed from Perkins' siderographic plates.

A famous example of color work from the incunabula of printing which provides a unique parallel to Congreve's work is the Psalter printed by Fust and Schoeffer at Mainz in 1457. The initial letters in this Psalter are remarkable for the precision of the

[23] British patent 4898 (February 1824).

[24] Some of Whiting's blocks for this competition were printed in the *Art Union* (London, 1848), p. 194.

[25] SIR E. D. BACON, op. cit. (footnote 19), p. 1.

Figure 22.—TRADE CARD printed by a process similar to Congreve's printing-embossing process. Unsigned, about 1825. Reduced from 4 x 7½ inches. (Original in Constance Meade Collection, Oxford University Press.)

registration between their two colors, red and blue. Engraved ornament, printed in one color, completely surrounds the initial itself in the contrasting color. There may be a millimeter or less separating the two, but the colors never overlap. For some 19th-century printers the Psalter was a symbol of superb achievement and a challenge to their own ingenuity. Senefelder, in his *Complete course of lithography* (London, 1819) and William Savage, in *Practical hints for decorative printing* (London, 1818–23), chose to demonstrate their own prowess in color printing with reproductions of the initial "B" from the first page of the Psalter. T. C. Hansard followed suit in his *Typographia* (London, 1825). Savage made a careful study of the original initials and decided that they were produced by exceptionally good registration of two impressions. It is now thought that a compound system similar to Congreve's was used, and the two colors printed at a single pull.[26] Surprisingly, Congreve himself never attempted to make a facsimile, and there is no thoroughly reliable evidence to show that he even knew of the initials or their bearing on his own process. There is only the weight of probability. It is not likely that he was unaware of the work of his contemporaries. Branston, at that time Congreve's chief assistant, was concerned with the production of Savage's *Practical hints*. A disparaging note in Congreve's *Analysis* seems to refer to Savage's color work:

> A very elaborate work has lately been published on this subject [color printing], which proves the impossibility of uniting two colours with any degree of accuracy, by the ordinary processes, where the forms of its adaptation are at all complicated.[27]

Some years later a French scholar-printer, J. H. H. Hammann, stated plainly that Congreve was well aware of the Mainz Psalter initials and their significance. Hammann, however, was writing thirty years after Congreve's death, and he did not declare the source he was quoting:

> Le célèbre imprimeur, M. Bensley, montrait un jour à M. Congrève comme un phénomène typographique la grande lettre B, qui est la première du Psautier, et dont

[26] See the IPEX catalogue for the British Museum Exhibition, *Printing and the mind of man* (London: F. W. Bridges & Sons Ltd., and The Association of British Manufacturers of Printers' Machinery [Proprietary] Ltd., 1963), Part I, p. 32.

[27] SIR W. CONGREVE, loc. cit. (footnote 10).

les ornements en bleu et en rouge rentrent si parfaitement les uns dans les autres; l'examen attentif qu'en fit M. Congrève lui fit découvrir qu'une pareille régularité ne pouvait être obtenue par des impressions successives, et que le tout avait dû être imprimé d'un seul coup de presse au moyen de deux parties gravées séparément et s'adaptant l'une dans l'autre après avoir été couvertes séparément, l'une de l'encre bleu, l'autre de l'encre rouge. C'est aussi de cette manière qu'on procède maintenant dans l'impression à la manière Congrève.[28]

Compound printing was a cheap process to work provided that a long run of prints was wanted, for the blocks were tough and hard wearing and could be kept in endless supply by casting from the originals. Apart from cheapness, there were two particular advantages for the ticket- and label-printing trades. Any part of the design which might have to be changed, such as the title, the date, the number of lottery prizes, or the grade of ticket, could be engraved on a separate piece of metal and taken out and changed as necessary without altering the rest of the block. This principle was already familiar in a simpler form in the "pierced block" which had been part of the job-printer's stock-in-trade since the 18th century. For this, an engraved wood block had holes cut through where names or numbers were to appear, and these names were engraved on separate fitting blocks and inserted into the holes.

As a second advantage to Congreve's process, it was extremely difficult to make a good forgery of a compound print without the equipment for casting, which ordinary forgers were unlikely to have. Some of the ream labels were very roughly printed, but it was still immediately obvious that they were genuine from the exact registration of the engraving through the different colors. Besides these two practical advantages, the prints looked attractive whether they were gay for the lottery bills, formal for the official seals, or rich and splendid for the coronation tickets.

In the 19th century Congreve's prints were commonplace. They were found in everyday use on posters, tickets, book wrappers, labels, and bank notes. The process came to be so well accepted in its role of protector against forgery that sometimes the typical compound design, rather than the peculiar details of printing, was taken as a sign of authenticity. Then, when the process was superseded by a more modern one, the old design was carried over to the new process although, of course, it no longer represented any actual security. Figures 20 and 21 show a late 19th-century paper-manufacturer's label, printed lithographically, and the official paper seal of the 1820s that served as model. In the same way the recent "Stephens' Ink" label (figure 16) is a close copy of the 19th-century one (figure 15). Compound prints themselves had no more collectors' value in their own time than bus tickets or match folders have today. As a result, they are now extremely hard to find. But it is not unusual to see modern designs, like those illustrated, which are derived from compound-printed prototypes.

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[28] Translated, this reads: "The famous printer, Mr. Bensley, once showed to Mr. Congreve as a rare phenomenon of printing the Psalter's first large B, with the blue and red ornaments fitting so perfectly into one another. Mr. Congreve examined it carefully and was convinced that such precision could not have been produced by successive impressions. It must all have been printed at a single pull of the press, using two parts which were fitted into each other after being engraved and inked separately, one in blue and one in red ink. This is the same as the method used today in the Congreve process." J. H. H. Hammann, *Des arts graphiques* (Paris and Geneva, 1857), p. 112.

U.S. Government Printing Office : 1967

For sale by the Superintendent of Documents, U.S. Government Printing Office
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Anthracite in the Lehigh Region of Pennsylvania, 1820–45

John N. Hoffman

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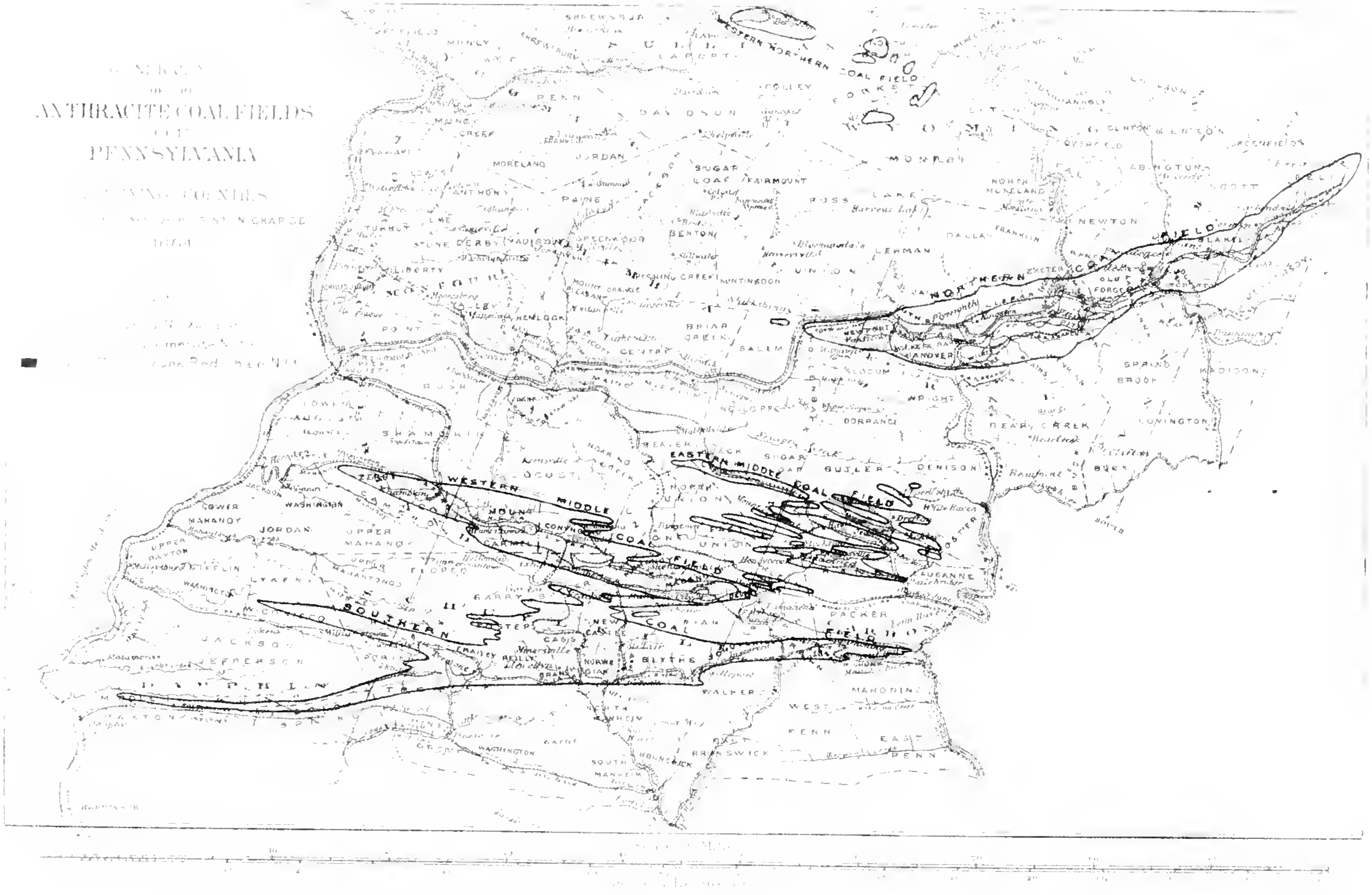

Figure 1.—Anthracite coal fields of Pennsylvania and adjoining counties, 1884. Mauch Chunk is located at the eastern tip of the Southern coal field. (Engineers Club of Philadelphia, *Proceedings*, 1884, vol. 4, no. 3, pl. 11.)

John N. Hoffman

ANTHRACITE
In the Lehigh Valley of Pennsylvania 1820-45

This monograph presents the historical and technological developments of the anthracite industry in the Lehigh region of Pennsylvania from 1820 to 1845. The first constructive effort to develop this region began in 1818 with the enactment of a law by the Legislature of Pennsylvania granting "unlimited powers" to three individuals to improve the navigation of the Lehigh River. Regular shipments of anthracite from the Lehigh region began in 1820.

The development of the industry during this period was achieved through the combined efforts of the Lehigh Coal and Navigation Company and its former companies, who operated the only navigation facility from the region and engaged in mining operations. During the first 25 years of the industry, 17 additional companies were chartered by the Pennsylvania Legislature to take advantage of the navigational improvements constructed on the Lehigh River. These companies were authorized to engage in mining and railroad operations, but none was given "unlimited powers."

Large amounts of capital were required to develop the coal-bearing properties and to bring the coal to market, with most of the money being invested in the construction of transportation facilities. Approximately $12.2 million was invested by the various companies to develop this industry during the period 1820 to 1845.

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Introduction

The anthracite deposits of Northern Pennsylvania are found in the counties of: Carbon, Columbia, Dauphin, Lackawanna, Lebanon, Luzerne, Northumberland, Schuylkill, Sullivan, Susquehanna, and Wayne. The coal-bearing formations cover a surface area of approximately 484 square miles and are divided into four fields: northern (176 square miles); eastern middle (33 square miles); western middle (94 square miles); and southern (181 square miles).

In anthracite trade circles, the four fields are regarded as three producing areas: The Schuylkill (the western middle field and the southern field west of Tamaqua); The Lehigh (the eastern middle field and the southern field east of Tamaqua); and The Wyoming (the northern field).

The topography of the area in the pioneer days of the Commonwealth excluded the use of turnpikes and the construction of new roads for the transportation of bulky commodities from the hinterland to the highly populated east-coast areas. The entire anthracite area was drained by three large streams, but none was navigable with safety in its natural state.

The Lehigh River was early recognized as being a natural route for the transportation of materials to market. The Pennsylvania Legislature passed a Lehigh River improvement act in 1771, and other programs followed in 1791, 1794, 1798, 1810, 1814, and 1816.[1] Several of the acts included the appointment of commissioners to supervise the river improvements and moderate appropriations to help finance the work. In every case the money was undoubtedly spent, but the construction efforts, if any, did not materially improve the navigation of the river.

Discovery of Coal in the Lehigh Region

The discovery of coal in the Lehigh area is credited to Philip Ginder[2] who, in 1791, found coal on Mauch Chunk (Sharp) Mountain where the town of Summit Hill is now located, about nine miles west of the town of Mauch Chunk.[3] Ginder gave some specimens of his find to Col. Jacob Weiss at Fort Allen (Weissport). The Colonel sent the specimens to Philadelphia for examination. Sometime later Colonel Weiss was informed that the specimens were found to be "Stone Coal."

On February 13, 1792, Colonel Weiss and several friends from Philadelphia formed the unincorporated Lehigh Coal Mine Company.[4] This organization obtained from Colonel Weiss the land upon which the discovery was made (Weiss had obtained the land previously from Ginder) and, therefore, obtained additional warrants. The total land holdings in this area subsequently totaled approximately 8,000 acres.

The organization commenced mining operations and produced several tons, having little difficulty in digging the coal from the ground. They were then confronted with the problem of what to do with the coal. Mining operations were suspended for the time being and their efforts were concentrated on proving anthracite's value by arousing public interest in their product. The public, however, was reluctant to accept this new fuel. Another problem faced the owners; that of transporting their mined coal out of the primitive forests to the landings along the Lehigh River. Six wooden arks were constructed on the river above Mauch Chunk, loaded with coal, and made ready for high water (freshets) to float them down to Philadelphia, via the Lehigh and Delaware Rivers. Each ark held approximately ten tons of coal and had a crew of six men. After a perilous trip down the rivers in the spring of 1803, two of the six arks finally reached Philadelphia. No ready buyer could be found but, after much effort by the owners, the coal was sold to the city for use as a fuel for a steam engine at the city's waterworks. This experiment was a failure as the fireman was not successful in getting the coal to burn.[5] The organization's hope of prosperity was lost.

In December 1807, the owners granted a lease to Rowland and Butland to remove coal from one of the veins exposed on the mining property. The partnership was disbanded and the lease forfeited during the next

[1] Erskine Hazard, "History of the Introduction of Anthracite Coal into Philadelphia" (*Historical Society of Pennsylvania Memoirs,* vol. 2, pt. I; Philadelphia: Carey, Lea, and Carey, 1827), p. 157.

[2] Thomas C. James, "A Brief Account of the Discovery of Anthracite Coal on the Lehigh" (*Historical Society of Pennsylvania Memoirs,* vol. 1, pt. 2; Philadelphia: Carey, Lea, and Carey, 1826), p. 318. Dr. James used the family name as Ginter, but the monument erected at Summit Hill, Pa., commemorating the 150th anniversary (1941) of the discovery of anthracite was inscribed "Ginder."

[3] Mauch Chunk and East Mauch Chunk became Jim Thorpe by referendum in 1954.

[4] James, op. cit., p. 319.

[5] Ibid.

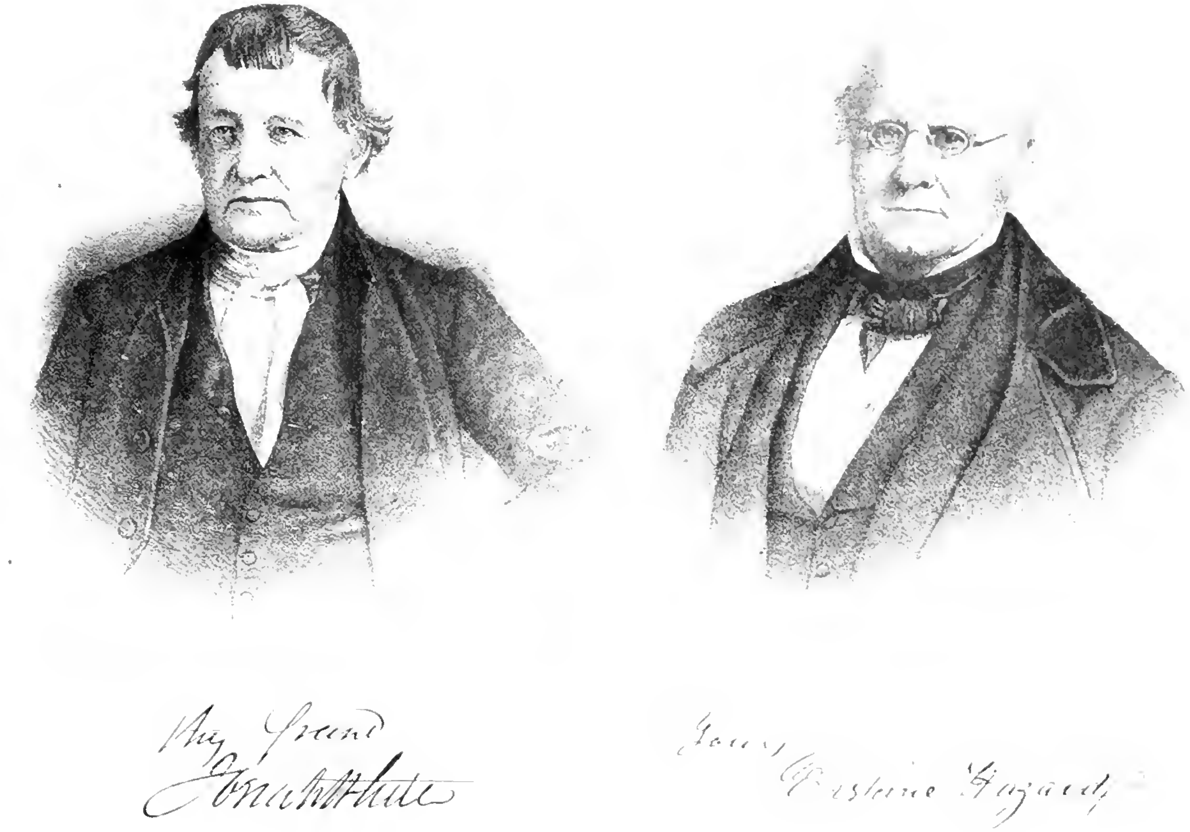

Figure 2.—*Left:* Josiah White. *Right:* Erskine Hazard. Both lithographs were by A. Newsam, ca. 1840. (M. S. Henry, *History of the Lehigh Valley*, 1860.)

year as they failed to mine any coal from the property.[6]

In December 1813, the owners, still desirous of developing their holdings, granted a lease for 10 years to Charles Miner, Jacob Cist, and John W. Robinson.[7] As an additional incentive, the owners gave this new group the right to cut timber on their property and use the timber for constructing riverboats for moving the coal down the river. In return for the lease, the lessees agreed to market a minimum of 10,000 bushels of coal annually. Revenues from the sale of the coal went to the new organization.

The owners received nothing from the lease, but hoped that by the time the lease expired, and with a public more accustomed to burning anthracite, the mines would be a valuable asset.

This new group in the spring of 1814, managed to load and send five arks of coal from the landing at Mauch Chunk. Two arks finally reached Philadelphia, but three arks were wrecked in passage down the Lehigh River. Most of the coal that survived the trip was purchased by Josiah White and Erskine Hazard for $21 a ton for use in their wire manufacturing plant located at the Falls of the Schuylkill.[8] This price did not compensate the new partnership for the mining costs, the transportation costs from mine to the river, and the losses incurred in transporting the coal down the river. Cost of the operation as given by Charles Miner in his testimony before the Packer Commission's study of the coal trade in 1834, showed that $330.77 was expended for each ark containing 24 tons of anthracite.[9]

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[6] *History of the Lehigh Coal and Navigation Company* (Philadelphia: W. S. Young, 1840), p. 3. Hereafter referred to as *Lehigh History*.

[7] Hazard, op. cit., p. 158.

[8] *Lehigh History*, op. cit., p. 4.

[9] S. J. Packer, "Senate Comm[illegible] Report on the Coal Trade," *Senate Journal*, vol. [illegible] Harrisburg: H. Welsh, 1834), p. 540. Hereafte[illegible] as *Packer Report*.

Mining coal @ $1 per ton	$24.00
Transportation 9 miles @ $4 per ton	96.00
Loading ark	5.00
Ark construction	130.00
Crew's wages	28.27
Pilot wages	47.50
Total	$330.77

This expenditure was required whether or not the ark arrived safely in Philadelphia. As a result of this one venture, this group, like its predecessors, was compelled to abandon the operation and forfeit the lease.

During November 1817, Josiah White and Erskine Hazard, being in need of coal for their wire plant, turned their attentions to the coal lands located along the Lehigh River. Josiah White was one of the commissioners named in the act of incorporation of the Schuylkill Navigation Company in 1815. At the election of managers by the stockholders, White was not elected due to his ownership of the wire manufacturing plant at the Falls of the Schuylkill and his possible conflict of interest.[10] White's unpleasant associations with the managers of the Schuylkill Navigation Company also contributed to his searching for a new source of fuel.

Mr. White and George F. Hauto visited the mining operations on Mauch Chunk (Sharp) Mountain and the Lehigh River southward from Mauch Chunk during December 1817.[11] Josiah White's report on his trip to the region was quite favorable as he was convinced that coal could be obtained cheaper from this area. His investigation also revealed that the lease of the coal lands by the third partnership had been forfeited and the most recent law which had been passed by the legislature to improve the navigation of the Lehigh River had not been carried out to completion.

Messrs. White, Hauto, and Hazard, upon application to the original owners, were granted a 20-year lease on the mine holdings. Their lease allowed 3 years for preparation of the property and required that they deliver at least 40,000 bushels of coal annually to Philadelphia. Annual rent for the property was one ear of corn payable on demand.[12]

Lehigh Navigation

After White, Hauto, and Hazard had obtained the lease for the coal lands, they turned to the Pennsylvania Legislature for an act to authorize them to improve the navigation of the Lehigh River. Their plans were presented to the legislature and strong opposition was encountered: the navigation plan for the Lehigh River was considered impractical because of the failure of previous plans to accomplish the same purpose. On March 20, 1818, the legislature gave this new group, as individuals, "the privilege of ruining themselves" (Appendix I).[13] Major provisions of the act were: (1) the division of the Lehigh River into two sections; (2) the locks to be at least 18 feet wide and 80 feet long; (3) downward navigation to be accomplished at least once every 3 days (except during the winter); and (4) the retention by the legislature of the right to purchase the navigation and all improvements at anytime after the expiration of 36 years.[14]

The Lehigh Navigation Company came into existence on August 10, 1818, when the money subscribed by stockholders had been obtained. Subscriptions amounted to $50,000 with 25 percent of the profits from the operations reserved for the stockholders. The balance was to go to the three original founders who, in addition, had the exclusive control of the company. Work commenced immediately on the project.

Another organization, the Lehigh Coal Company, was being formed by the owners of the Navigation Company to mine the coal, to build a road from the mines to the river, and to bring the coal to market by the river navigation. On October 21, 1818, this organization was completed with a subscription of $55,000.[15] Subscription was similar to the Navigation Company with the percentage of profits retained for the stockholders being 20 percent instead of 25 percent.

The mine wagon road was laid out in 1818, and completed in 1819. It was a descending road designed

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[10] Charles V. Hagner, *Early History of the Falls of the Schuylkill* (Philadelphia: Claxton, Remsen, and Haffelfinger, 1869), p. 45.

[11] Richard Richardson, *Memoir of Josiah White* (Philadelphia: J. B. Lippincott and Company, 1873), p. 40.

[12] *Lehigh History*, op. cit., p. 5.

[13] See Appendix I; *Pennsylvania Legislative Acts*, 1818 (Harrisburg: C. Gleim, 1818), p. 205.

[14] Pennsylvania claimed ownership of the Lehigh River on July 19, 1965.

[15] *Lehigh History*, op. cit., p. 9.

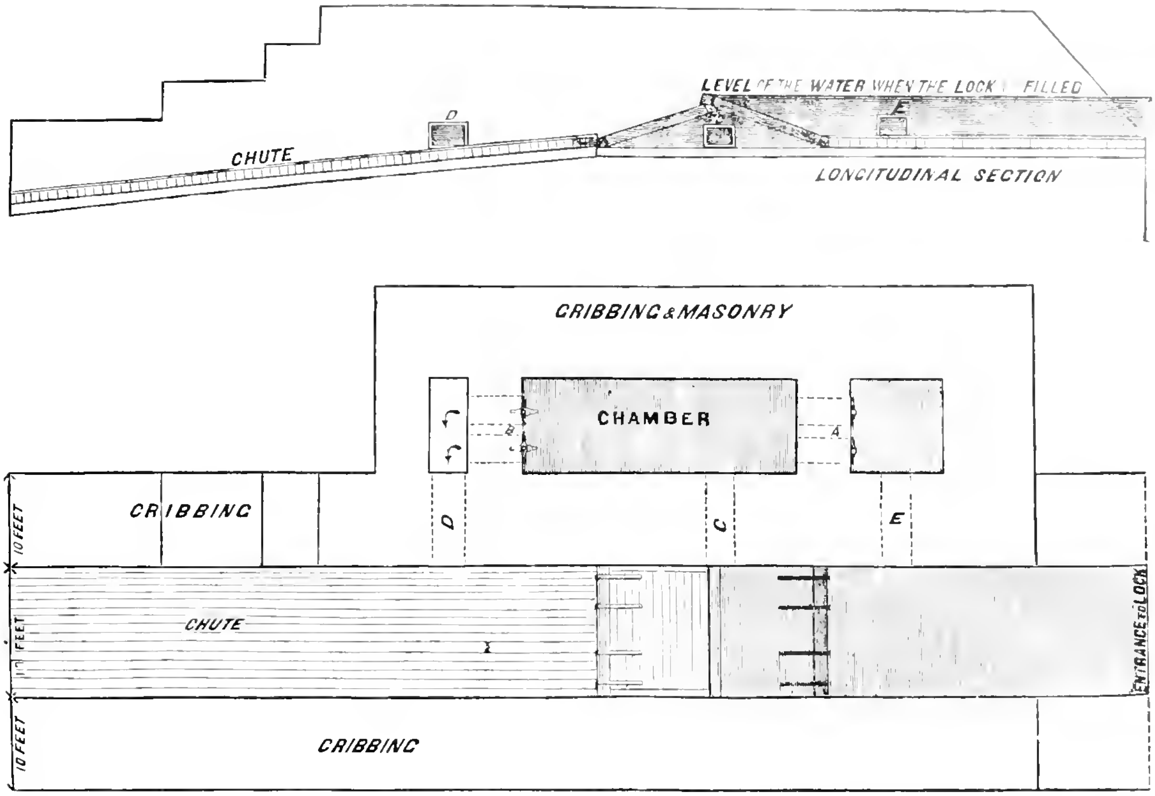


Figure 3.—PLAN OF THE BEAR TRAP LOCKS. *To fill the locks:* close wickets at *B;* open wickets at *A;* water passes through sluices *E* and *A* into water chamber, then through sluice *C* underneath gates; gates elevated; water collects back of gates and forms pool upstream. *To empty the locks:* close wickets at *A;* open wickets at *B;* water passes from water chamber and under gates through sluices *B* and *D;* gates lowered; water passes over lowered gates carrying the boat downstream. Chute length-gate to downstream end: 68 feet. Chute length-gate to upstream end: 38 feet. Chute width: 17 feet. Gates length: 27 feet. Water chamber length: 33 feet. Water chamber width: 10 feet. (Richard Richardson, *Memoir of Josiah White*, 1873, pp. 128–129.)

to accommodate a railroad; the rails could be placed when business would warrant this additional expense. This wagon road was the first in the Commonwealth ever laid out using surveying instruments and employed the principle of spreading out the difference in elevation from the beginning to the end over the entire distance as evenly as the topography would permit.

A drought occurred late in 1818 and the water level of the Lehigh River fell 12 inches below what, up to that time, had been considered the lowest water level. This required the storage of make-up water by constructing additional dams near Mauch Chunk. Josiah White introduced a lock and dam with sluice gates to provide an adequate water level for the passage of the canalboats as required. The workmen on the navigation called the locks the "Bear Trap," to elude the curiosity of persons who were inquiring about the purpose of their construction efforts. Twelve of these locks and dams were installed during 1818 and all proved to be workable. Josiah White obtained a patent for the design of the locks on October 19, 1819.[16] This new construction delayed the opening of the waterway as additional capital proved difficult to obtain.

On March 7, 1820, Hazard and White bought out G. Hauto's interests after some disagreement among them as to the conduct of the operations. The claims of Hauto against the company were not settled until 1830.

The Lehigh Navigation and Coal Company was

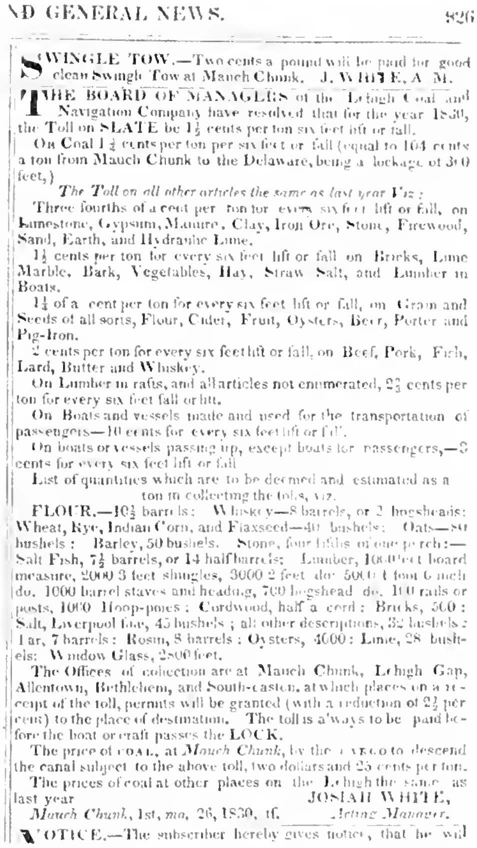
[16] RICHARDSON, op. cit., p. 58. Richardson cites December, but the U.S. Patent Office records indicate October

formed on April 21, 1820, by the merger of the Lehigh Coal Company and the Lehigh Navigation Company (Appendix II). White and Hazard subscribed to approximately three-fifths of the additional amount of capital required to effect this reorganization. With this additional capital the navigation was placed in operation after repairing some dams that had been destroyed during the winter of 1819. Three hundred and sixty-five tons of coal were sent to Philadelphia in 1820, and so began the first regular shipment of coal from the Lehigh region via the navigation.[17]

The organization was completely reorganized by the directors on May 1, 1821, with an accompanying increase in stock. The name of the new amalgamation was "The Lehigh Coal and Navigation Company." All the operations became more closely aligned and Josiah White and Erskine Hazard gave up their special rights and became ordinary stockholders. The management became the responsibility of five managers, with two (White and Hazard) located in Mauch Chunk and three in Philadelphia.[18]

Financial problems still confronted this new organization with investors being reluctant to purchase more stock and the stockholders being concerned about their personal liability as the organization was not incorporated. To overcome these difficulties, an application was submitted to the legislature, which, on February 13, 1822, approved an act of incorporation. This act also enabled the company to increase its capital stock with new subscriptions amounting to $83,950.[19] Later in the same year, the descending route of the Lehigh Navigation was inspected by commissioners appointed by the Governor for this purpose. The commissioners' report was favorable and on January 17, 1823, the Governor granted the company a license to take tolls, but no toll was charged until 1827.[20]

The boats, or arks, on the navigation were designed as flat bottomed shallow boxes, from 16 to 18 feet wide and from 20 to 25 feet long. Two of these boats were connected by "hinges" to allow them flexibility when passing through the dams. As the boatmen became experienced in handling the arks in pairs, the number of sections in one ark was increased until overall lengths of 180 feet were obtained. These arks were steered with long oars, similar to those used on rafts. The arks were


ND GENERAL NEWS. 826

SWINGLE TOW.—Two cents a pound will be paid for good clean Swingle Tow at Mauch Chunk. J. WHITE, A. M.

THE BOARD OF MANAGERS of the Lehigh Coal and Navigation Company have resolved that for the year 1830, the Toll on SLATE be 1½ cents per ton six feet lift or fall.

On Coal 1¾ cents per ton per six feet or fall (equal to 10¼ cents a ton from Mauch Chunk to the Delaware, being a lockage of 360 feet,)

The Toll on all other articles the same as last year Viz:

Three fourths of a cent per ton for every six feet lift or fall, on Limestone, Gypsum, Manure, Clay, Iron Ore, Stone, Firewood, Sand, Earth, and Hydraulic Lime.

1½ cents per ton for every six feet lift or fall on Bricks, Lime Marble, Bark, Vegetables, Hay, Straw Salt, and Lumber in Boats.

1¼ of a cent per ton for every six feet lift or fall, on Grain and Seeds of all sorts, Flour, Cider, Fruit, Oysters, Beer, Porter and Pig-Iron.

2 cents per ton for every six feet lift or fall, on Beef, Pork, Fish, Lard, Butter and Whiskey.

On Lumber in rafts, and all articles not enumerated, 2⅔ cents per ton for every six feet fall or lift.

On Boats and vessels made and used for the transportation of passengers—10 cents for every six feet lift or fall.

On boats or vessels passing up, except boats for passengers,—8 cents for every six feet lift or fall

List of quantities which are to be deemed and estimated as a ton in collecting the tolls, viz.

FLOUR.—10½ barrels: Whiskey—8 barrels, or 2 hogsheads: Wheat, Rye, Indian Corn, and Flaxseed—40 bushels: Oats—80 bushels: Barley, 50 bushels. Stone, four fifths of one perch:—Salt Fish, 7½ barrels, or 14 half barrels: Lumber, 1000 feet board measure, 2000 3 feet shingles, 3000 2 feet do. 5000 1 foot 6 inch do. 1000 barrel staves and heading, 700 hogshead do. 100 rails or posts, 1000 Hoop-poles: Cordwood, half a cord: Bricks, 500: Salt, Liverpool fine, 45 bushels; all other descriptions, 32 bushels: Tar, 7 barrels: Rosin, 8 barrels: Oysters, 4000: Lime, 28 bushels: Window Glass, 2800 feet.

The Offices of collection are at Mauch Chunk, Lehigh Gap, Allentown, Bethlehem, and South-easton, at which places on a receipt of the toll, permits will be granted (with a reduction of 2½ per cent) to the place of destination. The toll is always to be paid before the boat or craft passes the LOCK.

The price of COAL, at *Mauch Chunk*, by the CARGO to descend the canal subject to the above toll, two dollars and 25 cents per ton.

The prices of coal at other places on the Lehigh the same as last year JOSIAH WHITE,

Mauch Chunk, 1st, *mo*, 26, 1830, tf. *Acting Manager.*

NOTICE.—The subscriber hereby gives notice, that he will

Figure 4.—LEHIGH NAVIGATION RATES OF TOLL, January 28, 1830. (*Mauch Chunk Courier.*)

built by hand and five men could fabricate one section in 45 minutes.[21] These arks made only one downward trip, and upon reaching Philadelphia were broken up and the lumber sold. The hardware was returned by the boatmen to Mauch Chunk and reused in the construction of new arks. This type of boat was in use on the navigation until 1833, when the Delaware Division of the Pennsylvania Canal was opened and permitted up-and-down river passage.

The wooden arks were constructed mainly of pine lumber obtained from nearby forests. The boards were placed in cross courses and fastened together with nails. To ensure tight fitting joints, a joiner's plane was drawn along the edge (lengthwise) of the board to produce a continuous even surface. In the boat yards at Laurel Run (18 miles above Mauch Chunk), the plane was driven by waterpower and at Mauch Chunk

[17] *Lehigh History*, op. cit., p. 11.
[18] Ibid., p. 12.
[19] Ibid., p. 13.
[20] Ibid., p. 15.

[21] Ibid., p. 14.

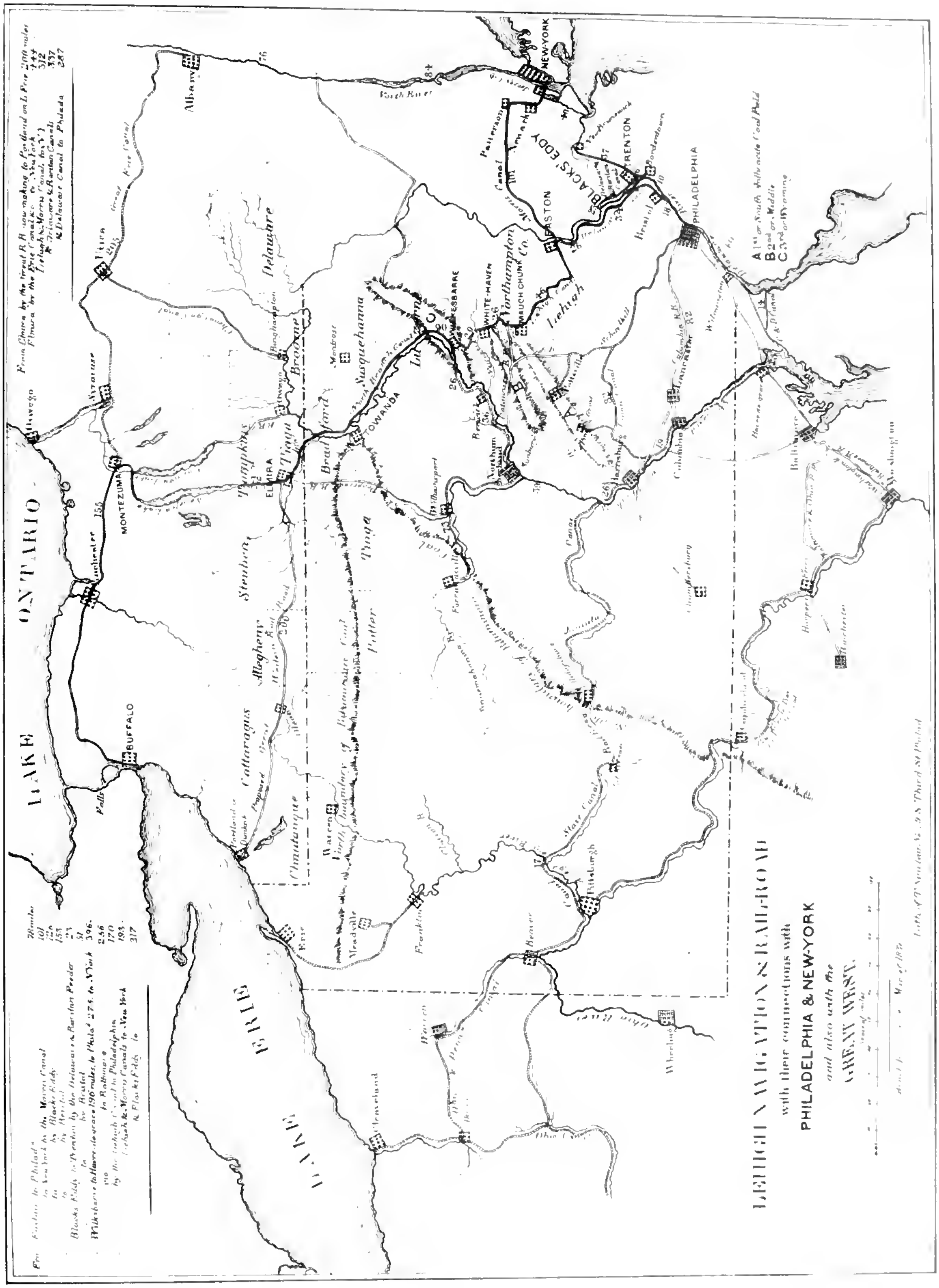


Figure 5. LEHIGH NAVIGATION AND RAILROAD, 1836. (L.C.N.C., *Annual Report for 1836* [Philadelphia: James Kay], 1836.)

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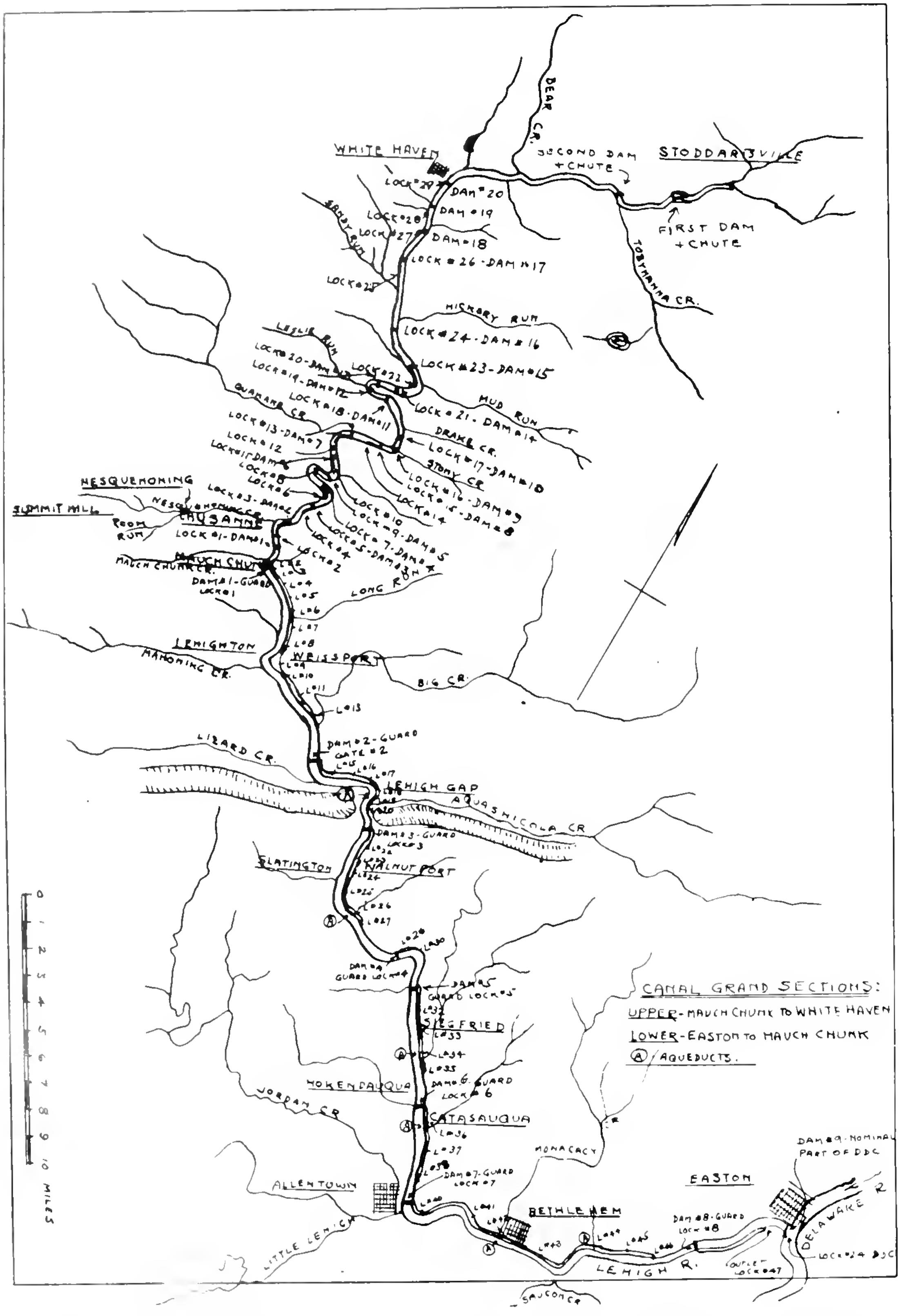


Figure 6.—The ca system of the Lehigh Coal and Navigation Company, ca. 1867. (L.C.N.C.)

by crank and manpower. Caulking was done with white pine strips, half an inch square, placed into grooves made for this purpose in the plank. Rushes were also used at times for caulking operations.[22] The consumption of large quantities of lumber in the construction of these temporary boats soon became apparent and additional timber resources were of utmost importance. In 1823, navigation was extended up the Lehigh River approximately 16 miles to procure additional supplies of lumber.[23]

Public acceptance of anthracite seemed to emerge during the 1824–25 season. In the previous 3 years, the supply exceeded the demand and a quantity of coal remained on hand at the end of each winter. However, the entire stock of anthracite in 1825 was sold by the 31st of December.[24] Shipments of anthracite down the Lehigh River tripled between 1824 and 1825.

During 1825, the company circulated a pamphlet containing facts illustrative of the character of Lehigh coal (Appendix III). Signed statements from blacksmiths, foundries, rolling mills, distilleries, and home and industrial users were included to indicate the various and efficient uses of Lehigh coal.[25]

The variety of industries presented is an indication of the extensive efforts by the company to prove the value of their product. Grates and furnaces for burning anthracite were also being manufactured by this time. Jacob F. Walter, a grate manufacturer in Philadelphia, was instrumental in this promotional effort.[26] Walter received a patent on his grate design on June 8, 1827.

By 1826, the wagon road from the mines to the river landing at Mauch Chunk was in need of improvements to handle the increased demand for coal. As this road had always presented a constant maintenance problem, the managers decided to construct the railroad.

The railroad from Mauch Chunk to the mines at Summit Hill was started in January 1827, and was in operation by May.[27] Total length was 9 miles with gravity descent from the mines to the river. This railroad was the first in the country constructed for the movement of coal.[28] Some characteristics of the Mauch Chunk railroad were:

1. The cross ties were laid 4 feet apart on a stone foundation. The rails, from England, were rolled iron bars, three eighths of an inch thick, one and one-half inches wide and mounted on wooden timbers.
2. The cars carried one and one-half tons of coal and descended the road usually in groups of fourteen. Each group was attended by two men who regulated the rate of descent. The empty cars weighed 1,600 pounds.
3. The descending trip took 30 minutes and the ascending trip took 3 hours.
4. Cost of the road amounted to $38.726 or about $3,050 per mile.[29]

During 1827, the managers had the Lehigh Navigation surveyed by Canvas White [30] to estimate the cost of enlargement and the conversion of the present system to canal and slackwater navigation between Mauch Chunk and Easton. As a result, the dimensions of the navigation were fixed at 60 feet wide on the surface and 5 feet deep: the locks were to be 100 feet long and 22 feet wide adapted to handle boats with a capacity of 120 tons.

The Pennsylvania Canal Commissioners met in the fall of 1827 for the purpose of proceeding with the construction of the Delaware Division of the Pennsylvania Canal. The managers of the Lehigh Navigation tried to convince the commissioners to follow the Lehigh's design, but the commissioners were convinced

[22] *Hazard's Register of Pennsylvania* (vol. 6, no. 18, October 30, 1830; Philadelphia: W. F. Geddes, 1830), p. 275.

[23] *Lehigh History,* op. cit., p. 14.

[24] Anthracite shipments from the Schuylkill field began with the completion of the Schuylkill Navigation in 1825.

[25] Lyman and Ralston, *Facts Illustrative of the Character of the Anthracite* (Boston: T. R. Marvin, 1825), p. 9. "We have used the Lehigh coal several years past to heat bar iron for our rolling mill at Bridgetown, Cumberland county, New Jersey; prior to the introduction of this, we used the Richmond coal for the same purpose, and from experience thus obtained, we are satisfied that for this purpose, one bushel of the former is worth at least two of the latter." "Philadelphia, May 19, 1824, Benjamin and David Reeves."

[26] Richardson, op. cit., p. 66. Throughout the literature, this surname is given both as "Walter" and "Walters"; the former predominates.

[27] The Lehigh Coal and Navigation Company, *Annual Report for 1827* (Philadelphia: S. W. Conrad, 1828), p. 4. Hereafter referred to as L.C.N.C.

[28] One earlier road, 3 miles in length, was in use by the Quincy Railroad in Massachusetts for hauling granite from their quarry to loading docks on the Neponset River. David Stevenson, *Sketch of the Civil Engineering [illegible] North America* (London: John Weale, 1838), p. 238.

[29] L.C.N.C., *Annual Report for 1827* (Philadelphia: S. W. Conrad, 1828), p. 7.

[30] A prominent engineer previo[illegible] employed in the construction of the Erie Canal.

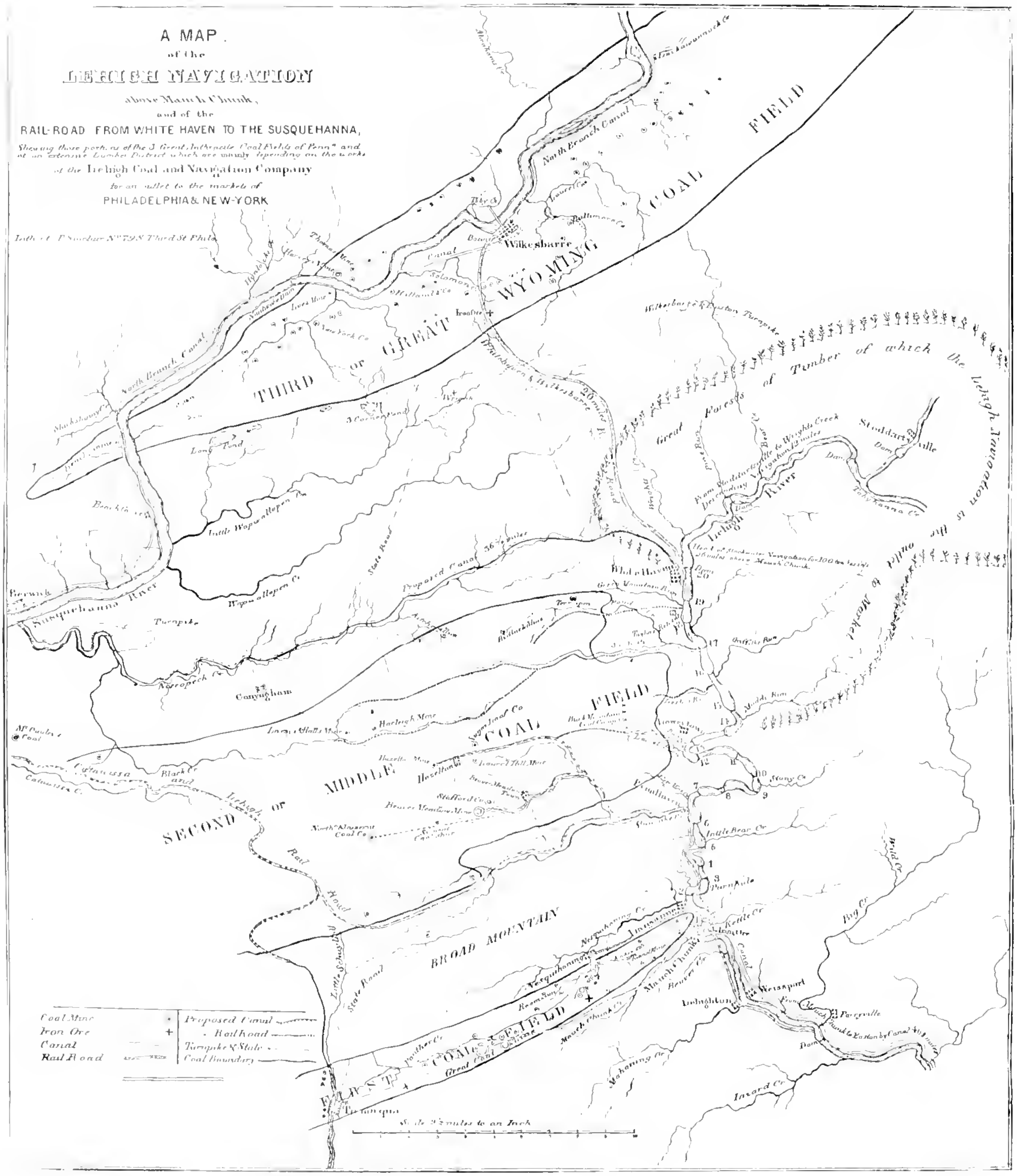


Figure 7.—LEHIGH NAVIGATION above Mauch Chunk and the railroad from White Haven to the Susquehanna River, 1840. (*History of the Lehigh Coal and Navigation Company*, 1840.)

that European experience, in using 25-ton boats, was more applicable and decided to make the locks half the width but the same length as those of the Lehigh Navigation.[31]

The Lehigh slackwater navigation between Mauch Chunk and Easton was opened for use in June 1829.[32] The Delaware Division improvements, started 4 months after the Lehigh, were not completed until 1832. To ensure the Delaware's completion, Josiah White was impressed as a consultant to design and construct a useful navigational system.[33] The delay in the construction of the Delaware Division caused the Lehigh managers to pass eight semiannual dividend payments. The company was required to use temporary arks which were the only kind of boats that could be used in the downward navigation on the Delaware.

The Lehigh Company expended all of its authorized capital while engaged in improving and enlarging their facilities and, in 1828, applied to the legislature for an increase of capital.[34] The attitude of the public toward this venture changed as the managers had proven that the Lehigh was navigable, but now there were many objections to the concessions granted under the original charter. The increase in capital was denied as the Lehigh managers refused to relinquish their valuable concessions. With the denial by the legislature for an increase in capital, the company's first private loan was negotiated during 1828 (details remain unknown).

During the next 6 years, the coal traffic continued to grow despite the necessity of continual improvements to keep the navigation operational. The capacities of the boats were gradually increased and the *Mauch Chunk Courier* announced, near the end of the 1833 season, the use of a 100-ton boat on the navigation.[35] Shipments of coal decreased in 1834, as the result of slack business conditions throughout the country, but an increase in the coal trade was noted in the following year.

In 1835, with public attention being directed to the Beaver Meadows coal region and the deadline approaching for the completion of the navigation on the upper section, the Lehigh managers decided to extend the navigation up to Stoddartsville. This work was begun in 1835 and completed on September 26, 1837.[36]

The prejudices against the company had subsided by then and on March 13, 1837, the legislature authorized the company to build the Lehigh and Susquehanna Railroad, 19 miles long, to connect the northern anthracite field with the Lehigh Navigation (Wilkes-Barre to White Haven).[37] Under the same authority, the company was permitted to increase its capital to $1.6 million from the previous limit of $1 million.

The Governor's commission inspected the Stoddartsville section of the navigation and recommended the issuance of a warrant to collect tolls beginning November 2, 1837 (Appendix IV).[38] The managers reported to the Governor that the railroad was completed on March 19, 1838, and on June 19, 1838, received a warrant to charge tolls on that property.[39] With the completion of the railroad, a shorter line of communication was obtained to the west by use of the Pennsylvania canal system which was completed in 1835. Total construction costs of the Lehigh and Susquehanna Railroad amounted to $1,326,700.

As early as 1834, the company offered to any iron manufacturer who successfully used Lehigh anthracite in his furnace special privileges—coal at a reduced rate, grants of waterpower, and reduced canal rates for shipments to market.[40]

No offers were received until July 1839, when the owners of the Lehigh Crane Iron Company accepted the company's longstanding offer.[41] The Company, incorporated on May 20, 1839, for the manufacture of iron from coke or mineral fuel, was formed through the efforts of three of the managers of the Lehigh Coal and Navigation Company.[42]

As superintendent of their operations, David Thomas, an ironmaster from Wales, was employed. Thomas was an associate of George Crane, who had

[31] *Lehigh History*, op. cit., p. 20.

[32] L.C.N.C., *Annual Report for 1829* (Philadelphia: T. A Conrad, 1830), p. 12.

[33] Josiah White resigned his office of Acting Manager at Mauch Chunk during 1831 and moved to Philadelphia. *Hazard's Register of Pennsylvania*, op. cit (vol. 8 no. 8, August 20, 1831), p. 128.

[34] *Lehigh History*, op. cit., p. 22.

[35] *Mauch Chunk Courier*, November 9, 1833.

[36] L.C.N.C., *Annual Report for 1838* (Philadelphia: James Kay, 1839), p. 37.

[37] *Pennsylvania Legislative Acts*, 1836–37 (Harrisburg: T. Fenn, 1837), pp. 52–57.

[38] L.C.N.C., *Annual Report for 1838* (Philadelphia: James Kay, 1839), p. 45.

[39] Ibid., p. 53.

[40] Richardson, op. cit., p. 100.

[41] L.C.N.C., *Annual Report for 18[illegible]* (Philadelphia: W. S. Young, 1840), p. 27.

[42] Josiah White, Erskine Hazar[illegible]nd Thomas Earp.

Figure 8.—David Thomas. Lithograph by A. Newsam. (M. S. Henry, *History of the Lehigh Valley*, 1860.)

invented and patented a process of iron making using anthracite in Wales in 1837.[43] In 1838, Crane purchased the American rights for a similar process from the executors of Dr. F. W. Geissenhainer, who had received a patent on December 19, 1833, after successfully using anthracite at Valley Furnace (Pottsville). Crane was later granted an American patent for smelting iron with anthracite.[44]

A blast furnace was built at Craneville (Catasauqua) and on July 4, 1840, the first successful blast using Lehigh coal was made.[45]

Anthracite furnaces were built throughout the East as a result of this (and later) experiments conducted by Thomas.

[43] Walter R. Johnson, *Notes on the Use of Anthracite in the Manufacture of Iron* (Boston: C. C. Little and J. Brown, 1841), p. 12.

[44] Richardson, op. cit., p. 102.

[45] *Mauch Chunk Courier*, July 25, 1840. Previously, an experimental water-powered furnace built in Mauch Chunk used Lehigh coal during 1838–39. Mechanical problems forced the furnace to close down.

Lehigh Crane Iron Furnace

Furnace Design

Stack height	40 feet
Bosh diameter	12 feet
Number of tuyeres	3
Water wheel diameter	12 feet
Temperature	600° F.
Hearth area	3½ feet square

Capacity (week)

104	tons of iron ore
69⅓	tons of anthracite
52	tons of limestone
50	tons of pig metal produced

Business conditions were satisfactory for several years until a flood occurred on January 10, 1841.[46] As a result, coal could not be sent to market, and all the resources of the company had to be called up to restore the damage to the canal. A mortgage was negotiated on the coal lands in the vicinity of Mauch Chunk to obtain the funds required for reconstruction. The navigation was again opened to traffic on July 10, 1841.[47]

The managers acted with great speed during this reconstruction period and made a request to the legislature for an increase in capital funds. The managers presented their case on the premise that a few years of prosperity would bring the company out of debt. An amending act which was passd on March 13, 1841, stated "that it shall be lawful for the Lehigh Coal and Navigation Company to increase their capital stock by the sale of shares or otherwise to an amount which shall not exceed the actual cost of the navigation and railroad . . . provided the capital stock . . . shall not exceed six million dollars." [48]

The period from the reconstruction of the flood damage, 1842 to 1845, again showed an increase in coal traffic. The navigation was adequate in size, consistent with the demand, and the company possessed a monopoly on the trade from the region. The coal traffic increased both from the company's mines and from

[46] L.C.N.C., *Annual Report for 1840* (Philadelphia: W. S. Young, 1841), p. 17.

[47] L.C.N.C., *Annual Report for 1841* (Philadelphia: Brown, Bicking and Guilbert, 1842), p. 7.

[48] *Pennsylvania Legislative Acts,* 1841 (Harrisburg: Peacock and M'Kinley, 1841), pp. 36–37.

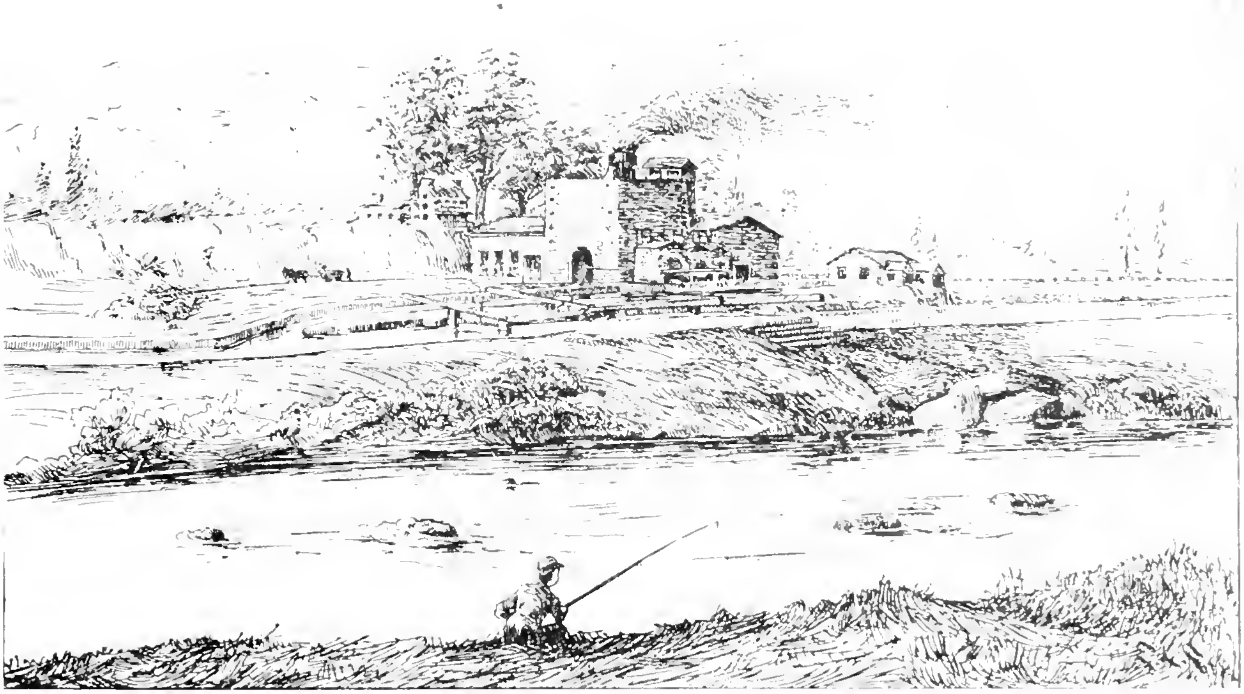


Figure 9.—EARLY ANTHRACITE IRON-FURNACE at Catasauqua. (*Pop. Sci. Monthly*, 1891, vol. 38, no. 4, p. 451.)

other mines under development, by Beaver Meadows, Hazleton, Sugar Loaf, and Buck Mountain Coal Companies. (See description of companies, pp. 110–114.) The coal trade was the main source of revenue for the company. Competition from the railroad did not begin until 1855.[49]

Also showing an increase in this period were two classes of traffic; lumber and materials involved in the manufacture of iron. Iron ore and limestone was carried up the canal to the blast furnaces and later came back down in the form of pig iron. Lumber shipments continued to grow until 1850 and then began to decrease.

The general trade classification, including flour, whiskey, grain, bricks, etc., never became a major source of revenue. When railroad connections became available, this traffic disappeared more rapidly from the navigation than did the heavier class of traffic.

Lehigh Company Coal Properties

The coal lands belonging to the company totaled approximately 8,000 acres and comprised the entire eastern end of the southern anthracite field. These lands begin on the east, on the top of Broad Mountain (Mount Pisgah) a half mile from the Lehigh River near Mauch Chunk, and extend 14 miles to Tamaqua on the Little Schuylkill River. On the northern side of this coal basin, nine coal beds ranging from 5 to 28 feet in thickness are found, and in some places extend up to 111 feet. On the southern side of the basin four major seams of coal are found measuring 9, 15, 20, and 50 feet, for a total thickness of 94 feet.[50]

At the great mine at Mauch Chunk (Sharp Mountain the seams were located near the surface, and mining operations were greatly simplified during the early days. The working force primarily consisted of hand laborers, and open-pit quarry-type operations

[49] The Delaware, Lehigh, Schuylkill and Susquehanna Railroad (changed to the Lehigh Valley Railroad in January 1853) was incorporated on April 23, 1846.

[50] *Lehigh History*, op. cit., p. 23

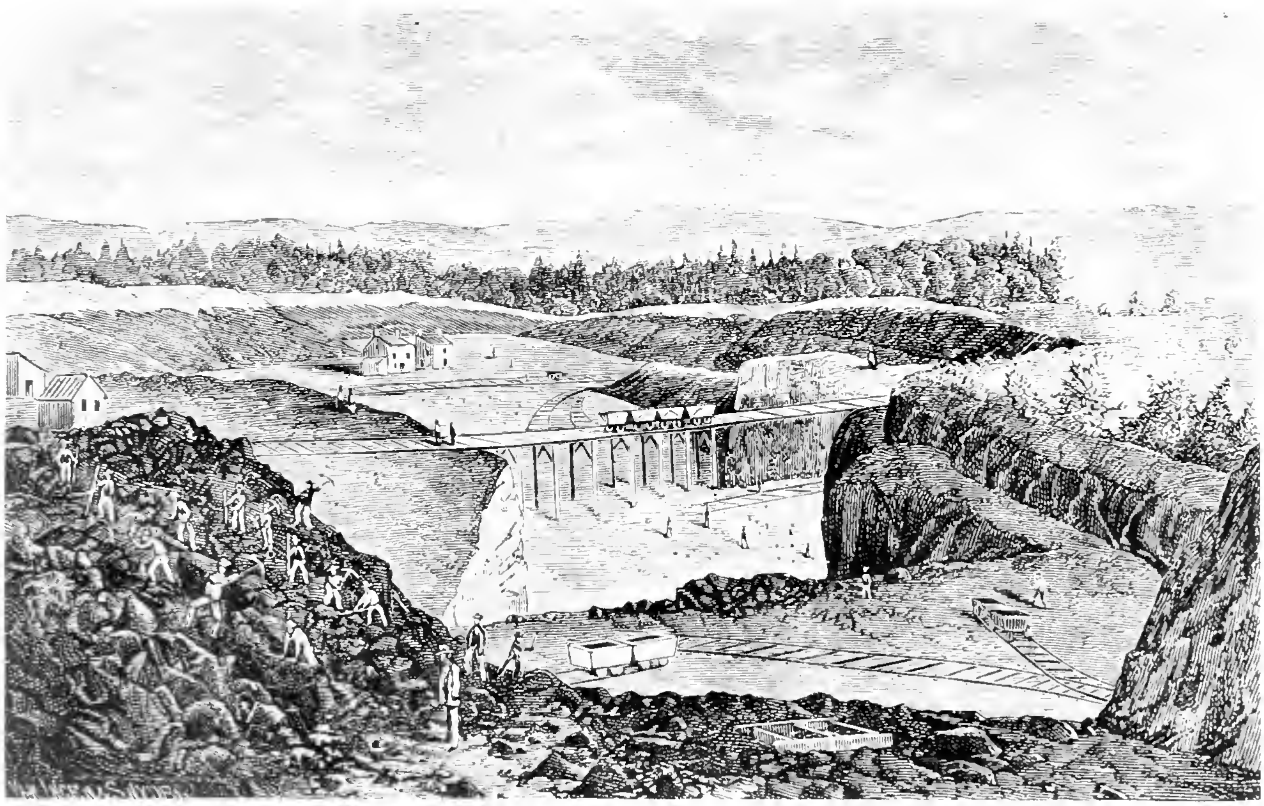


Figure 10.—Coal mine at Summit Hill, 1821. (Richard Richardson, *Memoir of Josiah White*, 1873, p. 48.)

were used.[51] The overburden was relatively light and varied from 3 to 15 feet. The exposed area was entered in many locations by roads cut around and through the coal seams.

The exposed coal was removed by using hand picks in the natural joints and by driving wedges in the seams running parallel with the host strata. A few blows by these tools were usually required to free the coal. For ease in handling, sledges were sometimes used to break the larger pieces before loading into wagons.

In some cases, when the coal was interrupted by slate and rock, it was necessary to drill holes by hand and separate the strata by blasting. Large pieces of material resulting from the blast were reduced in size by sledging. Refuse material from the quarry was hauled away and dumped over an adjacent hill where it would not interfere with mining operations.

The company, with high hopes of discovering additional coal deposits nearer the navigation, began on March 1, 1824, to excavate a tunnel about two and one-half miles west of Mauch Chunk. This "Hacklebernie" tunnel was the first large mining tunnel driven in the United States. It measured 16 feet wide and 8 feet high and was extended some 790 feet before the operations were temporarily suspended on June 9, 1827.

Coal was found in the tunnel but, at the time the company suspended operations, it was decided that the continuance of the operation was not essential for current production requirements. The company anticipated the need in later years for a drainage tunnel in mining the coalbeds above, and this tunnel could then be continued to serve that purpose.[52]

During the 3 years of tunnel operations, the company expended $26,812 to remove approximately 3,745

[51] Laborers were furnished with daily rations of whiskey, at a reduced pay scale, if so desired. *Hazard's Register of Pennsylvania* (vol. 1, no. 20; Philadelphia: W. F. Geddes, 1828), p. 312.

[52] Work on the tunnel was resumed in 1846 and driven for a total length of 2,200 feet.

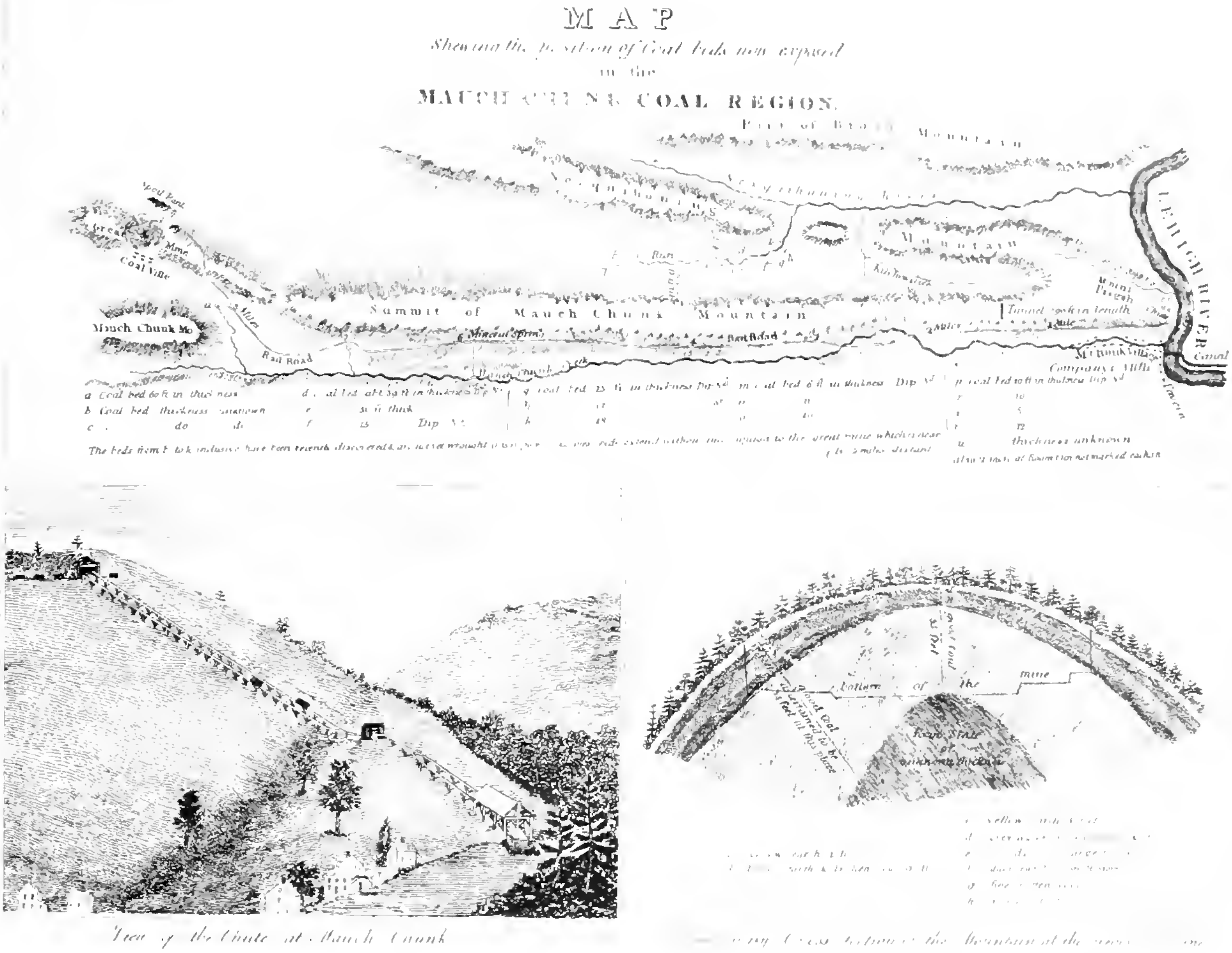


Figure 11.—THE MAUCH CHUNK COAL REGION. The "Hacklebernie" tunnel is shown in the upper right. (Benjamin Silliman, *The American Journal of Science and Arts*, 1831, vol. 19, no. 1, pl. 1.)

cubic yards of hard conglomerate at a unit cost of $7.16 per cubic yard. The following costs were charged to the operation:[53]

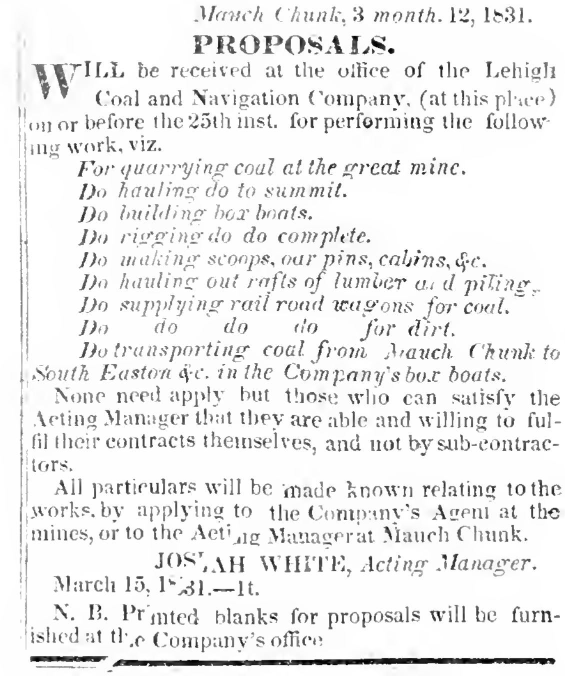
Labor—23,129¾ days	$18, 697. 09
Tools and materials	3, 785. 86
Powder—521 kegs	1, 831. 00
Candles and oil for lights	812. 71
Lumber, including pipes for air	508. 54
One horse blowing wind for 268 days	196. 80
Superintendence	980. 00
Total	$26, 812. 00

The working day at the mines began at sunrise and ended at 4:30 p.m. According to a news item that was given wide circulation by the press, the average number of tons of coal quarried each woking day totaled 268. This quantity of coal was loaded at the mines, transported on the railroad, unloaded from the wagons at the chute, and loaded into boats. The news item ended "we not only load the vessels, but create the freight, and also build the vessels to carry it all on the same day"![54]

During 1830, a deposit of coal was discovered on the north side of Mount Pisgah near Rhume (Room) Run, (Nesquehoning) only 4 miles from the Lehigh River.

[53] I. DANIEL RUPP, *History of Northampton, Lehigh, Monroe, Carbon, and Schuylkill Counties* (Harrisburg: Hickock and Cantine, 1845), pp. 202–203.

[54] *Hazard's Register of Pennsylvania*, vol. 5, no. 24, June 12, 1830), p. 384.


Mauch Chunk, 3 *month*. 12, 1831.

PROPOSALS.

WILL be received at the office of the Lehigh Coal and Navigation Company, (at this place) on or before the 25th inst. for performing the following work, viz.

For quarrying coal at the great mine.
Do hauling do to summit.
Do building box boats.
Do rigging do do complete.
Do making scoops, oar pins, cabins, &c.
Do hauling out rafts of lumber and piling.
Do supplying rail road wagons for coal.
Do do do do for dirt.
Do transporting coal from Mauch Chunk to South Easton &c. in the Company's box boats.

None need apply but those who can satisfy the Acting Manager that they are able and willing to fulfil their contracts themselves, and not by sub-contractors.

All particulars will be made known relating to the works, by applying to the Company's Agent at the mines, or to the Acting Manager at Mauch Chunk.

JOSIAH WHITE, *Acting Manager*.

March 15, 1831.—1t.

N. B. Printed blanks for proposals will be furnished at the Company's office

Figure 12.—Advertisement requesting bids, March 28, 1831. (*Mauch Chunk Courier.*)


Figure 13.—Descending coal and mule wagons. The artist has added two mules to the usual complement of four per wagon. (T. L. Mumford, *The Switzerland of America*, 1883, p. 15.)

Benjamin Silliman, reporting on the quality and quantity of the coal at this new deposit, stated that "the coal appears to be of the finest quality, and some of it, in the high lustre and perfection of its fracture, exceeds anything I have elsewhere seen." He estimated that "when all the beds are perforated there can be no doubt that the entire thickness will exceed two hundred feet, which is about three times that of the great mine at Mauch Chunk." [55]

The managers immediately started plans to locate a railroad from this new deposit to the landing at Mauch Chunk. The road, completed in 1833, included three inclined planes and the entire road from the mine was descending.[56] The design of the self-acting planes was such that the descending loaded wagons returned the empty ones to the top of the plane.

During 1831, the company began to negotiate contracts for the mining and transporting of coal to the landing at Mauch Chunk. Advertisements appeared requesting that proposals be submitted to the company to perform other needed services, such as sorting the coal before loading, loading into wagons, and loading the boats at Mauch Chunk.[57]

The location of coal deposits near the surface permitted the mine operators to hold down labor costs. Quarry operations permitted the use of common laborers at a wage rate lower than that paid to the underground miners required in the Schuylkill field. The wage differential during this period ranged from a low of approximately 18 cents per day in 1831, to a high of 33 cents per day in 1845. Calculations using this labor differential on a per ton basis revealed that a reduction of from 10 to 25 cents per ton could be effected by employing common labor.

An inventory, conducted by the acting manager, of equipment at the company mines in 1831 contained the following items: [58]

Total Company

9 Oxen	33 Horses
30 Canalboats	115 Mules

[55] Benjamin Silliman, "Notes on a Journey from New Haven, Connecticut to Mauch Chunk, Pennsylvania" (*American Journal of Science and Arts*, vol. 19, no. 1; New Haven: H. Howe, 1830), p. 18.

[56] L.C.N.C., *Annual Report for 1833* (Philadelphia: James Kay, 1834), p. 9.

[57] *Mauch Chunk Courier*, March 15, 1831.

[58] L.C.N.C., *Annual Report for 1831* (Philadelphia: W. F. Geddes, 1832), p. 9.

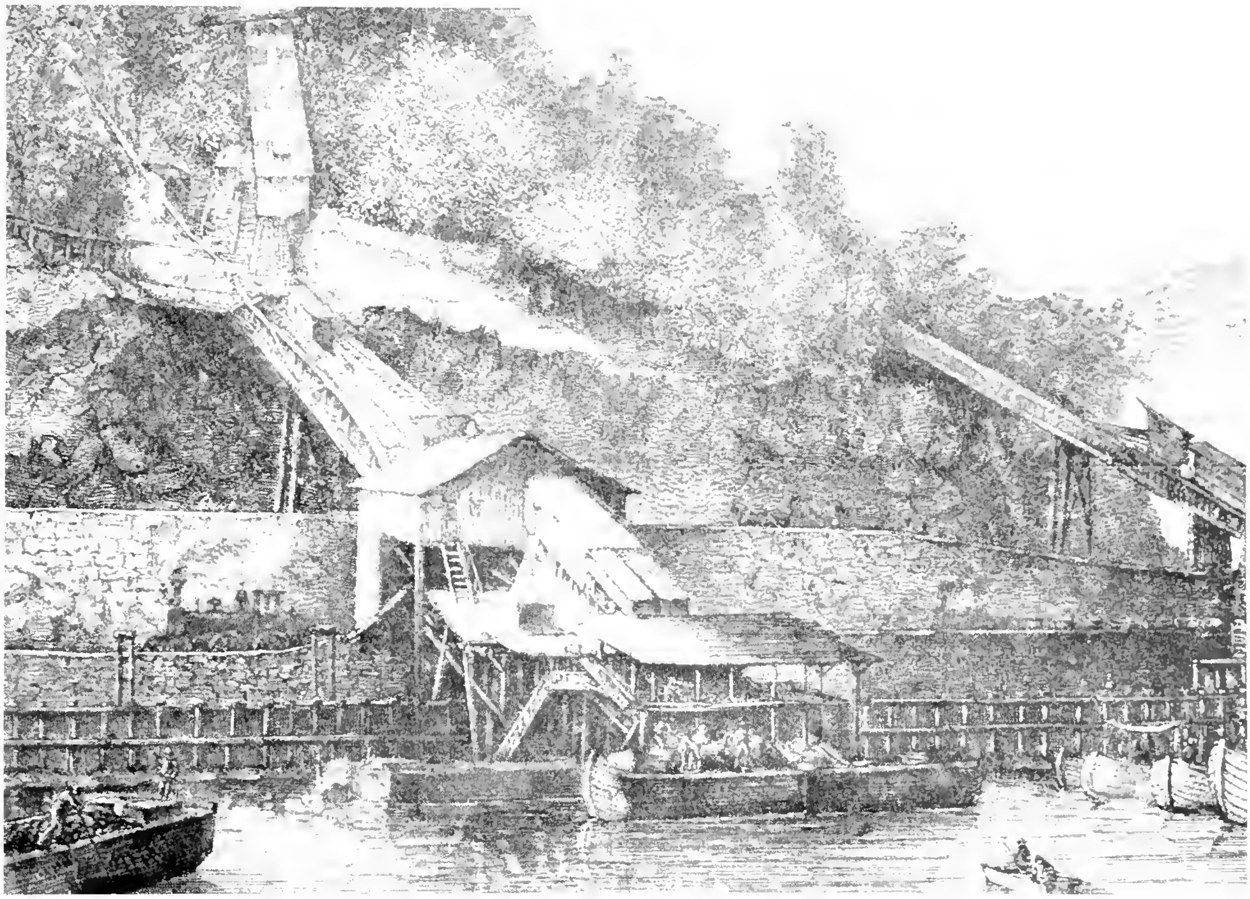


Figure 14.—LOADING BOATS on the Lehigh Canal; from an old woodcut. (L.C.N.C.)

Great Mine		*Room Run*	
21	Mule wagons	21	Coal wagons
44	Dirt wagons	13	Dirt wagons
308	Coal wagons		
9	Miscellaneous wagons		

An unusual method of railroad operation required the listing of mule wagons in the inventory. The railroad was a gravity road and the loaded coal wagons plus mule wagons (each holding four mules) rode down the track (fig. 13). After being unloaded, the empty coal wagons were returned by mule power to the summit mines along with the empty mule wagons. The speed of the loaded wagons down the track was between 5 and 7 miles per hour.[59]

The coal wagons were square boxes widened at the top and mounted on cast iron wheels of 18 to 24 inches in diameter. The axle holding the wheels turned as the wheels turned. The wheels were constructed with a 4-inch flange and an inner lip to keep them positioned on the rails.

A lever was fixed to each wagon near the left front wheel and extended above the side of the wagon. By pulling this lever back, every wheel was clasped by two semicircular pieces of wood. The friction thus applied retarded or instantly stopped the wagon. In a trainload of wagons, these levers were tied together with a rope so that the trip operator could control the speed of the entire load. Average trainloads consisted of 14 wagons, each with a capacity of one and a half tons of coal.[60]

The problem of getting coal from [illegible]gon to ark was

[59] L.C.N.C., *Annual Report for 1828* (Philadelphia: S. W. Conrad, 1829), p. 7.

[60] *Hazard's Register of Pennsyl*[illegible] vol. 2, no. 31, August 2, 1838).

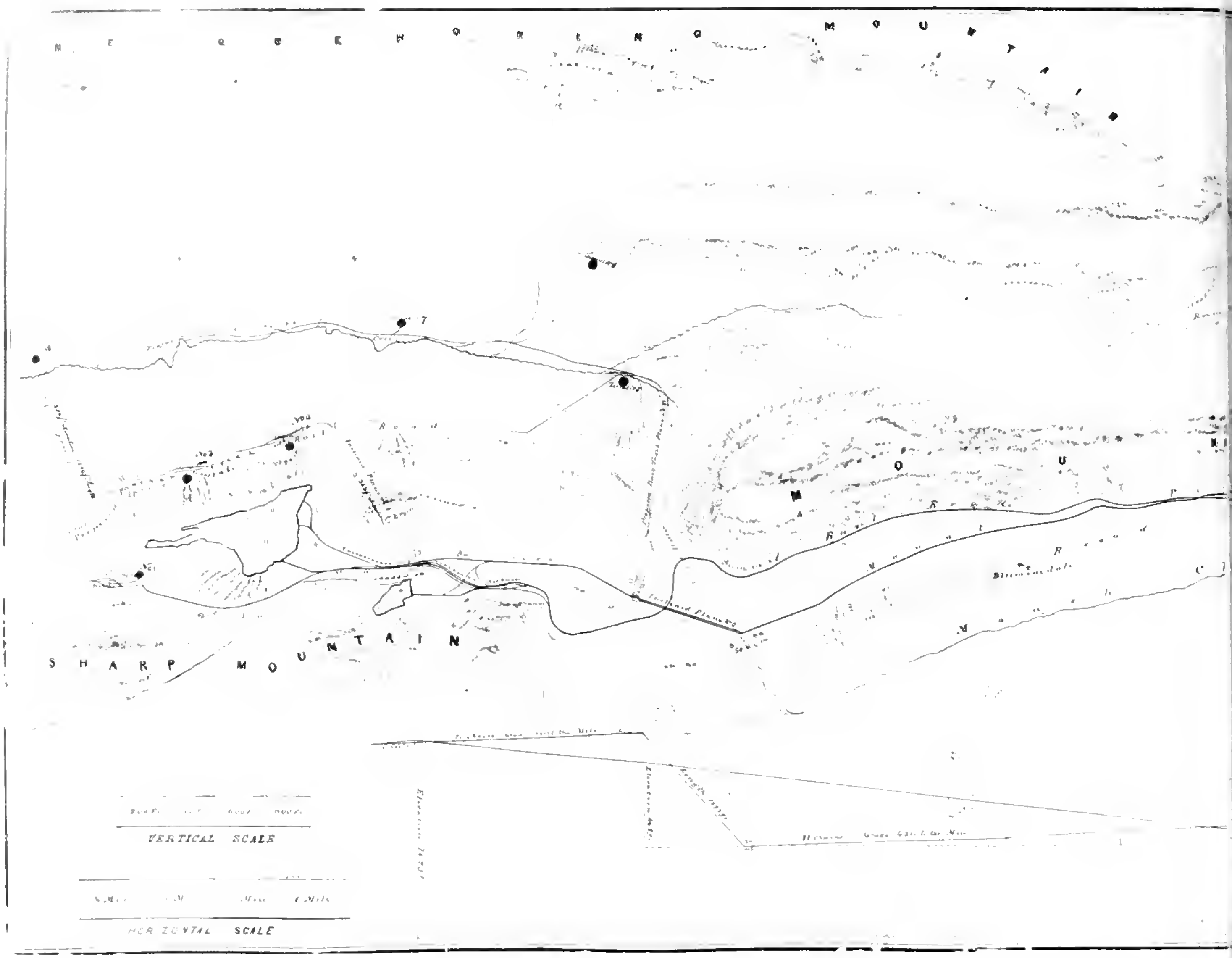


Figure 15.—1845 Plan of the mining and transportation facilities. (L.C.N.C.)

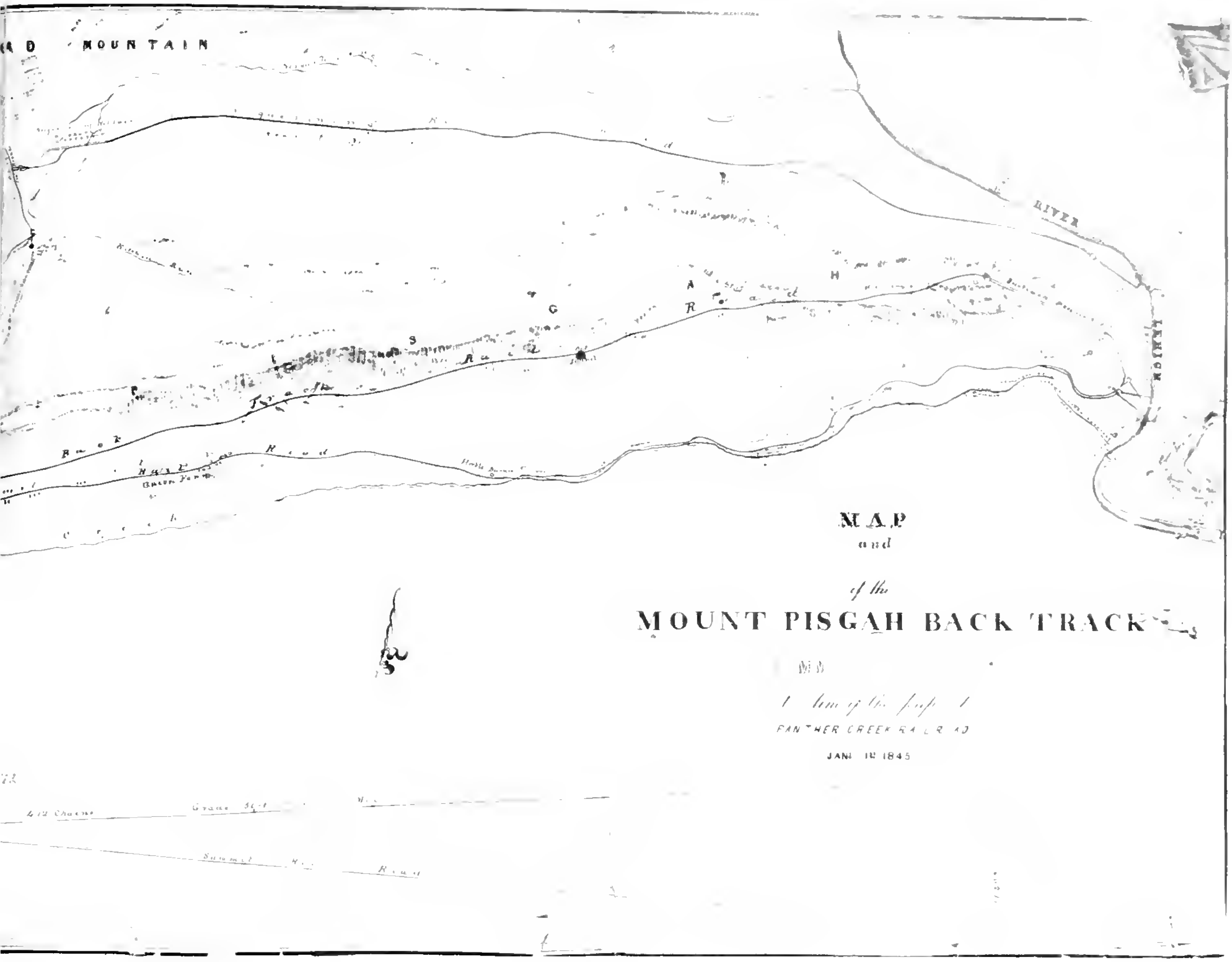
solved by constructing an inclined loading chute at Mauch Chunk that extended downward from Mount Pisgah to a coal-loading house along the Lehigh River. The coal house projected over the river's edge to facilitate loading the boats. The inclined chute was double tracked for the steepest descent and single tracked thereafter. The length of the chute was 700 feet and the difference in elevation was 215 feet.

Individual wagons were unloaded at the bottom of the incline by a projecting bar which contacted the lower end of the wagon and knocked it open, thus releasing the coal into the loading pocket.

A large wooden drum was installed at the top of the chute around which a rope or small cable wound. The turning of this drum on a horizontal axis released the rope and controlled the descent of the loaded wagon. At the same time, the other end of the rope, which was fastened to the empty wagon, wound up and returned the empty wagon to the top. A metal band was fitted around this drum to prevent it from revolving at too great a speed and was tightened or loosened by a lever attached to the band. The capacity of the loading chute was 200 wagons a day.[61]

During 1838, the company installed, on the 1200-foot plane on the Room Run road, an iron band (one-twelfth of an inch thick by three inches wide) as a substitute for the rope or small cable that was used previously to hoist the coal wagons up and down the incline. The experiment proved successful and similar

[61] Silliman, op. cit., p. 9.



iron bands were installed on the other two inclined planes. Maintenance costs were reduced and replacements were seldom required.[62]

In 1839, the company leased the entire Room Run operations for a 3-year period. The contractors were to mine 30,000 tons of coal the first year and thereafter to increase their output by 5,000 tons per year. The company received a royalty payment for each ton of coal mined. Similar leasing arrangements were planned for the old mine property at Summit Hill whenever a second or return track could be built between the mines and the loading chute at Mauch Chunk.[63]

[62] L.C.N.C., *Annual Report for 1838* (Philadelphia: James Kay, 1839), p. 31.
[63] Ibid., p. 20.

A separate return track was eventually constructed during 1844 and opened for use with the 1845 season.[64] The empty coal wagons from the loading chutes at Mauch Chunk were returned to the mines via this new road, thereby increasing the capacity of the original road by eliminating the delay caused by waiting for the loaded train to pass at turnouts. At about the same time, stationary engines were installed at the inclined planes leading into the mines, replacing animal power and thereby increasing the road's haulage capabilities. A plan of the facilities, as they existed at the beginning of the 1845 season is shown in figure 15.

[64] L.C.N.C., *Annual Report for 1[illegible]* (Philadelphia: James Kay, 1846), p. 6.

Incorporation of Additional Companies

The Lehigh Coal and Navigation Company conducted the first successful mining operations in the Lehigh region, and during the first 25 years (1820–45) was joined by 17 other corporations (Table 1). The companies, chartered by the Legislature of Pennsylvania, were granted similar privileges, powers, and limitations, but none received the unlimited concessions granted previously to the Lehigh Coal and Navigation Company.

These charters contained authorization to acquire coal lands (maximum 2,000 acres) and to construct a railroad, if needed, to connect their operations with existing transportation facilities.

TABLE 1.—*Companies incorporated utilizing the facilities of the Lehigh Navigation* [1]

Company	*Date Incorporated*	*Capitalization*
Lehigh Coal and Navigation.	February 13, 1822.[2]	$6,000,000
Beaver Meadows....	April 7, 1830....	800,000
Little Schuylkill and Susquehanna.	March 31, 1831	2,000,000
Hazleton Coal..	March 18, 1836	250,000
Summit Coal....	March 18, 1836	250,000
Laurel Hill Coal..	June 16, 1836.	250,000
Buck Mountain Coal.	June 16, 1836	250,000
Northampton and Luzerne Coal.	June 16, 1836.	250,000
Mountain Coal.	February 28, 1837.	250,000
Stafford Coal.....	March 3, 1838	350,000
Sugar Loaf Coal	April 16, 1838...	250,000
Tammanend Coal.....	April 16, 1838...	250,000
Wyoming Coal........	April 16, 1838...	300,000
Hanover Coal ..	February 6, 1839.	250,000
Potosi Coal ..	June 24, 1839	250,000
Middle Field Coal. ...	May 29, 1840	250,000
Diamond Coal. ..	March 19, 1841	250,000
Black Creek Coal.	April 3, 1841...	200,000
Total.....		$12,650,000

[1] *Pennsylvania Legislative Acts*

[2] Unincorporated from 1818 to this date.

COAL MINES TO LET.

The Summit Coal Company have completed their Rail Road, erected screens, and opened mines, ready for working to the extent of Fifty Thousand tons of coal per annum. Capable of being wrought by uncovering, entirely above water level which they are prepared to lease on advantageous conditions for a term of years.—These mines are in the immediate vicinity of the Beaver Meadow works, and the transportation is continuously deceending to the Lehigh River. The mining operations can be carried on with great economy, owing to the favorable position of the Veins.

Proposals may be left at the office No 57 South 3d street Philadelphia directed to

J. L. Fenemore.

Secretary of the Board of Directors.

Philadelphia, Dec. 16, 1841.

Figure 16.—SUMMIT COAL COMPANY December 20, 1841, request for bids. (*Mauch Chunk Courier.*)

The Beaver Meadows Company was chartered in 1830, and one year later the Little Schuylkill and Susquehanna Company received its charter. After a lapse of 5 years, the Hazleton Coal Company and the Summit Coal Company were chartered at the same time in 1836. The remaining companies were chartered between this date and April 1841. All of these companies utilized the navigation facilities of the Lehigh River in transporting their products to market.

Coal production during this period was limited to eight active operations. One company, the Laurel Hill, conducted operations for about one year and then consolidated with the Hazleton Coal Company. Another company, the Sugar Loaf Coal Company, produced anthracite for 6 years (1839–44) and then also combined with the Hazleton Coal Company. Development work on the properties of the remaining companies continued, but little, if any, shipments of coal from these mines entered the market prior to January 1845. Anthracite shipments on the navigation between 1820 and 1845 are given in Table 2.

The BEAVER MEADOWS RAILROAD AND COAL COMPANY, incorporated on April 7, 1830, was authorized to hold coal lands in Northampton County [65] and to construct a single- or double-track railroad from their

[65] Carbon County was taken from Northampton County land in 1843.

TABLE 2.—*Anthracite shipped from Lehigh region by source, via navigation, from 1820 to 1845, in short tons* [1]

Year	*Lehigh Company*	*Beaver Meadows*	*Hazleton*	*Sugar Loaf*	*Buck Mountain*	*Others*	*Total*
1820	365						365
1821	1,073						1,073
1822	2,240						2,240
1823	5,823						5,823
1824	9,541						9,541
1825	28,393						28,393
1826	31,280						31,280
1827	32,074						32,074
1828	33,150						33,150
1829	25,110						25,110
1830	41,750						41,750
1831	[2] 42,743						42,743
1832	75,937						75,937
1833	122,938						122,938
1834	106,518						106,518
1835	131,250						131,250
1836	146,738						146,738
1837	192,595	31,500					224,095
1838	153,547	44,442	14,221			[3] 2,001	214,211
1839	140,760	38,595	33,826	7,510		[3] 1,159	221,850
1840	102,264	43,707	50,366	28,958	54	[4] 236	225,585
1841	78,164	26,232	21,263	17,170	–	209	143,038
1842	163,762	45,423	31,082	31,934	–	352	272,553
1843	138,826	54,729	44,579	26,814	2,844	34	267,826
1844	219,245	70,379	70,760	2,866	13,844	–	377,094
1845	257,740	77,161	70,659	[5] –	23,858	74	429,492
Totals	2,283,826	432,168	336,756	115,252	40,600	4,065	3,212,667

[1] L.C.N.C., *Annual Reports* for the years 1820–45.
[2] Room Run production beginning in 1831.
[3] Laurel Hill production combined with Hazleton Coal Company in 1840.
[4] Tammanend production of 27 tons included.
[5] Sugar Loaf production combined with Hazleton Coal Company in 1845.

mines to any convenient point on the Lehigh River at any location above Mauch Chunk. Supplemental legislation authorized the continuance of the railroad down the Lehigh valley or to any other convenient point. Mining operations were begun in 1831.

The first shipment of coal from this property was made during 1837, and the quantity of coal moved during that year amounted to 31,500 tons.[66]

Coal was loaded into railroad cars with a capacity of two and one-half tons and hauled in trains of 20 cars by locomotive to the loading docks on the navigation. Four locomotives were in use on the road by the end of the navigational season in 1837.[67]

The first locomotive on the railroad was built by the firm of Garrett and Eastwick of Philadelphia and was named the "Samuel D. Ingham" after the president of the company.[68] The locomotives were of the wood-

[66] L.C.N.C., *Annual Report for 1837* (Philadelphia: James Kay, 1838), p. 6.

[67] Ibid., p. 19.

[68] M. S. HENRY, *History of the* [illegible] *Valley* (Boston: Bixler and Corwin, 1860), p. 40[illegible]

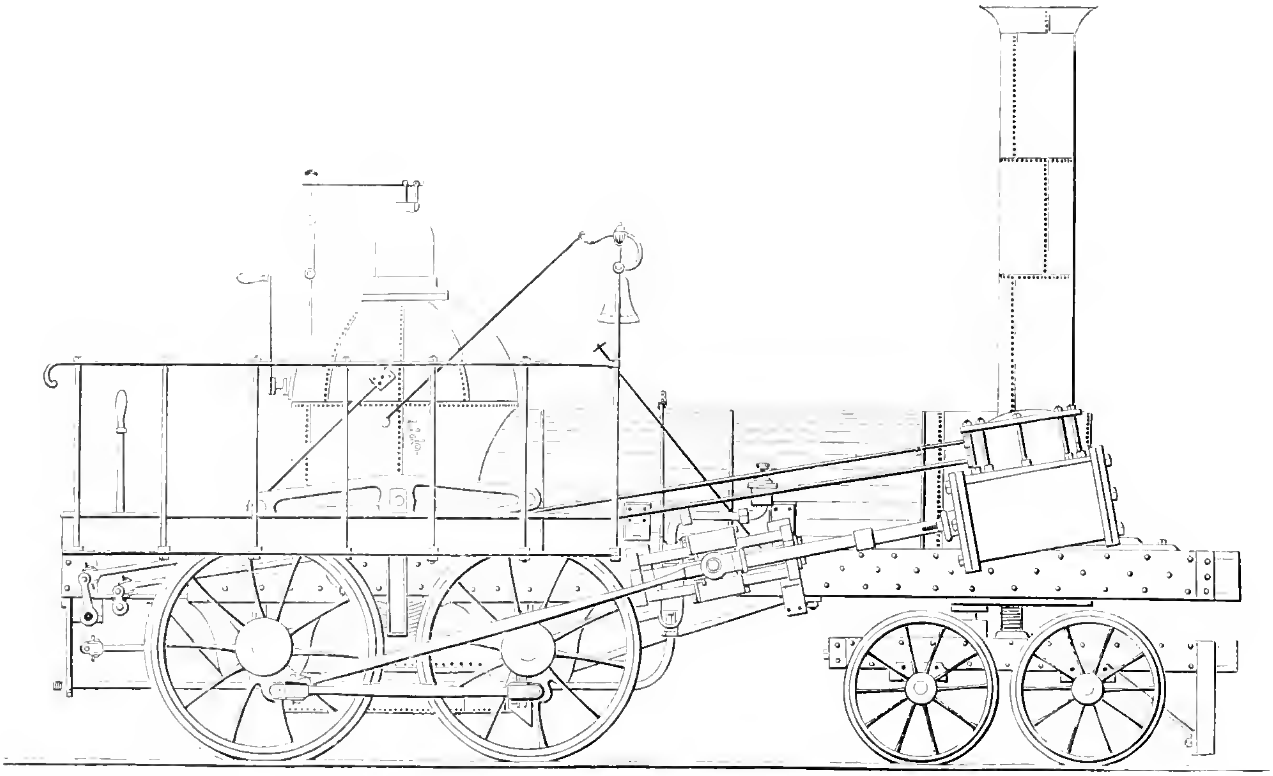


Figure 17.—1837 "Hercules," Garrett & Eastwick's first 8-wheel locomotive. The "Hercules" quickly replaced the "Samuel D. Ingham," also built by Garrett & Eastwick. (Joseph Harrison, Jr., *The Locomotive Engine*, 1872, p. 49.)

burning type, but after experimentation and redesign were burning anthracite exclusively (except for the first-built fire).

The railroad extended from the company's mines to Parryville, 6 miles below Mauch Chunk, for a total distance of 20 miles. The completed road differed from the original layout due to opposition by the Lehigh Coal and Navigation Company to the exact location of the road and apparent infringements of the Lehigh Company's prior concessions.[69]

By June 1839, the Beaver Meadows had five locomotives in use and was shipping 38,595 tons of anthracite to the Lehigh Navigation. During 1840, the company leased the mining operations to Vancleve and Company. The transportation of the coal was accomplished by using the cars and locomotives owned by the Beaver Meadows and under contract to the same company.[70]

The Beaver Meadows Railroad was subject to disruptions in traffic due to the flooding of the Quakake Creek and Lehigh River. After the flood of 1841, the company was forced to abandon the tracks extending from Mauch Chunk to Parryville. To replace this section, a new loading facility was built in East Mauch Chunk for loading the boats for the downriver trip.

The Hazleton Coal Company, incorporated on March 18, 1836, was authorized to hold coal lands within Sugar Loaf Township in Luzerne County and Lausanne Township in Northampton County.[71]

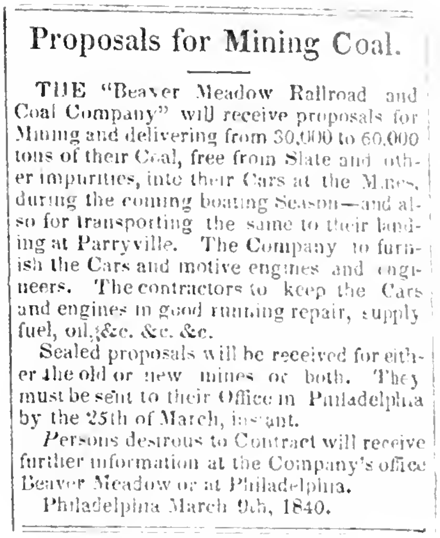
Another section of the act authorized the construction of a railroad, consisting of one or two tracks, from any point on their lands to an intersection with the Beaver Meadows Railroad.

The company started mining operations on their property and the construction of the railroad during 1836. The first shipment of coal over the completed road was made on May 14, 1837. Shipments to the

[69] *Pennsylvania Legislative Acts, 1837–38* (Harrisburg: T. Fenn, 1838), p. 393.

[70] Beaver Meadows Railroad and Coal Company, *Annual Report for 1842* (Philadelphia: Elliott's Printing Office, 1843), p. 7.

[71] Lausanne Township became part of Carbon County in 1843.



Proposals for Mining Coal.

THE "Beaver Meadow Railroad and Coal Company" will receive proposals for Mining and delivering from 30,000 to 60,000 tons of their Coal, free from Slate and other impurities, into their Cars at the Mines, during the coming boating Season—and also for transporting the same to their landing at Parryville. The Company to furnish the Cars and motive engines and engineers. The contractors to keep the Cars and engines in good running repair, supply fuel, oil, &c. &c. &c.

Sealed proposals will be received for either the old or new mines or both. They must be sent to their Office in Philadelphia by the 25th of March, instant.

Persons desirous to Contract will receive further information at the Company's office Beaver Meadow or at Philadelphia.

Philadelphia March 9th, 1840.

Figure 18.—BEAVER MEADOW RAILROAD AND COAL COMPANY March 14, 1840, request for bids. Vancleve and Company were the successful bidders. (*Mauch Chunk Courier.*)

navigation during the first year of operation were 14,221 tons.[72]

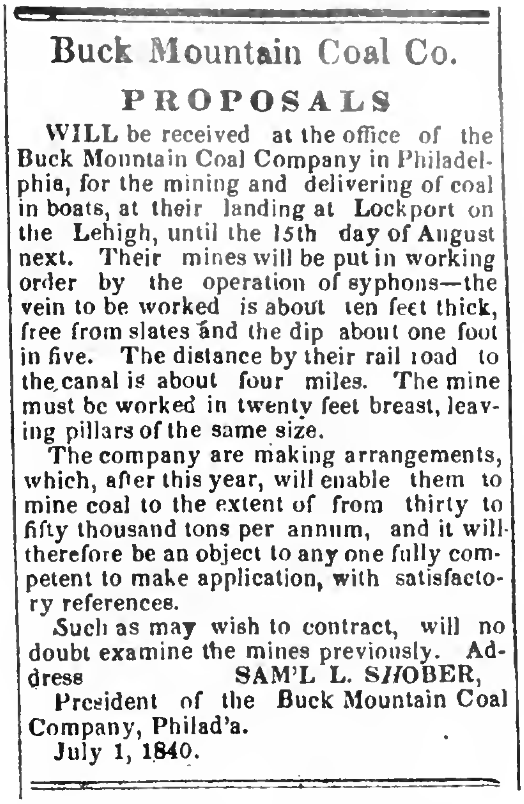
The railroad, 10 miles in length, extended from their mines at Hazleton to an intersection with the Beaver Meadows Railroad at Weatherly. The coal then moved over the Beaver Meadows Railroad for 5 miles to Penn Haven, located 8 miles above Mauch Chunk. At Penn Haven, the coal was loaded into boats for movement down the Lehigh River.

Anthracite was the fuel for the steam locomotives used on the road. Two locomotives were in operation during the first year and additional locomotives were planned to be purchased in the future as the demand for coal increased.

In 1840, Ario Pardee, Robert Miner, and William Hunt, formed a company and contracted with the Hazleton Coal Company for the purposes of mining coal, transporting the coal to Penn Haven, and loading the boats at the river docks.[73] This contract was in force for several seasons and, in 1842, was extended to include the marketing of a portion of the annual tonnage. The Hazleton Coal Company retained part of the tonnage which they marketed, but paid Pardee and Company a fee for this privilege. Pardee and Company

[72] L.C.N.C., *Annual Report for 1837* (Philadelphia: James Kay, 1838), p. 11.

[73] H. C. BRADSBY, *History of Luzerne County* (Chicago: S. B. Nelson and Company, 1893), p. 291.



Buck Mountain Coal Co.

PROPOSALS

WILL be received at the office of the Buck Mountain Coal Company in Philadelphia, for the mining and delivering of coal in boats, at their landing at Lockport on the Lehigh, until the 15th day of August next. Their mines will be put in working order by the operation of syphons—the vein to be worked is about ten feet thick, free from slates and the dip about one foot in five. The distance by their rail road to the canal is about four miles. The mine must be worked in twenty feet breast, leaving pillars of the same size.

The company are making arrangements, which, after this year, will enable them to mine coal to the extent of from thirty to fifty thousand tons per annum, and it will therefore be an object to any one fully competent to make application, with satisfactory references.

Such as may wish to contract, will no doubt examine the mines previously. Address SAM'L L. SHOBER,
President of the Buck Mountain Coal Company, Philad'a.
July 1, 1840.

Figure 19.—BUCK MOUNTAIN COAL COMPANY July 11, 1840, request for bids. (*Mauch Chunk Courier.*)

negotiated a new contract in 1844 in which a royalty was paid to the Hazleton Coal Company for each ton of coal mined and marketed.

The BUCK MOUNTAIN COAL COMPANY, incorporated on June 16, 1836, was authorized to acquire coal lands in Sugar Loaf and Hanover Townships in Luzerne County. The company was also subjected to the same powers, restrictions, and immunities that were granted previously to the Hazleton Coal Company including the construction of a railroad, if market conditions justified such a means of transportation. Supplemental legislation permitted the company to hold coal lands in Northampton County.[74]

Construction of the railroad started in 1839, and was completed in 1840 (figure 19). The railroad was 4 miles in length and extended from their mines at Spring Mountain to the company's coal breaker at Rockport, 15 miles above Mauch Chunk. During 1840,

[74] *Pennsylvania Legislative Acts*, 1838–39 (Harrisburg: Packer, Barrett and Parke, 1839), pp. 145–146. These lands became a part of Carbon County in 1843.

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the company mined and sent to the navigation 54 tons.[75] The flood on the Lehigh River during the winter of 1841 delayed further coal shipments for 2 years.

The LAUREL HILL COAL COMPANY, incorporated on June 16, 1836, was authorized to hold coal lands in Sugar Loaf Township in Luzerne County and in Lausanne Township in Northampton County. Their mining operations were located adjacent to the Hazleton Coal Company property.

The company was also authorized to construct a railroad consisting of one or two tracks. The railroad could extend from any location on their lands to any convenient connection with the proposed railroad to be constructed by the Hazleton Coal Company.

A later amendment authorized the construction of the railroad from their lands to a connection with either the Hazleton Railroad or the Lehigh River and granted them the same powers and immunities given previously to the Beaver Meadows Company.[76]

Laurel Hill Coal Company disposed of their real estate holdings near Hazleton to the Hazleton Coal Company during 1839, and discontinued their mining operations.

The SUGAR LOAF COAL COMPANY was incorporated on April 16, 1838. The act was submitted to the Governor on April 2, 1838, but he failed to sign the measure within the 10-day limit, and it automatically became law under the Commonwealth's constitution. The company was permitted to hold, either by lease or by purchase, coal lands in Sugar Loaf Township in Luzerne County.

In addition to the mining privilege, the company was authorized to construct a railroad. This railroad could consist of one or two tracks, and extend from any point on their lands for a connection with the Hazleton Company's railroad, or any other railroad required to transport their products to market.

A single-track railroad, 2 miles in length, was constructed during 1839. Two locomotives were in use on the railroad during 1839 and transported 7,510 tons to the navigation.[77] Mining operations were conducted between 1839 and 1844, after which time their properties were consolidated with the Hazleton Coal Company.

The TAMMANEND MINING COMPANY, incorporated on April 16, 1838, was authorized to hold coal lands in Union and Rush townships in Schuylkill County.

The construction of a railroad was authorized, extending from any point on their lands and intersecting at such places that were deemed convenient, with the Lehigh Branch of the Little Schuylkill and Susquehanna Railroad.

The Little Schuylkill and Susquehanna Railroad was authorized on March 26, 1838, to construct the Lehigh branch. This branch connected with the company's main line at Linder's Gap and extended for 12 miles to an intersection with the Beaver Meadows Railroad near the mouth of Black Creek. Construction began during 1838, and the road was opened for traffic in 1840. One locomotive hauled 27 tons of coal from the Tammanend mines to the Lehigh Navigation in 1840.[78]

Delaware Division of the Pennsylvania Canal

As the quantity of anthracite mined and transported from the Lehigh region was dependent upon a connection with the Delaware Division of the Pennsylvania Canal at Easton, Pa., a summary of the construction efforts on this canal is included here.

The original purpose of this State-owned canal was to supplement the improvements already underway on the Lehigh River. The Lehigh Company applied to the 1824 legislature for permission to undertake the improvement of the Delaware River, but their proposal was rejected.[79] As mentioned previously, the canal commissioners in 1827 limited the size of this canal, but in their report for 1830 showed a complete reversal in their attitude by stating, "the Delaware Division may be fairly considered to be an extension of the Lehigh Coal and Navigation Company Canal." [80]

Coal was to be the main commodity handled and the main source of income was to be from tolls. The

[75] L.C.N.C., *Annual Report for 1840* (Philadelphia: W. S Young, 1841), p. 6.

[76] *Pennsylvania Legislative Acts*, 1837–38 (Harrisburg: T. Fenn, 1838), pp. 151–152.

[77] L.C.N.C., *Annual Report for 1839* (Philadelphia: W. S. Young, 1840), p. 6.

[78] L.C.N.C., *Annual Report for 1840* (Philadelphia: W. S. Young, 1841), p. 6.

[79] RICHARDSON, op. cit., p. 81.

[80] PENNSYLVANIA CANAL COMMISSIONERS, *Annual Report to the Senate of Pennsylvania* (December 23, 1830; Harrisburg: H. Welsh, 1831), p. 35.

canal was also to develop the trade upstate from the city of Philadelphia and this would, in effect, help industrialize the entire northeastern section of the State.

Construction of the canal was begun in October 1827, starting at Bristol and working northward. The Bristol to Philadelphia section was deemed less important and its construction was deferred until last. Water was admitted into the canal in 1830, but its insufficiency left some sections unnavigable. The poor construction in many of the first-built sections and the porous character of the earth through which part of the canal was constructed aggravated this condition.[81]

From the very beginning of the State's construction program, the management of the canal was hampered by both interstate and sectional disputes. The canal size, including the entire system of locks and control of water level, was inadequate. This size limitation prevented the canal from becoming an effective outlet for trade moving from the Lehigh region. The original plan to supply the canal with water from the Lehigh River likewise proved to be unworkable. Negotiations with the State of New Jersey to provide an adequate water supply for the canal failed to materialize, mainly because Pennsylvania was jealous of New Jersey's threat of receiving benefits from such agreements. (A compromise with New Jersey was made in 1846, and the construction of an outlet lock was authorized at Well's Falls.[82])

Two years later, October 1832, the canal was navigable after being thoroughly repaired by using better construction materials and by sealing the bottom with hydraulic lime.[83] The waterway was built 25 feet wide at the top and the size of the locks was limited to 11 by 90 feet. Total cost exceeded $1.2 million as against the original estimate of about $.7 million.[84] The commissioners realized their mistake in limiting the size of the canal and, by continuous reconstruction efforts, raised the tonnage capabilities of boats moving on the Delaware Canal to 60 tons by 1841.[85]

[81] Ibid., December 6, 1832, p. 18.

[82] *Pennsylvania Legislative Acts*, 1846 (Harrisburg: J. M. C. Lesure, 1846), p. 409.

[83] Josiah White had used this same material in the construction of the Lehigh Navigation.

[84] PENNSYLVANIA CANAL COMMISSIONERS, op. cit., December 9, 1836, p. 16.

[85] Ibid., January 15, 1841, p. 8.

Two problems faced the canal's operation and were constantly mentioned in the annual canal commissioners' report starting in 1833.[86] In the dry season it was almost impossible to maintain the water level at 5 feet and the canal was subject to damage by freshets. In the report of 1835, the commissioners stated that dredging had started at the lower end of the canal and would proceed in a northward direction.[87] No constructive improvement program was initiated until 1852, when the Pennsylvania Legislature authorized the start of improvements to make the locks equal in size to those on the Lehigh.[88]

From the statistics reported by the canal commissioners, the chief source of income for the canal was from coal movements. By the year 1837, after 6 years of operation, the earning capacity of the canal had grown sufficiently to pay the interest on the cost of construction. The coal rate had risen to nearly 6 mills per ton per mile and income remained steady.[89]

Besides the coal traffic, general trade shipments on the canal during 1834 showed that, upward from Bristol, the major items were wheat, fish, butter, cheese, tobacco, and leather. From Easton southward went flour, rye, corn, butter, and cheese.[90]

From the commissioners' report of 1845, it is noted that the character of the general trade had changed and that agricultural and dairy products decreased in importance. Up from Bristol, we find the following: glassware, bacon, chinaware, hides, and coffee. Southward from Easton came the following items: iron ore, lumber, lime, and whiskey. The State had expended over $1.7 million on the canal's development up to 1845.[91]

Capital Requirements

Significant financial aid for the business ventures undertaken in the Lehigh region was required to construct both mining and transportation facilities. Most of the capital was expended in providing carriers because the locations of the mines were remote from the markets. Costs of the transportation facilities constructed during the period 1820 to 1845, are listed in Table 3.

[86] Ibid., December 2, 1833, p. 12.

[87] Ibid., December 3, 1835, p. 16.

[88] Ibid., November 30, 1852, p. 11.

[89] Ibid., December 27, 1838, p. 12

[90] Ibid., December 2, 1834, p. 21

[91] Ibid., November 30, 1845, p

Table 3.—*Construction costs for railroad and navigation companies in the Lehigh region*, 1820–41 [1]

Year opened	*Company*	*Miles*	*Cost*
	Railroad		
1827	Lehigh (Mauch Chunk).	[2] 9.0	[3] $48,226
1833	Lehigh (Room Run).	5.0	123,000
1837	Beaver Meadows..	20.6	365,000
1838	Hazleton [4].........	10.0	120,000
	Sugar Loaf [4].......	2.0	20,000
	Laurel Hill [5].......	0.2	1,000
1839	Summit Hill.......	2.0	20,000
1840	Buck Mountain....	4.0	40,000
	Lehigh and Susquehanna.	20.0	1,326,700
	Tammanend......	2.0	20,000
1841	Little Schuylkill and Susquehanna.	12.0	500,000
Total......		86.8	$2,593,426
	Canal		
1820	Lehigh..........	85.0	$4,455,000
1832	Delaware Division	60.0	1,736,000
Total......		145.0	$6,191,000
Grand Total....		231.8	$8,784,426

[1] Company annual reports.

[2] Wagon road 1820–27.

[3] Includes $9,500 for loading chute.

[4] The Hazleton and Sugar Loaf companies consolidated their operations in 1844.

[5] Operations ceased in 1839.

The largest expenditure for carriers was made in the development of navigational facilities using the Delaware and Lehigh Rivers. The development of a navigational facility using the Delaware River was vital to the Lehigh Coal and Navigation Company's movement of coal from Easton. Total expenditures for the improvement of these two waterways with a combined length of 145 miles amounted to $6.2 million: the Lehigh Navigation, 85 miles, cost $4.5 million; and the Delaware Division of the Pennsylvania Canal, 60 miles, cost $1.7 million.

The organizational structure and operational management of these two navigational facilities varied widely. The Lehigh Coal and Navigation Company was incorporated by the Commonwealth of Pennsylvania and was managed by a board of directors elected annually by the stockholders. The Delaware Division of the Pennsylvania Canal was a State owned and financed facility and was controlled by the canal commissioners, who were appointed by the Governor. Many of the early difficulties in improving the navigation route from Stoddartsville to Bristol can be attributed to the differences in the composition of these two organizations.

Approximately 87 miles of railroads were constructed for use in conjunction with the Lehigh Navigation at a cost of approximately $2.6 million. The Lehigh Coal and Navigation Company spent the largest amount, $1.33 million, on the construction of the Lehigh and Susquehanna Railroad. This line connected the mining operations of the northern anthracite field at Wilkes-Barre with the Lehigh Navigation at White Haven. The high cost of this road was caused by the extreme terrain conditions found between these regions.

The costs of other railroads constructed during this period ranged between $1,000 and $20,000 per mile, and were dependent on the type of terrain traversed and the permanency required for the road. The usual cost estimate per mile for construction of a railroad in this region was $10,000. Capital was difficult to raise for the construction of railroads because of the unproven capabilities of this method of transportation. Public opinion in the Commonwealth during the early years of this period favored the construction of navigational facilities.

The true value of an acre of coal land in the Lehigh region during the early days of the industry was difficult to determine. Values that commonly used in the anthracite regions ranged from a low of $20 an acre to a high of $400 an acre.[92] Using an average value of $200 an acre, and with a total coal-bearing

[92] *Packer Report*, op. cit., p. 31.

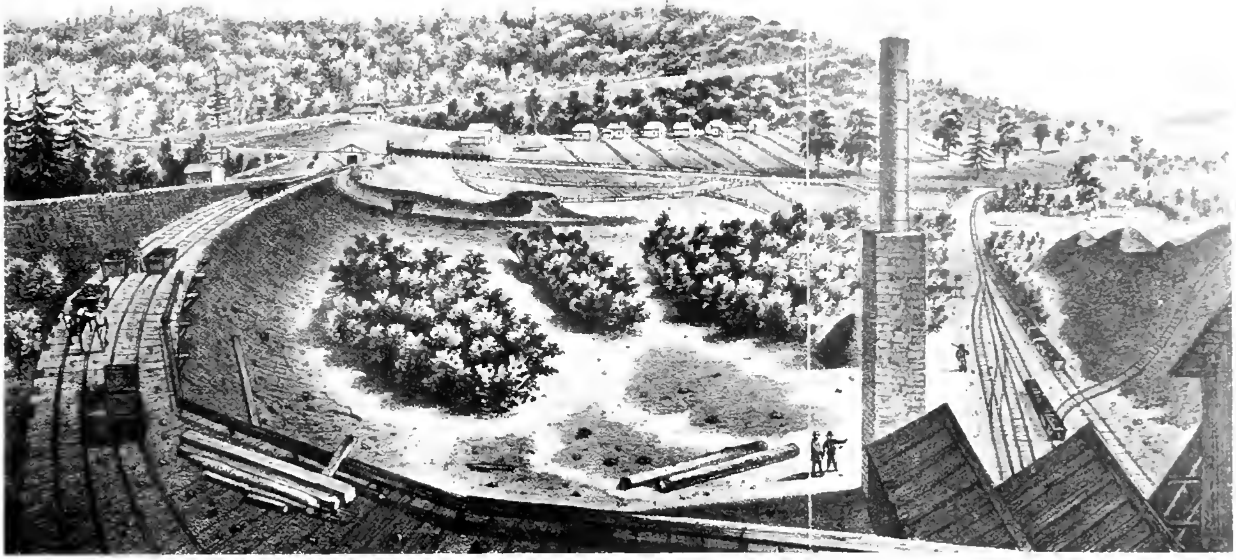


Figure 20.—"Switch-back rail-road" at Mauch Chunk, ca. 1850. Currier lithograph. (M. S. Henry, *History of the Lehigh Valley*, 1860.)

area of 42,000 acres, the value of coal lands under control of the incorporated companies was estimated at $8.4 million. If 25 percent of the acreage of land authorized under the charter provisions of the various companies was purchased, the investment required was $2.1 million. In most cases, the newly chartered companies would have been unable to purchase their entire authorization of land at this average price, construct the transportation and mining facilities required, and still be within the capital limitations under their respective charters. These limitations placed many acres of coal lands under leasing arrangements rather than outright purchases.

No fixed amount of capital was needed for the day-to-day operations of the individual mining properties, but it was necessary for the company to have some working capital to pay for the essential services that were incurred in the period between the mining of the coal and the receipt of monies from the sale of their product. Daily mining costs were low initially because of coal's close proximity to the surface, but as mining depths increased the amount of capital required to perform these operations also increased.

Development costs, including capital needed for day-to-day operations, was estimated to be 10 percent of the authorized capital or approximately $1.25 million. Several companies were authorized to increase their capitalization by subsequent acts of legislature, while others were required to consummate business loans or consolidate their operations with others to keep their mining operations in an active status.

The total of these three major investments—land, mining operations, and transportation facilities—amounted to almost $10.5 million. This total investment is considered a conservative estimate since incomplete details of commercial loans negotiated by some companies precluded their inclusion in the determination of this estimate. By adding the cost of the Delaware Division of the Pennsylvania Canal, as it properly should be, the total investment costs were increased to $12.2 million. These millions of dollars of investments during the first 25 years of mining operations can truly be considered an outstanding accomplishment by the State's business community for the future economic development of the anthracite industry in the Lehigh region.

Summary

The quantity of anthracite transported on the Lehigh Navigation during the period 1820 to 1845, was slightly more than 3.2 million tons. The Lehigh Coal and Navigation Company exercised exclusive control on the movement of coal produced in this region, as

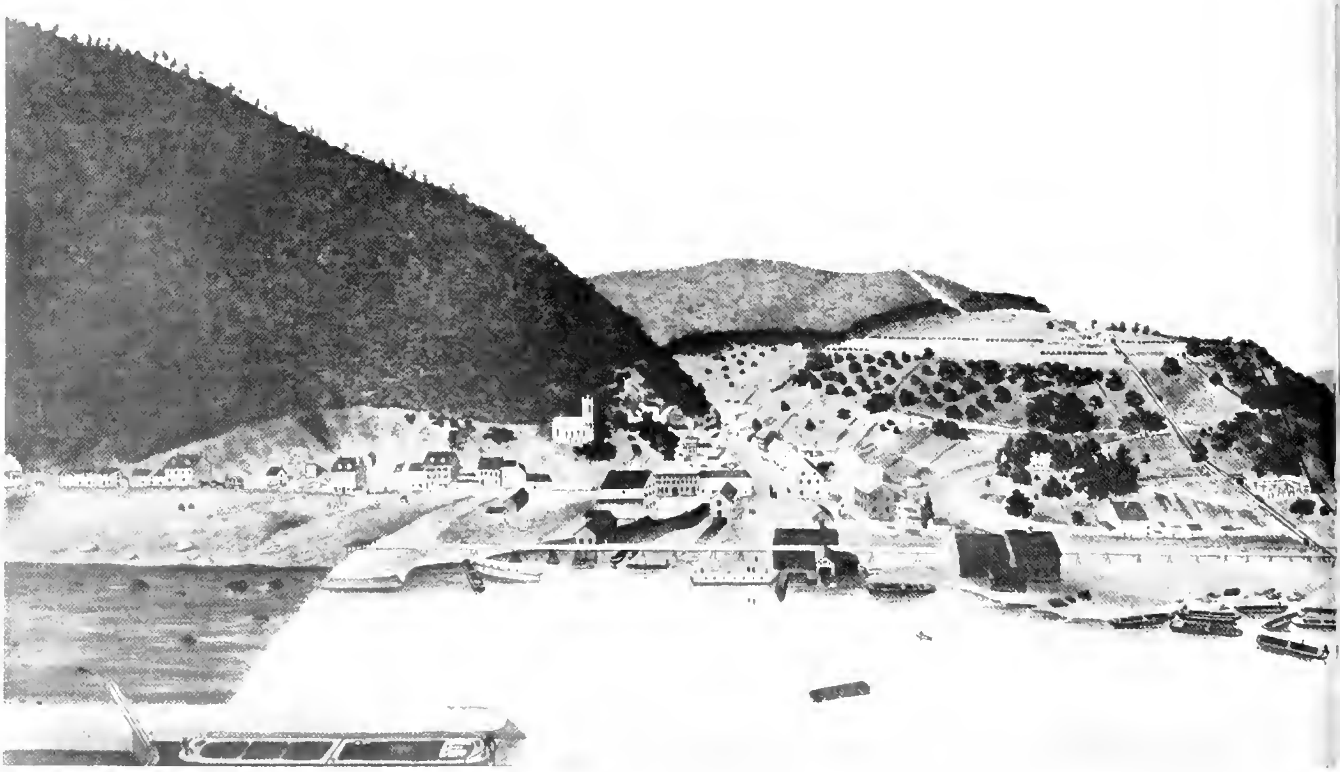


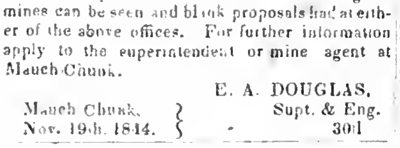
Figure 21.—Watercolor of Mauch Chunk, ca. 1845, by an unknown artist. (L.C.N.C.)

they provided the only carrier between Stoddartsville and Easton.

The Lehigh Coal and Navigation Company began regular shipments of anthracite from the region in 1820, after some navigational improvements were made on the Lehigh River. Seventeen years later, in 1837, the Beaver Meadows Railroad and Coal Company became the next anthracite producer in the region. By January 1845, 18 companies with a total capitalization of $12.65 million were formed and chartered to conduct mining operations.

Eight of these companies chartered during this period (including the two that ceased operations) were actively engaged in the mining and transportation of anthracite to market and had invested approximately $10.5 million. The remaining 10 companies were developing their properties, but made no shipments of coal to market prior to January 1845.

The first steam locomotives in the Lehigh region appeared during 1836 on the railroad operations of the Beaver Meadows Railroad and Coal Company. The success of these locomotive experiments were immediately recognized by the operators. As market requirements increased, so did the use of locomotives. Coal movements were more easily facilitated by using steam power and the navigation company was soon challenged to provide more efficient transportation facilities.



To Contractors.

PROPOSALS will be received at the office of The Lehigh Coal & Navigation Company either in Mauch Chunk or Philadelphia until the 7th of next month, for mining and delivering into boats from the summit hill mines 200,000 Tons of Coal, during next season. The Company propose to divide the mines into two or more parts, and to be worked by as many companies of contractors. Specifications & mode of working the mines can be seen and blank proposals had at either of the above offices. For further information apply to the superintendent or mine agent at Mauch Chunk.

E. A. DOUGLAS,
Supt. & Eng.

Mauch Chunk,
Nov. 19th, 1844.

30tl

Figure 22.—Lehigh Coal and Navigation Company November 21, 1844, request for bids from subsidiary companies. (*Mauch Chunk Courier.*)

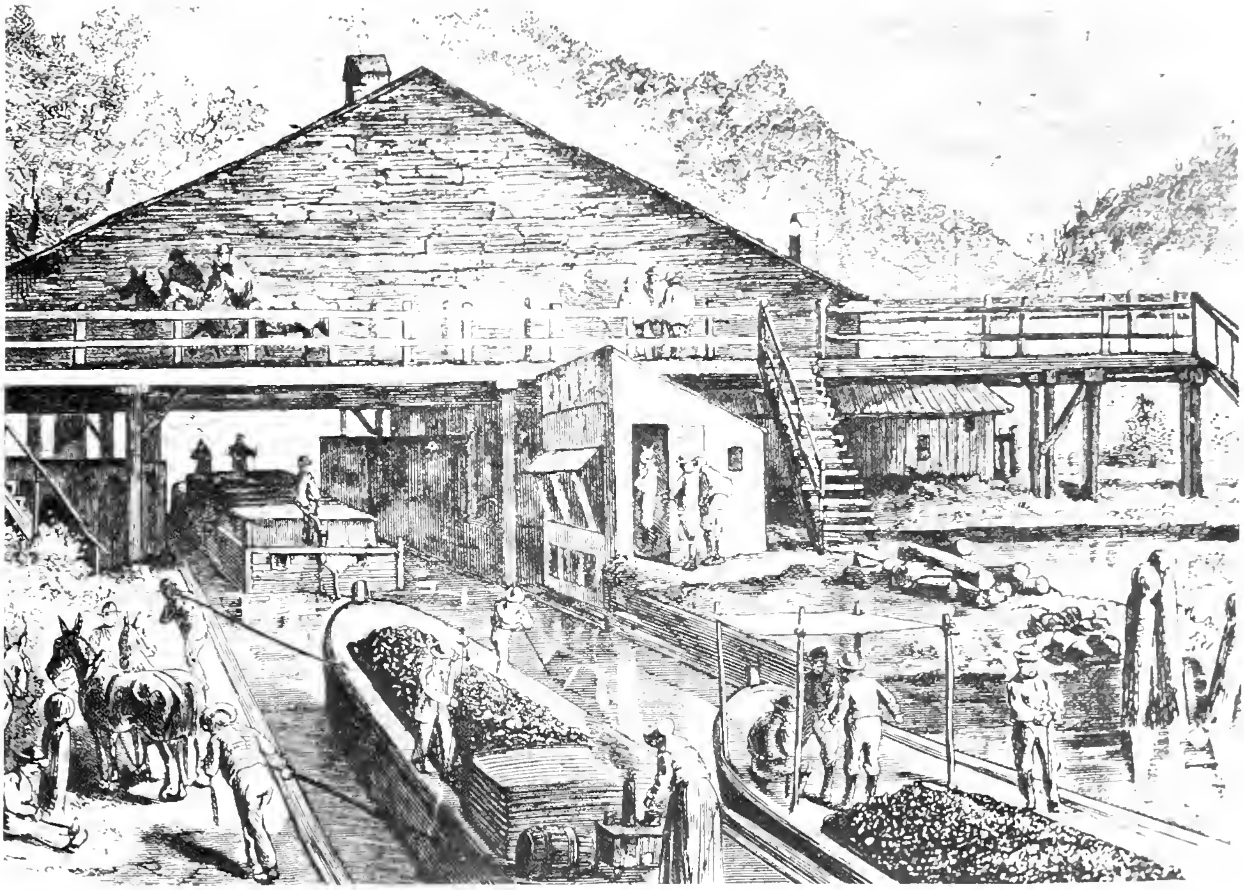


Figure 23.—WEIGHING THE CANALBOATS in the weigh lock on the Lehigh Canal. (L.C.N.C.)

From 1820, anthracite shipments from this region generally showed an annual increase with an exceptionally large increase for 1825, 1832, and 1833. The increase was the result of greater use of anthracite in the home by the introduction of grates and furnaces designed to burn anthracite and the completion of the Delaware Division of the Pennsylvania Canal which permitted the use of permanent shipping facilities.

Up to the fall of 1831, a surplus of coal occasionally occurred at the close of each shipping season, but after that time and until the late 1830's the demand usually exceeded the supply.

Factors which caused fluctuations in annual production were: (1) the inability of the producer to anticipate supply and demand requirements; (2) consumer reluctance to accept anthracite as a reliable source of heat and energy; (3) occasional flooding of the Lehigh River; (4) operational difficulties between the administrative procedures of the two navigational facilities; and (5) general business conditions.

The companies incorporated in this region received similar powers, privileges, and immunities, and were authorized to engage in mining and railroad operations. None, however, was granted the "unlimited powers" which had previously been given to the Lehigh Coal and Navigation Company. The Pennsylvania Legislature was criticized many times for granting such unlimited concessions. Adequate justification is found, however, in the primitive conditions of the State and the basic need for the development of such works.

With the introduction of Schuylkill anthracite to the market, two types of anthracite became available to consumers. These types were identified by the color of the ash, as being either white or red ash coals. The Lehigh region was a white-ash producer, while the Schuylkill region (which produced both types) was, in these early years of the industry, considered a red-ash producer.

TABLE 4.—*Number of boat trips and tonnage of anthracite transported on the Lehigh and Schuylkill Canals, 1820–45*[1]

Year	*Lehigh Canal*		*Schuylkill Canal*	
	Number of Boat Trips	Tonnage	Number of Boat Trips	Tonnage
1820	[2] 15	365	–	–
1821	[2] 43	1, 073	–	–
1822	[2] 90	2. 240	–	–
1823	[2] 233	5, 823	–	–
1824	[2] 382	9, 541	–	–
1825	329	28, 393	260	5, 306
1826	546	31, 280	650	16, 767
1827	584	32, 074	1, 183	31, 360
1828	605	33, 150	1, 751	47, 284
1829	494	25, 110	2, 909	79, 973
1830	852	41, 750	2, 978	89, 984
1831	931	42, 743	2, 338	81, 854
1832	1, 916	75, 937	5, 961	209, 271
1833	2, 774	122, 928	6, 054	252, 971
1834	2, 331	106, 518	5, 167	226, 692
1835	3, 735	131, 250	7, 109	339, 508
1836	3, 465	146, 738	9, 139	432, 045
1837	5, 316	224, 095	9, 535	523, 152
1838	5, 127	214, 211	7, 891	433, 875
1839	5, 238	221, 850	8, 174	442, 608
1840	5, 371	225, 585	8, 223	452, 291
1841	2, 804	143, 038	14, 111	584, 692
1842	5, 450	272, 553	9, 276	491, 602
1843	5, 240	267, 826	8, 138	447, 058
1844	7, 098	377, 094	6, 408	398, 887
1845	8, 104	429, 492	4, 974	263, 587

[1] Company annual reports, the *Pottsville Miner's Journal*, and the *Mauch Chunk Courier*.
[2] Calculated 25-ton boats.

The delay in the completion of improvements on the Delaware Division and the inefficient utilization of the navigation by the use of temporary boats prevented expansion of mining activities in the Lehigh region. This condition for many years prevented the opening of additional properties in the coal areas bordering the Lehigh River.

Organizations and individuals desirous of engaging in anthracite mining ventures turned their efforts to the Schuylkill region. With the Schuylkill region receiving more attention, its production moved ahead at a rapid pace and greatly overshadowed the activities in the Lehigh region. The tabulation in Table 4 shows the growth in production and in the number of boat trips on the Schuylkill and Lehigh Navigation for the period 1820 to 1845.

The active companies in the Lehigh region soon discovered that to conduct operations in all phases of the industry was not in their best interests for continued growth. Leasing arrangements were negotiated for the individual services—mining, transportation, and marketing. This procedure proved to be practicable and eventually contracts were negotiated (to individuals and organizations) whereby a royalty was received for the privilege of managing the mining and shipping operations.

The companies attempted to retain ownership of their equipment and properties, but consolidations and mergers of companies occurred in several instances to achieve more efficient mining operations. The leasing procedures separated corporate activities from mining operations and resulted in more efficient utilization of the industry's facilities.

The markets for anthracite were expanding quite rapidly during the early 1840s and did not present a major problem for the industry. The promotional efforts of The Lehigh Coal and Navigation Company were aided by the introduction of improved grate and stove design for burning anthracite, the use of anthracite as a fuel in blast-furnace operations and the use of anthracite for heating public buildings. The demand for Lehigh coal continued to grow as the various utilization means proved efficient.

The development of the Lehigh region during the first 25 years required an investment of approximately $12.2 million. The amount of capital obtained during the early years represented an outstanding accomplishment by the promoters of the industry. Credit should be given them for their strong convictions as to the future economic value of this natural resource.

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Appendixes

I

CHAPTER CII.

AN ACT

To improve the navigation of the river Lehigh.

SECT. 1. *BE it enacted by the Senate and House of Representatives of the Commonwealth of Pennsylvania in General Assembly met, and it is hereby enacted by the authority of the same,* That it shall and may be lawful to and for Josiah White, George F. A. Hauto and Erskine Hazard, of the county of Philadelphia, their heirs and assigns, or in case any or either of them should die, for the survivor or survivors, his or their heirs and assigns, their surveyors, engineers, superintendents, artists and workmen, to enter upon the said river Lehigh, to open, enlarge or deepen the same in any part or place thereof, between the Great Falls and the mouth of the said river Lehigh, in the manner which shall appear to them most convenient for opening, enlarging, changing, making anew or improving the channel; and also to cut, break, remove and take away all trees, rocks, stones, earth, gravel, sand or other material, or any impediments whatsoever within the said river: and to use all such timber, rocks, stones, gravel earth or other material in the construction of their necessary works, and to form, make, erect, set up any dams, locks or any other device whatsoever, which they shall think most fit and convenient to make a good navigation downward at least once in every three days, except during winter, with a channel not less than twenty feet wide and eighteen inches deep, for arks and rafts, and of sufficient depth of water to float down boats of the burthen of one hundred barrels, or ten tons; *Provided*, That during the said three days there shall be no interruption to the said navigation for or by reason of any neglect or default of the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns: *Provided also,* That no toll shall be demanded for any boat, vessel or craft in going up said river, unless the same is converted into a complete slack water navigation, as provided by this act.

Persons authorised to improve the Lehigh.

Power to enter thereon, &c.

and to use timber, rocks, &c.

and make dams, dams, locks, &c, of a certain description.

Proviso.

2d proviso.

SECT. 2. *And be it further enacted by the authority aforesaid,* That if any person or persons shall be injured by means of any dam or dams being erected, or the land of any person inundated by swelling the water by means of any dam or dams, or any mill or other water works injured by swelling the water into the tail-race of any mill or other water works

Remedy of persons injured by dams or swelling the water.

which may have been erected in said river; and if the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, cannot agree with the owner or owners thereof on the compensation to be paid for such injury, the same proceedings shall be had as is provided in the third section of this act, the persons valuing the damages, being first sworn or affirmed, or the jury as the case may be, shall take into consideration the advantages which may be derived by such owner or owners by the navigation aforesaid.

Power to enter on land and dig, &c.

SECT. 3. *And be it further enacted by the authority aforesaid,* That the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall have authority and power by themselves or their superintendents, engineers, artists and workmen, to enter in and upon and occupy for the purpose, all land which shall be necessary and suitable for erecting of a lock, sluice, canal, tow-path or other device, doing as little damage as possible, and there to dig, construct, make and erect such lock, sluice, canal, tow-path or other device, satisfying the owner or owners thereof; but if the parties cannot agree upon the compensation to be made to such owner or owners, it shall and may be lawful for the parties to appoint six suitable and judicious persons, who shall be under oath or affirmation, and who shall reside within the proper county where the land lies; or if they cannot agree on such persons, then either of the parties may apply to the court of common pleas of the proper county where the land lies, and said court shall award a *venire* directed to the sheriff, to summon a jury of disinterested men, in order to ascertain and report to said court what damages, if any, have been sustained by the owner or owners of said ground, by reason of such lock, canal, sluice, tow-path or other device passing through his, her or their land, which reports being confirmed by the court, judgment shall be entered and execution may issue, in case of non-payment, for the sum awarded, with reasonable cost to be assessed by the court. And it shall be the duty of the jury or the six appraisers as the case may be, in valuing any land, to take into consideration the advantage derived to the owner or owners of the premises from the said navigation: *Provided,* That either party may appeal to the court, within thirty days after such report may have been filed in the prothonotary's office of the proper county, in the same manner as appeals allowed in other cases: *And provided also,* That if any person owning land or any other property which shall be affected by this act, be femme coverte, under age, non compos mentis, or out of the state, then and in either of those cases the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall within one year thereafter, represent the same to a neighboring justice of the peace, or to the court of common pleas of the county as the case may be, who shall proceed thereon in the same manner and to the same effect as is directed by this act in similar cases.

Remedy for damage done thereby.

Proviso.

2d proviso.

Power to enter on lands contiguous, & take stone, timber, &c.

SECT. 4. *And be it further enacted by the authority aforesaid,* That the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, by and with their superintendents, engineers, artists, workmen and laborers, with their tools, instruments, carts, waggons and other carriages and beasts of draft and burthen may enter upon lands contiguous and near to the said river, giving notice to the owners or occupiers thereof, and from thence take and carry away any stone, timber, gravel, sand, earth or other material, doing as little damage thereto as possible, and repairing any breaches they make in the enclosures thereof, and making amends for any damages that may be done thereon, and paying for the materials to be taken away, the amount whereof, if the parties do not agree, shall be assessed and valued by any three disinterested freeholders residing in the neighborhood, under oath or affirmation, to be appointed by consent of the parties, or if they cannot agree, by any disinterested justice of the peace of the proper county, allowing an appeal to the court of common pleas as in the third section of this act.

Conditions thereof.

Remedy for damages.

SECT. 5. *And be it further enacted by the authority aforesaid,* That whenever any sluice or canal shall cross any public or private laid out road or highway, or shall divide the grounds of any person or persons into two parts, so as to require a ford or bridge to cross the same, the jury who shall enquire of the damages to be sustained, in manner directed by the third section of this act, shall find and ascertain whether a passage across the same shall be admitted or maintained by a ford or bridge to cross the same, and on such finding, the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall cause a ford to be rendered practicable, or a bridge fit for the passage of carts and waggons to be built, and forever thereafter maintained and kept in repair, at all and every places so ascertained by the said jury, at the costs and charges of the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, but nothing herein contained shall prevent any person from erecting and keeping in repair any foot or other bridge across any sluice or canal at his own expense, when the same shall pass through his ground: *Provided*, That such foot or other bridges so to be erected by the owners of such land, shall not interfere with any sluice or lock or other works of said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs or assigns.

To erect fords or bridges when directed by a jury.

Proviso.

SECT. 6. *And be it further enacted by the authority aforesaid,* That as soon as the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall have completed the improvements in the navigation of either of the grand sections hereinafter mentioned, in the manner prescribed in the first section of this act, they shall give notice thereof to the Governor, who shall, as soon as conveniently may be, appoint five persons of skill and practical knowledge of river navigation, three of whom shall not reside in the neighbourhood of said river; and the said commissioners shall proceed to examine the said improvements, and make a detailed and specific report thereof to the Governor, accompanied with such observations as may serve to explain the same; and the said report shall be laid before the next succeeding legislature, and if the legislature shall approve of the said improvements in the navigation, then and in that case the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall have the privilege and be entitled to use all the water from the said river, sluices, canals or other devices, to propel such machinery as they may

Commissioners to be appointed by the Governor to examine the improvements when completed, and report the same.

Report to be laid before the Legislature

Privilege thereupon granted.

think proper, to erect on the land which they may previously have purchased from the owner or owners, or to sell in fee simple, lease or rent for one or more years, the said water to any person or persons, to be used in such manner and on such terms as they may think proper: *Provided,* It be so done that it shall not at any time impede or interrupt the navigation.

Proviso.

SECT. 7. *And be it further enacted by the authority aforesaid,* That in order to ascertain the size of arks and rafts, and the tonnage of boats using and passing the said navigation, and to prevent disputes between the supercargoes and collectors of tolls concerning the same, upon the request of the owner, skipper or supercargo of such boat, raft or ark, or of the collector of said tolls, it shall and may be lawful for each of them to choose one skilful person to measure and ascertain the size of said raft or ark, and the tonnage the said boat is capable of carrying, and to mark the said tonnage so ascertained in figures upon the head and stern of said boat, in colours mixed with oil or other durable matter, and that the said boat or vessel so measured and marked, shall be permitted to pass on the said navigation for the price to which the number of tons so marked on her shall amount, agreeably to the rates per ton hereinafter established. And if the owner, skipper or supercargo of any raft, ark or boat, shall decline choosing a person resident within two miles of the place where the said toll is payable, to ascertain the tonnage thereof, then the amount of such tonnage shall be fixed and ascertained by the person appointed for that purpose by the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, or chosen by the said collector of tolls, and the tolls shall be paid according to such measurement, before any such boat, raft or ark shall be permitted to pass the place where such toll is made payable.

How the size of rafts or arks and tonnage of boats shall be ascertained.

Proceeding in case the owner, &c. declines choosing a person.

SECT. 8. *And be it further enacted by the authority aforesaid,* That if any person or persons shall wilfully and knowingly do any act or thing whereby the navigation shall be impeded, or any dam, lock, gate, canal, engine, machine, property or device whatsoever thereunto belonging, shall be injured or damaged, he, she or they so offending shall forfeit and pay to the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, four times the amount of the damages by them sustained, together with costs, to be recovered by action of debt before a justice of the peace, or in any court of competent jurisdiction.

Penalty for impeding the navigation or injuring the dams, locks, &c.

SECT. 9. *And be it further enacted by the authority aforesaid,* That if the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall neglect or refuse to keep in good order or repair, any dam, lock or sluice of their own construction, or shall neglect to remove any obstacle which may occur, so that boats, arks, rafts or other vessels may safely navigate the said river at the times and in the manner fixed in the first section of this act, on the complaint of any person or persons to the judges of the court of common pleas in the county where such default occurs, it shall and may be lawful for the said judges (due notice thereof in writing being previously given by

Proceeding in case of not keeping the locks, &c, in repair, or not removing obstructions, &c.

Commissioners to be appointed to view and report.

Effect thereof.

Penalty on conviction.

Service of process when good.

such complainant to the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, or to any or either of them), to appoint three commissioners to view the said breach or obstacle and report to them at their next sessions the state thereof, and whether it is conformable to the provisions of this act; which report on oath or affirmation, if it contain an offence against this act, shall be sufficient ground for the court to direct a bill of indictment to be sent to the grand jury against the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns: and upon conviction for every such offence they shall be liable to pay all damages resulting therefrom, to be recovered before a court of competent jurisdiction, and a fine not exceeding two hundred dollars at the discretion of the court, for the use of the poor of the said county or township; and the service of any civil process upon the toll gathered in the proper county, and next to the place where the offence shall have been committed, shall be held as good and available in law as if served on the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns.

River divided into two grand sections.

SECT. 10. *And be it further enacted by the authority aforesaid,* That the river Lehigh for the purpose of said improvements shall be divided into two grand sections, the first grand section to begin at the mouth of said river and to end at the mouth of Nescohoning creek, the second grand section to begin at the said Nescohoning creek and to end at the foot of the great falls; the second grand section to be subdivided into sections of ten miles each.

Proceeding on completion of the first grand section.

Governor to appoint three viewers.

Report to be made to the governor.

License to fix places to collect tolls.

SECT. 11. *And be it further enacted by the authority aforesaid,* That as soon as the said Josiah White, George F. A. Hauto and Erskine Hazard, and their heirs and assigns, shall have improved the said first grand section of said river ending at said Nescohoning creek, they shall give notice thereof to the Governor of the commonwealth, who shall thereupon forthwith appoint three skilful, judicious and disinterested persons to view and examine the said grand section, and report to him in writing whether that part of the navigation is completed in the manner aforementioned according to the true intent and meaning of this act; and if the report of them or a majority of them shall be in the affirmative, then the Governor shall by license under his hand and the lesser seal of the commonwealth, permit and suffer the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, to fix upon and appoint so many places at or between the places before mentioned as will be necessary and sufficient to collect the tolls and duties hereinafter granted to the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns; and the same process shall be had upon the completion of each succeeding ten miles in the second grand section.

Collectors of tolls to be appoin[ted].

SECT. 12. *And be it further enacted by the authority aforesaid,* That it shall and may be lawful for the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, as soon as they have obtained the Governor's permission as aforesaid for fixing upon and appointing proper places for collecting tolls and duties as aforesaid, to appoint so many collectors of tolls as they shall think proper, and that it may and shall be lawful for such toll collectors and their deputies to demand and receive of and from the persons having the charge of all boats, vessels, crafts and rafts passing down the said river such tolls and rates for every ton weight of the ascertained burthen of the said boat or craft, and for every one thousand feet board measure of boards, timber, planks or scantling, and for every ton weight of shingles or other material in rafts as the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall think proper at any place for receiving of toll as ascertained: *Provided,* That the amount of the said toll shall not in the whole exceed the rate of three cents per mile for every ton of the ascertained burthen of such boat, vessel or craft; and for every one thousand feet board measure of boards, timber, planks or scantling, and for every ton weight of shingles or other material in rafts from the great falls to the mouth of Nescohoning creek, and from thence to the mouth of the said river Lehigh, one cent per mile for every ton of the ascertained burthen of such boat, vessel or craft, and for every one thousand feet board measure of boards, timber, plank or scantling, and every ton weight of shingles or other materials in rafts: *Provided also,* That the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall be obliged to commence the improvement of the aforesaid first grand section ending at the mouth of the said Nescohoning creek within the period of two years from the passage of this act, and finish the same in six years: *And provided also,* That the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall commence the said second grand section ending at the great falls within the period of seven years from the passage of this act, and finish the same within twenty years: in failure whereof the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall forfeit all the rights, liberties and franchises hereby granted to the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns.

Rates of tolls.

Proviso.

2d proviso.

3d proviso.

SECT. 13. *And be it further enacted by the authority aforesaid,* That if any owner, skipper or supercargo of any boat, ark, craft or raft shall pass by any place appointed for receiving tolls without making payment thereof, with intent to defraud the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, out of such toll, he, she or they shall forfeit and pay for every time they shall so pass by each appointed place to the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, the sum of twenty dollars to be sued for and recovered before any justice of the peace, in like manner and subject to the same rules and regulations as debts under one hundred dollars may be sued for and recovered, together with reasonable costs of prosecution.

Penalty for attempting to defraud out of toll.

How recovered.

SECT. 14. *And be it futher enacted by the authority aforesaid,* That the said navigation with the rights and privileges appertaining thereto, shall be held by the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, as tenants in common and not as joint tenants, and in case of the decease of either or all of them before the same shall be completed, it shall and may be lawful for the survivor

Tenancy of the property

Survivors may complete the work.

or survivors or the heirs or assigns of either or all of them to complete the same, and to exercise all the rights and privileges hereby granted for the use and benefit of the survivor or survivors and the heirs of the deceased, in the same proportion as if all had lived till the work had been completed.

Duty in case the legislature deem the navigation insufficient.

Sect. 15. *And be it further enacted by the authority aforesame,* That at any time after the expiration of the periods herein fixed for the completion of each grand section in the manner aforesaid, should the legislature deem the navigation contemplated by the preceding sections of this act insufficient, the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, due notice in writing being given them thereof, shall convert the said navigation into a complete slack water navigation, and shall erect and complete at least one lock or other device overcoming at least six feet falls in each and every year, in such part of said respective grand sections as they may think proper, and so on until the whole shall be completed: and in such case after each and every such lock or other device has been inspected, and the Governor's license for each of them has been obtained in the manner prescribed herein, it shall be lawful for the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, to charge and receive for the passage up and down through each and every such lock or other device, as soon as it shall have been completed and the license for it obtained as aforesaid, for their own proper use and benefit, a toll not exceeding eight cents per ton per lock or other device of six feet fall or lift, and so in proportion for any greater or less fall or lift, and the same for every thousand feet board measure of boards, timber, plank or scantling in rafts: *Provided,* That the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall not receive for the distance thus made slack water, the toll granted them by the eleventh section of this act.

Tolls in case of a complete slack water navigation.

Proviso.

Duty in case of the legislature directing a slack water navigation.

Sect. 16. *And be it further enacted by the authority aforesaid,* That if the legislature after due notice given as aforesaid shall direct the said navigation to be converted into a slack water navigation, the said Josiah White, Georege F. A. Hauto and Erskine Hazard, their heirs and assigns, shall proceed to carry on the same under all the provisions, immunities, privileges, restrictions, penalties, rules and regulations contained in the first, second, third, fourth, seventh, eighth, ninth, eleventh, twelfth and fourteenth sections of this act.

Privileges allowed in such case of using the water to propel machinery.

Sect. 17. *And be it further enacted by the authority aforesaid,* That as soon as the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall have completed the said slack water navigation in either or both of the grand sections aforesaid, and the same shall have been approved by commissioners appointed as hereinbefore directed. the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall for such grand section or sections so finished as aforesaid, have the privileges and be entitled to use all the water from the said river, sluices, canals or other devices to propel such machinery as they may think proper to erect on the land which they may previously have purchased from the owner or owners, or sell in fee simple, lease or rent for one or more years the said water to any person or persons to be used in such manner and on such terms as they may think proper: *Provided*, It be so done that it shall not at any time impede or interrupt the navigation.

Size of the locks.

Duty of master, &c, of a boat on arriving.

Duty of Keeper.

Penalty.

SECT. 18. *And be it further enacted by the authority aforesaid*, That the locks shall be in the clear at least eighteen feet wide and eighty feet long, and it shall be the duty of the master or commander of any boat, ark or other vessel navigating the said river when they shall arrive within one-fourth of a mile from any lock so erected, upon the penalty of two dollars, to blow a trumpet or horn whereupon the keeper of such lock shall attend for the purpose of opening the gate or sluice to let the said boat, ark or other vessel pass without unnecessary delay and in safety: and if any boat, ark or other vessel shall be prevented from passing up or down any of said locks or sluices by reason of the lock not being raised for more than thirty minutes, the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall on conviction thereof before any justice of the peace of the proper county, forfeit and pay to the person so hindered the sum of one dollar for every thirty minutes beyond the said time that he shall be so prevented, and in the same proportion for any longer or shorter time; and the service of any civil process upon the toll gatherer in the proper county and next to the place where the offence shall have been committed, shall be held as good and available in law as if served upon the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns.

Service of process.

When the legislature may purchase the navigation.

When accounts shall be kept & laid before the legislature.

Duty of legislature.

SECT. 19. *And be it further enacted by the authority aforesaid,* That at any time after the expiration of thirty-six years from the date of this act, the legislature shall have the privilege of purchasing every right and title to the navigation; and the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, shall after the expiration of thirty years keep a regular account of all monies received by them for toll, and shall annually before the first day of January, under oath or affirmation make report thereof to the legislature, in failure whereof it shall be lawful for the legislature to resume the privileges hereby granted; and in such case in order to ascertain the purchase money, the one sixth of the nett amount of toll received in the six years next preceding such purchase shall be considered as equal to the interest of said purchase money at six per cent. per annum; and in case of such purchase or resumption by reason of forfeiture, the legislature shall be bound to fulfil all and every obligation enjoined by this act on the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns.

Right of resumption by the legislature on failure in certain cases.

SECT. 20. *And be it further enacted by the authority aforesaid*, That if the slack water navigation aforesaid shall not be begun by the said Josiah White, George F. A. Hauto and Erskine Hazard, their heirs and assigns, within one year after notice given as aforesaid, and shall not within twenty years thereafter be completed, or if they shall at any time hereafter misuse or abuse any of the privileges granted by this act, then or in either of these cases the legislature may resume all and

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singular the rights, liberties and provileges hereby granted.

Repeal.

SECT. 21. *And be it further enacted by the authority aforesaid,* That the twenty-eighth section of the act, entitled "An act making appropriations for certain internal improvements," passed the twenty-fourth day of March one thousand eight hundred and seventeen, be and the same is hereby repealed.

WILLIAM DAVIDSON, *Speaker of the House of Representatives.*
ISAAC WEAVER,
Speaker of the Senate.

APPROVED—the twentieth day of March, one thousand eight hundred and eighteen.

WILLIAM FINDLAY.

II

TERMS OF SUBSCRIPTION

TO THE

Lehigh Navigation and Coal Mine Company.

The Capital Stock of the Company shall consist of Two Hundred Thousand Dollars, divided into Two Hundred Shares.

Josiah White, George F. A. Hauto, and Erskine Hazard, each reserve fifty shares, for which they assign to the Company, all their interest in the law granted them at the last Session of the Legislature, for improving the navigation of the river Lehigh, and the lease for twenty years, which they hold on the "Lehigh Coal Mine Company's" lands.

The amount of the remaining fifty shares shall be invested in the said navigation, in working the coal mines, and in business connected therewith exclusively. J. White, G. F. A. Hauto, and E. Hazard, will specifically pledge their shares to the subscribers, as security that the whole nett profits of the Company, shall be exclusively appropriated to them until they receive an interest of eighteen per cent. per annum, on the amount of their subscriptions.

When the nett profits exceed nine thousand dollars per annum, the surplus shall be divided equally on the shares retained by J. White, G. F. A. Hauto, and E. Hazard, until they receive eighteen per cent. interest per annum.

When the profits amount to, or exceed, thirty-six thousand dollars, they shall be divided equally among all the shares.

J. White, G. F. A. Hauto, and E. Hazard, shall manage and personally superintend the business until the navigation be completed, and the coal business reduced to system; for which service they shall each be entitled to receive One Thousand Dollars annually. The subscribers shall be entitled, if they deem it necessary, at any time to appoint a person to be associated with J. White, G. F. A. Hauto, and E. Hazard, or the survivors, or survivor, of them, in the management, which person shall have the same authority, devote the same personal attention, and receive the same compensation as each of the other managers. A majority of the managers shall govern the affairs of the Company.

Fifteen per cent. of the amount subscribed, shall be paid within ten days after the whole fifty shares shall have been subscribed. The remainder to be called for in instalments, as required by the work, of which twenty days notice shall be given.

Any subscriber neglecting or refusing to pay the instalments, within ten days after the time appointed for their payment, shall forfeit what he has already paid, for the benefit of the Company, and shall cease to be a stockholder.

The stock shall be transferable upon giving notice to the managers for the time being, who are authorized to give certificates as evidence of stock.

Should fifty thousand dollars be found an insufficient capital for all the purposes of the Company, additional shares shall be created, which shall be subject to the same regulations as the fifty shares now subscribed for, which new shares shall be added to the original two hundred, and the dividends shall be made on the whole number of shares.

J. White, G. F. A. Hauto, E. Hazard, and the subscribers, shall all be at liberty to subscribe to the additional stock, in the proportion of the original shares they may hold.

If any, or all the subscribers, decline advancing their proportion to the new stock, J. White, G. F. A. Hauto, and E. Hazard, engage to make up the deficiency.

It shall be the duty of the managers for the time being, to keep a fair book of account, of all expenditures made by them in the prosecution of the business intended, and of all monies received by them, or their agents, on the Company's account, so as to exhibit a clear, correct, and just state of the concern, which book shall be open to the inspection of the stockholders, or any of them who shall choose to examine the same.

Meetings of the stockholders shall take place on the first Monday in January in each year, at which by-laws for the regulation of the Company shall be made, and each share shall be entitled to one vote.

Dividends of the nett profits, reserving a contingent fund to meet the exigencies of the Company, shall be made semi-annually.

We, the subscribers, promise to pay to Josiah White, George F. A. Hauto, and Erskine Hazard, or to the order of any two of them, One Thousand Dollars for each share of stock set opposite to our respective names, in the manner, and subject to the terms above written, provided that they shall have first executed and recorded a mortgage to us of the whole of their shares, as security for the performance of their part of the above terms; which mortgage shall cease to be binding as soon as the nett profits of the Company shall amount to eighteen per cent., or the amount of our subscriptions shall have been received by us in dividends.

FACTS

ILLUSTRATIVE OF THE CHARACTER

OF

THE ANTHRACITE,

OR

LEHIGH COAL,

FOUND IN THE

GREAT MINES AT MAUCH CHUNK,

IN POSSESSION OF THE

LEHIGH COAL AND NAVIGATION COMPANY,

WITH CERTIFICATES

FROM VARIOUS MANUFACTURERS,

PROVING ITS DECIDED SUPERIORITY

OVER

EVERY OTHER KIND OF FUEL

BOSTON:

Printed by T. R. Marvin, Congress-street

1825.

III

LEHIGH COAL.

The importance and value of this coal in various manufactures, as well as for domestic use, are now beginning to be more generally known. Its use is in consequence rapidly extending, it having been found, for most of the purposes to which it has been applied, greatly superior to all other descriptions of fuel.

For melting metals, for nailing, for rolling and slitting of iron, for malting, distilling, burning lime, baking and evaporating salts, it is entitled to a decided preference; and for various other uses in the arts it is confidently believed that, on trial, its advantages will be found to be equally great. Of all known species of fuel, it makes the most durable fire, creating an intense but regular and steady heat, without smoke or unpleasant smell, and producing no soot. The pipe or *chimney* therefore can never *take fire,* neither will the misery of a *smokey chimney* ever be felt where this coal is used.

For blacksmiths it is superior to the bituminous coals for all general purposes. But some alteration is necessary in the tue-iron. The gudgeons of the bellows ought to be placed 4 or 5 inches above the level of the nose of the pipe. The back of the fire place should be brought up slanting backwards, so that part of the fire may rest on it. The hearth should be filled up nearly level with the bottom of the tue-iron, which should be 1⅛ to 1¼ inches diameter, and a little art, which is soon acquired, is necessary to keep the fire open.

Furnaces for burning this coal should be so constructed as to *free themselves from ashes.* For this purpose the bars of the grate should be made smaller at the bottom than at the top where the coal rests, and should be placed not less than seven eighths of an inch apart, giving the grate or stove a *strong draught of air.*

The following certificates, selected from a great number which might be given, will confirm the statement above made of the great value of this fuel.

The following certificate was given to the *then* proprietors of the great Lehigh Coal mine, by Messrs. White and Hazard, when owners of an extensive wire factory, and rolling and slitting mill, at the falls of Schuylkill, five miles above Philadelphia—

"We have used the Lehigh coal, and in the heating of bar iron for rolling, we find it to contrast with Virginia as follows:—

With Lehigh coal, three men will roll *ten cwt. of iron* for wire, and burn *five bushels* of coal per day of 12 hours.

The wages are	4 00
Five bushels of coal at 90 cents is	4 50
	$8 50

With Virginia coal it takes *ten bushels* to heat *five cwt.* of bars, which is all the three men can do with this coal in one day.

The wages as above is four dollars per day, but rolling but *five cwt.* a day, it will take *two days* to roll *ten cwt.* making the wages for that quantity	8 00
Suppose the coal to cost only 2½ cts. per bushel, 20 bushels would be	0 50
	$8 50

It follows that to us Lehigh coal at *ninety cents* is equally cheap as Virginia coal at *two and a half cents* per bushel."

WHITE & HAZARD.

Whitestown, November, 1814.

"We the undersigned do certify that we are now using the stone coal for heating hoops for cut nails, and find it to exceed any other coal or wood fire for this purpose.

Our practice is, in the morning when we leave the shop for breakfast, to throw a quantity of coal on the fires which will be fit for working on our return, and will last until we leave it at 9 in the evening, when we again put on a quantity which lasts until the next morning at breakfast time. We find a very great advantage in thus having the fire ready to work at an early hour in the morning.

Such a fire requires about half a bushel of coal in twelve hours. We find also that the hoops beat in half the time that they do with any other fire.

Upon the whole we think that the Lehigh coal is much the best for nailing and not attended with one fourth the trouble of any other fire, and that the nails are, in our opinion, superior to others on account of the quickness of the heat, which does not cause the iron to scale so much.

We also can cut one fourth more nails with this fire, than a wood fire."

GEORGE SMITH.
JOHN MORGAN.
DANIEL CLOCKGLASER.

December 12th, 1814.

"I have used in my business for years past, occasionally, charcoal, sometimes Virginia coal, and at others Lehigh, and from use and careful examination of their relative value, I am perfectly satisfied that one bushel of Lehigh coal is equal in durability and value to nearly three of Virginia, and from ten to twelve of Charcoal; and further I find it is the only coal I can depend on for welding of gun barrels, as with it I am always sure of a true and uniform result. I have now used them twenty years, and would not be willing to be without it even if it costs me two dollars per bushel.

I own three tilt hammers, and have worked for the United States and the state of Pennsylvania for the last eight years.

It requires about a peck of the Lehigh coal per day, with a small proportion of Charcoal, for one fire; with this I manufacture 8 gun barrels, or 20 pistol barrels, or 1 quart of coal to a musket barrel."

DAVID HESS,
Smith and gun barrel maker, Northampton, Pa.

Dec. 3d, 1814.

"I have used this kind of coal (the Lehigh) for the last two years, both for the malt kiln, as well as under the brewing copper, and also for distilling, for which purpose I find it to be superior to wood, cheaper, safer, and attended with much less labour.

In distilling, with 30 bushels of this coal and half a cord of wood, (to raise occasionally the heat) I distil 100 bushels of grain in a still, containing 125 gallons, upon the common old construction, in ten days—when I formerly used 5 cords of wood for the same quantity, taking longer time and requiring much more labour.

In order to dampen the fire whilst occasionally washing or drawing off the still, I have only to throw on some of the *finest* of the coal, and when again I want to raise the heat, I put on a stick or two of wood. The length of the bars of my grate is 22 inches, of inch square iron; they are set in loose, the ends widened, so that the bars may be about seven eights* of an inch apart, and placed thus side by side, they make a grate of 15 inches wide. The stills are set bare to the fire, about 16 inches above the grate, with single flues passing round each still, with doors to the furnace.

For malting, the advantages are, that producing no smoke and containing no sulphur, there is no danger of its smoking or otherwise injuring the malt, whilst the *regularity of the heat* is such, that the fires require little or no attention at night, and there is also no danger, with common attention, of burning the malt.

For brewing, or under the boiler, I prefer it for the reasons which induce me to use it in distilling."

WILLIAM BOWN,
Brewer and Distiller.

December 20th, 1814.

Extract from a memorandum furnished by Mr. Joseph Smith of Bucks county, Plough manufacturer.

"From the whole of my observations, (and I have been particularly attentive to the subject for a month past) I am fixed in the opinion that *one bushel* of the Lehigh coal is worth *two* of the Richmond, and ten or twelve of the best charcoal; and it is found to work *steel better* than any other kind of coal; not burning either that or iron as other coal does.

One of my journeymen, who was the most averse, is now using the Lehigh coal at Boyertown, Berks county, at $75 per hundred bushels, in a neighbourhood where charcoal can be purchased for one tenth of the sum."

JOSEPH SMITH.

Tinicum, Bucks county, Pa.
4th Mo. 2d, 1814.

*TRIANGULAR bars with a flat side uppermost, placed HALF AN INCH apart, have been found to answer better.

"We the subscribers, residents of the county of Bucks, do certify, that on the recommendation of Joseph Smith, we were induced to make trial of the Lehigh coal in our smith-shops. We have used it about four months; and believe, at the price we gave, ($24 per ton) they are the most economical coals we could use. We find that the weight on the fire, the only objection to them, is more than compensated by the intensity of heat and freedom from that corrosive quality and cinder, to which all other kinds of coal are subject."

Given under our hands, February 24th, 1815.

JACOB B. SMITH, of New Hope.
EDMUND KINSEY, of Milton.

"I have for two months past made use of Lehigh coal in my distillery, and am much pleased with it. I have ascertained that three bushels of coal (with a little dry wood to kindle) is sufficient to run my singling still six times, my doubling still once, and boil all the water for mashing, &c. I find in using this coal a great saving of labour, and the copper is not so liable to be injured as by wood, because there is not so much danger of burning the still, or running foul at the worm.

My mode of setting stills for this kind of coal is as follows: I draw a circle sufficiently large to give room for a circular flue round the body of the still, of about four inches, leaving an opening of twelve inches wide and two feet deep for an ash hole; I then raise the ash hole twelve inches high and put on my grate, which is made of inch square bars, placed about three quarters* of an inch apart, and a sufficient number to cover the ash hole. I prefer to have the square bars rivetted (instead of putting them in loose as some do) into a cross bar at each end, to keep the bars stationary. I have put up a cast iron door frame in front, of 15 inches wide and 12 high, with a cast iron door to it; then raise the side wall and back of the furnace, a little flaring, to the height of the cast iron door frame, levelling the top; then put down four bricks for bearers, on which I set my still, then drawing a flue of about four inches round the sides of the still, inclose it at the top rise of the breast.

This mode I find to answer a very good purpose for stone coal. It is not necessary to have a slider or damper in the chimney, because by closing the front of the ash hole and opening the door of the furnace, it will sufficiently check the operation of the fire when required."

GEORGE HAINES.

March 10th, 1815.

"We have used the Lehigh coal in our cupola, and after an experience of two years, we find that by using one bushel of Lehigh coal to five bushels of charcoal, we can melt double the quantity of iron in the same time—for instance, where we formerly melted twenty-five hundred of iron in our cupola, starting at 10 o'clock, A. M. and ending at 6, P. M. we, by using Lehigh coal mixed with charcoal as aforesaid, now melt fifty hundred weight. By using charcoal exclusively we formerly considered castings over ten hundred precarious to run by cupola, we now by using Lehigh coal can run castings over twenty hundred without danger. We discover Lehigh coal does not harden the iron, but it comes out grey."

CAD. & O. EVANS.

City Foundry, Philadelphia, May 26th, 1824.

"I have used Lehigh coal for melting copper and brass, for the last two years, and give it the preference to any other fuel.

I consider common pine coal a nuisance in a brass founder's shop for melting metal."

CHARLES GREEN.
Brass Founder. No. 54, New street.

Philada. May 14th, 1824.

"We, James and Joseph Whitaker, proprietors of the Delaware rolling mills, have used Lehigh coal for rolling our iron for nearly three years, and find it so much superior to all other species of fuel which we have ever used, that we would, now that our workmen are accustomed to and prefer it, rather pay 30 cents per bushel for it, than get Richmond or Liverpool coal for nothing."

J. & J. WHITAKER.

Philada. May 24th, 1824.

"I have used Lehigh coal in a rolling and slitting mill for the last three years and consider it superior to any other fuel that I have employed. In 1812, I gave $14 per ton for it, or 50 cents per bushel, and even at that price considered that I saved, and preferred it to any other coal that I could get. At present the Lehigh and Virginia cost me the same price per bushel de-

*See note to W. Bown's certificate respecting the bars.

livered at my mill. But with from 7 1-2 to 8 bushels of Lehigh coal I roll as much iron as would require 13 bushels of Virginia, and the work is done in from two to three hours less time; so that my profit by using the Lehigh is 4 dollars 55 cents per ton, or 1 dollar 75 cents per day. This however is not all the advantage—my foreman will work with Lehigh coal for lower wages than with Virginia, the trouble is so much less; for instance on Monday morning the fire is made with a little wood or half a bushel or more of Virginia coal to start it, and it can be got ready for a heat in about one and a half or two hours; when once in order you have nothing to do but add coal, heat after heat—no cinder or other trash to take out until the day's work is done—then rake up the fire by pushing to the back all the coal that remains in the oven, shut down the damper, and in the morning you have fine live coals, the quantity very little diminished during the night; from Monday to Monday, no wood or other fuel wanted, and your oven always warm in the morning. Any one acquainted with the business can compare this with the trouble of Virginia coal, and after all, you cannot make so regular a heat as with Lehigh, but are apt, without a great deal of care, to burn the iron in one place and not have it hot in another. My furnace was constructed to burn Virginia coal: I made no alteration in it, except taking some of the bars out of the grate, so as to make the spaces between the bars wider.

This statement, which may appear partial, is given only for information. I have no interest in the Lehigh company, other than that of getting a regular supply for my business of this excellent fuel."

AMOS A. JONES.

Verreville, May 15th, 1824.

"We have used the Lehigh coal several years past to heat bar iron for our rolling mill at Bridgetown, Cumberland county, New-Jersey; prior to the introduction of this, we used the Richmond coal for the same purpose, and from experience thus obtained, we are satisfied that for this purpose, one bushel of the former is worth at least two of the latter."

BENJAMIN & DAVID REEVES.

Philada. May 19th, 1824.

"The quantity of Lehigh coal in Philadelphia heretofore, not being equal to the demand, I have not been able to obtain sufficient for my use, and have burned it but seldom in the rolling mill, but constantly for several years in the nail factory. I shall use it in preference to any other fuel when I can be supplied, being well convinced of its superiority. I have had heated, for rolling into hoops, 11 tons of bar iron, with 33 1-2 bushels of your coal, when it would require nearly double that quantity of Virginia coal, or about six bushels to the ton. In the nail factory we consume about one bushel and three pecks of Lehigh coal to heat a ton of nail plates. As it requires no charring, is very durable, and the heat intense, much time is saved in the use of it. A fire made in the morning lasts till noon, then replenished, endures the rest of the day."

HENRY MOORE.

Old Sable Works, May 19th, 1824.

"We are of opinion that Lehigh coal is much to be preferred to wood, as fuel for drying malt, being more economical, requiring less room for storage, and less attention whilst burning, from its steady heat and great durability. The danger of accidents from fire is so much diminished by the use of this coal, that *it* alone would be sufficient to give it a decided preference."

DAWSON & MORRISON.

"From considerable experience I have found the Anthracite from Lehigh much superior either to the Rhode-Island or Kilkenny, (Ireland)."

WILLIAM MORRISON.

Philada. 5th Mo. 8th, 1824.

"For melting brass the Lehigh coal is preferable to any other; for one ton of Lehigh will do as much work as 200 bushels of charcoal for melting, beside is not half the labour in attending the furnace; and likewise for soldering our work. One person can do more than double the work with the Lehigh than they could with charcoal on the forge, and I find a great advantage in using it at the rolling mill, for heating the oven in which we neal the brass for rolling, for two fires will serve for the whole day.

I therefore think it is the cheapest by one half."

J. BARNHURST.

May 8th, 1824.

"Having a mill for rolling and slitting of iron, we have for many years been in the habit of using the Virginia coal for heating the iron, until about six months ago we were induced to try the Lehigh coal, and find it so much superior to any other, that we now use it exclusively, and we believe there is a saving in the expense of about fifty per cent in favour of the Lehigh at the present prices of each, as we can perform the same business with two tons of the latter that we could with 85 bushels of Virginia.

Our workmen also prefer the Lehigh as they have much less trouble in keeping their fire with it than any other that we have used."

JAMES & MAXWELL ROWLAND.

Philada. 5th Mo. 22d, 1824.

"This is to certify, that I have used at one of my blacksmith forges, for some time past, the Lehigh coal, and (about adopting it in all of them) find that one bushel of it will last longer than two of Virginia or Liverpool, it being much cleaner, and the smith likes it better, and can safely say that I have had the largest day's work done with that coal that I have had with any other for ten years."

JONAS GLEASON.

"N. B. I find you must alter your bellows tue-iron by making it about twice as large as is common, and begin your fire with a little charcoal or wood at the bottom, and not let any dead coal get to the tue-iron and you have no difficulty, and when you leave your fire, put in a small piece of wood or charcoal, to keep it while at dinner, &c.—A little instruction is necessary to a new beginner or he is apt to get too soon prejudiced." J. G.

Philada. May 7th, 1824.

"I Thomas Barnhurst, brass founder &c. of Philadelphia, certify, that I have been in the use of the Lehigh coal for several years, for brazing and melting brass and copper; and my experience authorises me to say, that in brazing or soldering, my hands can do in a given time with one half the expense, three times as much work as they can with any other kind of coal that I have ever used. And for melting any kind of metal, one fire will answer the place of eight fires of charcoal, at not greater expense than each fire of charcoal;—that taking into view the great saving of expense of fuel, and the very great additional quantity of work my hands can do with Lehigh coal more than any other kind, I think it invaluable either for melting or brazing."

THOS. BARNHURST.

Philada. May 10th, 1824.

"I Samuel Heston, of Bucks county, have followed the business of a blacksmith for thirty years, and until the year 1819 was in the habit of using charcoal and Richmond coal. During the war I obtained a parcel of Lehigh coal for trial, but could do nothing with it and considered it a worthless article. In the year 1819, I made a visit to Mauch Chunk and there had an opportunity of seeing this coal properly used. I brought some of it back with me in my waggon, and have been in the use of it ever since, hauling it from Philadelphia a distance of 28 miles, rather than purchase charcoal in my neighbourhood. I can do more work with one bushel of the coal than any man can do with three bushels of Richmond coal or six bushels of charcoal. In short I consider the discovery of Lehigh coal one of the most important ever made in this country, and should hardly be tempted now to use any other if it were given to me for nothing. When I went up to Mauch Chunk for curiosity, I had sold out all my stock, intending to move to the state of Ohio, and nothing but the prospect of being able to carry on my business to great advantage by using this coal, induced me to alter my mind and remain. Fifty people in my neighbourhood know that I should have gone but for this accidental circumstance.

SAMUEL HESTON.

May 20th, 1824.

"I have found from experiment that 10 bushels Lehigh coal may be considered equal to 50 bushels charcoal, or to one cord of good hickory wood, when used for drying malt for brewer's consumption. The principal advantages the Lehigh coal possesses, compared with other fuel, consists in the steadiness, regularity and safety of the heat emitted, and the little attendance it requires, it also dries malt paler than other fuel.

ADAM SECKEL.

Philadelphia, June 4th, 1824.

Letter from William Young, Esq. proprietor of the Rockland Factories on the Brandywine, to one of the Managers.

"I have your letter of 9th instant requesting information respecting the manner of using the Lehigh coal, its cheapness, safety, and other advantages.

I will with pleasure note such circumstances as have been found to answer all these purposes at the warehouse, No. 10, South Third street, and at the Rockland cotton and woolen factories on Brandywine. The first

I had of the Lehigh coal was in 1798, when Mr. Charles Cist sent a basket of that coal, which was put into a carron coal grate, and the fire place inclosed to make the current pass through the fire; the heat produced was intense.

As soon as a supply could be had, it was introduced at the warehouse, and sent to the factories on Brandywine. The manner of using is simple, safe and efficacious. It has been used in furnaces (at the factories) built on the ground floor. These furnaces are made of fire brick enclosed in cylinders of sheet iron; around this, and leaving a space of about four inches for an air chamber, a circular brick wall is built, and the air chamber covered above the top of the furnace. The air from without the building is introduced as low under the air chamber and grate of the furnace as practicable, in order to give the greater pressure from the external column of air, to promote the combustion in the furnace, and to increase the current of warm air from the air chambers through the tubes to carry to the points required in the factory.

The conduits for the cold air are large, and also the smoke pipes and air tubes, from 7 to 14 inches diameter. The larger the conduits, and the colder the air introduced, the effects are so much the more immediate and satisfactory, and it is presumed, that in cases where the coal has not been so advantageously used, it has arisen from a want of attention to these very important circumstances. The smoke pipe, which is about 14 inches diameter, contains a tube of warm air of about 7 inches diameter; these are carried through each floor in copper reservoirs, filled with water, which while they remove all risk from fire, the evaporation produces a refreshing air in the factory. The woollen factory, a building of about 34 by 85 feet, four stories high, has been rendered comfortable with one furnace, except where a stove is required at the gig mill. The cotton factory, about 40 by 70 feet, three stories high, has never required more than the use of one furnace, to render it so warm as required in the coldest season. Thus in the one case, supposing the building 81 feet long, 31 feet wide and 35 feet high, all in the clear within the walls and floors gives 87.885 cubic feet of air, and the other building 67 feet long, 36 1-2 wide and 32 feet high, the stories being so much higher within the walls, gives 78.240 cubic feet of air rendered comfortable by one furnace and air tubes. The expenses I cannot exactly ascertain, because until 1822 we could not obtain a supply of your coal for both factories, and the smith shop. For the winter season of 1822, 16 tons were used for the factories, and the smith shop, and the same quantity in 1823. The wood used for kindling, an occasional supply being taken from the other stores for weaving shop, dye house, &c. &c. cannot be ascertained, nor can we exactly state the expenses compared with other fuel, but our estimate has been, that 10 to 12 bushels of Lehigh coal, of 80lb. weight each, will yield the same quantity of caloric or heat as one cord of oak wood of 128 cubic feet; and one bushel of Lehigh coal will perform for us about the same service as one and a half bushels of such Liverpool as we have had.

It might also be stated that a neighbouring factory where they used oak wood, the building 4 stories high, and not much larger than these already mentioned, required about 200 dollars for wood for the season.

The circumstances already stated will show that the Lehigh coal used is by far the safest fuel. There is but one fire, and that shut up on the pavement floor: there are no sparks, and it is understood that the deposit in the pipes and chimnies are incombustible; this however may not be the case when the fires are kindled with wood, or where wood is used occasionally to continue the temperature till the time of shutting up in the evening; but in general three fires hold out to serve for each day.

The insurance offices have been so well satisfied about its additional safety, that the premiums are reduced where it has been in use in the manner stated, and which has been introduced from season to season into the most extensive factories near the Delaware, with some variation according to taste and circumstances. The convenience is also great; instead of carrying fuel into the different stories where dust, smoke, &c. are disagreeable and often injurious, the caloric is carried wherever required without risk, dust, smoke or labour. Coal has been used for six years at No. 10, S. Third street. The Rhode Island, which is more difficult to manage, was used until a supply of Lehigh could be obtained. The air is introduced from the outside of the room and as much below the grate as practicable, by which the combustion is carried powerfully on without any consumption of the warm air; and by means of the tubes the heated air is carried to any point required, within or without the warehouse, at a small expense, and without injury from smoke or dust: the temperature is regulated by valves or registers in the smoke pipes."

WILLIAM YOUNG.

Philada. May 19th, 1824.

"We the subscribers having made use of the Lehigh Coal in our parlours during the past season, are so well satisfied with it that we prefer it to any other fuel—being cheaper, safer, and more durable, after being once ignited, and therefore less troublesome to continue the fire than with wood or other Coal.

JOSEPH BALCH.
ISAAC WATERS.
C. BLANCHARD.
A. H. GIBBS.
I. P. DAVIS.

Boston, June 15, 1825."

NOTE.—It has been ascertained by calculation that by the substitution of Lehigh Coal for wood, the expenses of the Pennsylvania Hospital have been diminished about one thousand dollars per year, or say *one third*.—This is a well authenticated fact.

[From the New York Mercantile Advertiser.]

IMPORTANT TO AGRICULTURE, COMMERCE, AND MANUFACTURES.

It appears from actual experiment made on the Coals dug out of the mines of our country, such as the Schuylkill, Lackawaxen and the Lehigh, being all of the same family, that they possess a degre of heat in the ratio of 5 bushels to 18 bushels of the Liverpool Coal after it had been cok'd: it is confidently believed these Coals are the pure carbon, and that there is no such Coal to be found in Europe, and from the experiment made by Messrs. Robert M'Queen & Co. in this city, we have reason to say that the grand desideratum so long sought after in the manufactures of Europe to acquire a degree of heat beyond that which the Coke Coal will produce, will be found in the Coal above mentioned.

Herewith subjoined is a certificate from the practical hands of Mr. Hood, the foreman of Messrs. R. M'Queen & Co. who carry on in this city one of the most extensive Iron Foundries in the United States. Here is no theory, it is the result of actual experiment passed through the ordeal of the large crucible technically called a Cupola from which there is no appeal.

The following certificate is from Mr. Hood, Foreman of Messrs. Robert M'Queen & Co.

"I do hereby declare that I have, in the Cupalo Furnace of Robert M'Queen, Esq. made four different blasts with the Schuylkill Coal of Mr. Snowden, and find it fully to answer all our purposes. We used different proportions of Coal and Iron on the different days to try the strength of the Coal, and the result is, that the Schuylkill Coal, *in its native state*, without any trouble or the expense of coking, and with a much *smaller* quantity of coal, makes *better iron* than any coke we ever used. It renders the metal *much softer* and fitter for our purpose than coke. I have no doubt that this coal, as soon as introduced here, will entirely do away the use of coke, and produce great saving in our works."

(Signed) WILLIAM HOOD.

William Hood acts in the capacity of foreman for us, and we believe what he has stated to be correct.

(Signed.) ROBERT M'QUEEN & Co.

LEHIGH COAL,

APPLIED TO ROLLING IRON.

The furnaces should be 12 or 15 inches longer than the bars intended to be heated, with a grating under the whole, and a flat roof about 12 or 13 inches above the grating, and the draft taken through 2 or 3 openings in the roof connected with the stack—each of the openings should be provided with a damper, to regulate the draft at pleasure. With such a furnace you need never wait for the coal to burn up, after making the first fire. At the same time that you put on the iron, throw a few lumps of coal at the back end of the furnace which will be ignited by the time the iron is rolled off, then stir up the fire so as to free it from ashes, bring forward the fresh coal, and immediately put on the change of iron and renew the coal at the back of the furnace. With two furnaces worked on this plan, the rollers may be kept constantly at work, as the iron will heat in one as fast as it can be rolled out of the other. This will be found to require water to be always running upon the rolls to keep them cool. Five bushels of coal will be sufficient for 1 1-2 tons of iron. Supposing the Lehigh and Liverpool coal to be at the same price, the use of the Lehigh will be found to save the whole cost of the coal and hands—as the same hands can do double the work, with half the coal, in the same time that they can with Liverpool or Virginia coal. Soap Stone, with the end of the grain next to the [illegible], is the best material for the furnace and will stand [illegible] years without repair.

TO BURN LIME.

The furnace, or kiln, may be constructed of almost any shape: that of an egg answers very well. The lower part is contracted to a square of 18 or 20 inches having the bottom on an inclined plane, so that the burned lime may be drawn out below with a shovel while the coal and stone are thrown in above. The stone should be broken moderately small and the coal made very fine. To commence operations, put a sufficient quantity of wood in the kiln to ignite the coal; then a stratum of coal; then fill up the kiln with alternate strata of stone and coal, in the proportion of six bushels of the stone, to one of coal, and set fire to it; as it settles, fill it up. After the wood and lower coal are burnt out, the lime will show itself at the bottom and may be drawn out as it cools. Thus by drawing out the lime and keeping the kiln filled with stone and coal, the operation may be continued at pleasure. In some kilns it is necessary to keep all the crevices on the top filled with fine coal, to prevent the stone from melting with the strong draft. The proportions of stone to coal will be found to vary from 5 to 8 for one—the quantity depending upon the quality of the stone and the size to which it is broken. If the coal be left too coarse, the mass will be melted by the intense heat. This will be found the most economical and pleasant way of burning lime—as the kiln is cool both at bottom and top, and requires no further attention than drawing out the lime morning and evening, and filling it up with stone and coal.

TO DISTILLING.

A furnace and grate is made under the stills, with a door to close up the front, that no air may get into the furnace but what passes through the grate and coal. A damper should likewise be put in the chimney, to regulate the draft. When the liquor is run off, and you wish to change the stills, throw some fresh coal on the fire and close the damper and ash hole, by which means the heat is almost instantly checked, and the still can then be run off and recharged by the time the fresh coal is ignited and furnishes the heat necessary to continue the process; so that no time is lost in making up the fire. One ton of coal has been found sufficient to run off 630 gallons of liquor from the low wines, besides heating all the water for mashing 210 bushels of grain, and washing the casks, &c.

TO BREWING AND MALTING.

In malting, the whole product of the combustion of the coal, passes through the malt, which partially bleaches it, and makes it much preferable to other malt for making pale ale. By making a uniform constant heat, the fire requires little or no alteration. The same fixtures and management are used with the brewing kettle as in distillery.

TO BURNING BRICK.

The bricks should be piled with spaces of about three quarters of an inch between them, and fine coal should be thrown loosely into those spaces. The lower part of the kiln must then be ignited with wood and the heat will gradually work through to the top, burning the bricks in its progress. The hardness of the bricks is regulated by quantity and fineness of coal.

TO MELTING IRON.

In a cupola furnace, one ton of coal will melt two tons of pig or scrap iron. The coal should be broken to about the size of eggs. It requires more blaze than charcoal.

TO BAKING.

The Lehigh coal is peculiarly adapted to perpetual ovens—as the heat may be kept regular for any length of time. The ovens are made of sheet iron, and built in brick or stone work, so that the heat may pass all around it. The grate should be placed about 20 inches below the oven, and have separate doors to the ash hole and furnace, that either, or both, may be opened to regulate the heat. One bushel of coal is sufficient for an oven capable of baking 100 lbs. of bread per hour for a day of 12 hours.

The subscribers, agents of the Lehigh Coal Company, are prepared to execute orders for Coal in any quantities, and will also give the necessary information for the construction of Grates and Stoves, to those disposed to make trial of it.

LYMAN & RALSTON,

71 *Broad Street,*

BOSTON.

IV

Pennsylvania, ss.

In the name and by the authority of the Commonwealth of Pennsylvania.

SEAL OF THE STATE OF PENNSYLVANIA

JOSEPH RITNER,
GOVERNOR OF THE SAID COMMONWEALTH

To all to whom these presents shall come, sends greeting:

Whereas, pursuant to the eleventh and fifteenth sections of an act of the General Assembly, passed the 20th day of March 1818, entitled, "An Act to improve the navigation of the river Lehigh," Commissioners were appointed by me, on the 8th day of September 1837, to view and examine the descending navigation, by artificial freshets, on the river Lehigh, between Stoddartsville and the mouth of Wright's Creek, and also a number of Locks as part of the slack water navigation in the said river, between Mauch Chunk and the mouth's of Wright's Creek, upon the notification of the President and Managers of the Company for making the same, that the said descending navigation and locks, as aforesaid, are made and perfected agreeably to certain acts of assembly referred to in the first section of an act passed the 13th day of March, A.D. 1837, entitled, "An Act authorizing the construction of a Railroad to connect the North Branch Division of the Pennsylvania Canal, at or within the borough of Wilkesbarre, with the slack water navigation of the Lehigh," which authorize the making the same; and whereas, the said Commissioners, Samuel Breck, Nathan Beach and Owen Rice, Esquires, have reported to me in writing, under their respective hands and seals, and under their oaths and affirmations, that they have viewed and examined the said descending navigation, and the locks specified in their report, and that they are made and perfected in a complete and workmanlike manner, agreeably to the true intent and meaning of the acts of assembly on the subject: Now know ye, That in pursuance of the directions and authority in the said acts of the general assembly contained, I, the said Joseph Ritner, governor of the said commonwealth, do hereby permit, license, and suffer the said President Managers and Company to fix and appoint so many places on the aforesaid descending navigation and the locks, as aforesaid, forming part of the slack water navigation before referred to, as will be necessary and sufficient to collect the tolls and duties granted by Law to the said Company, from all persons having charge of all boats, arks, vessels, crafts and rafts, passing up and down the same.

Given under my hand and the great seal of the state at Harrisburg, this 2nd day of November, in the year of our Lord 1837, and of the Commonwealth the sixty-second.

By the Governor.

J. WALLACE, *Deputy Secretary*

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