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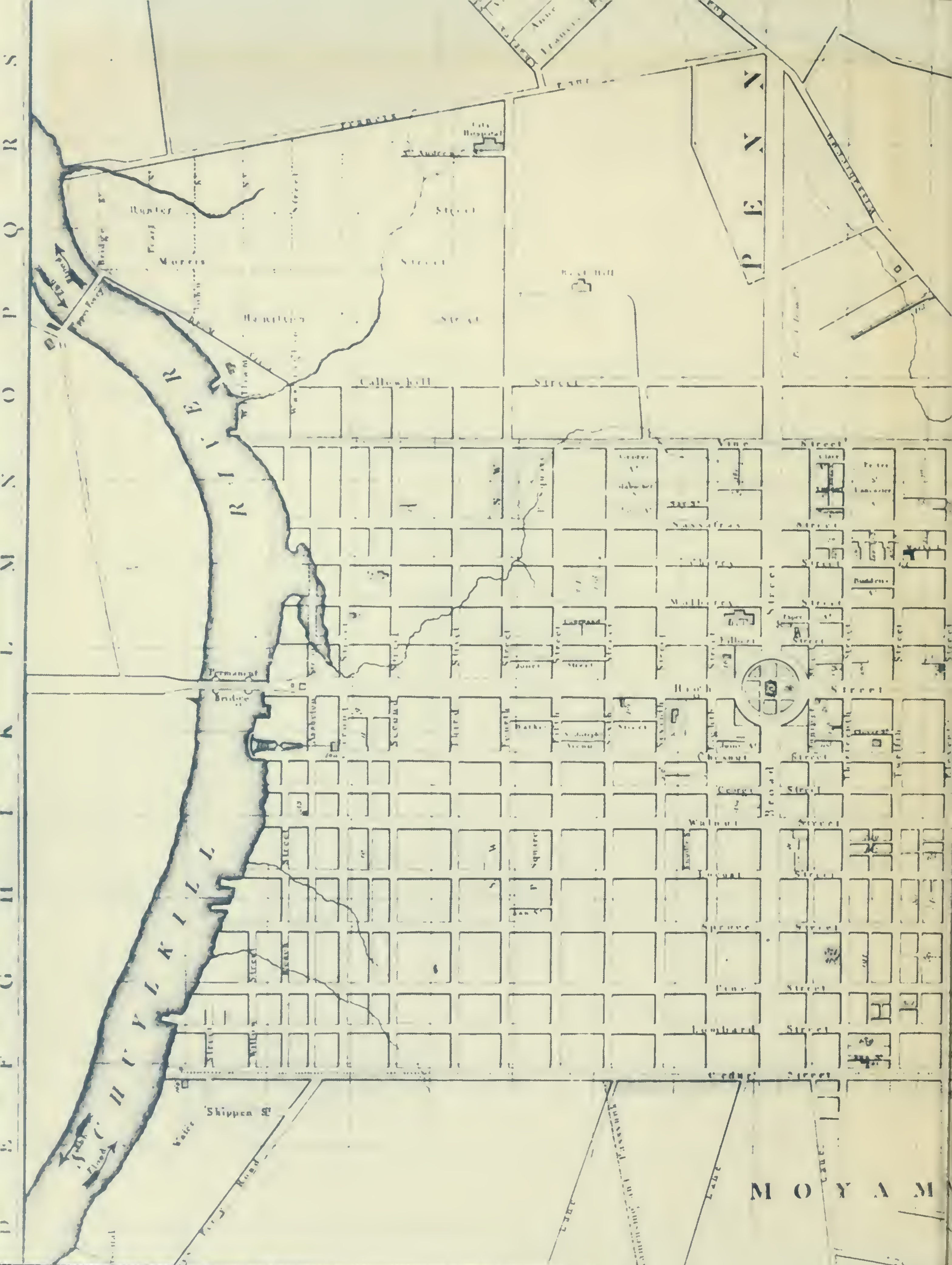
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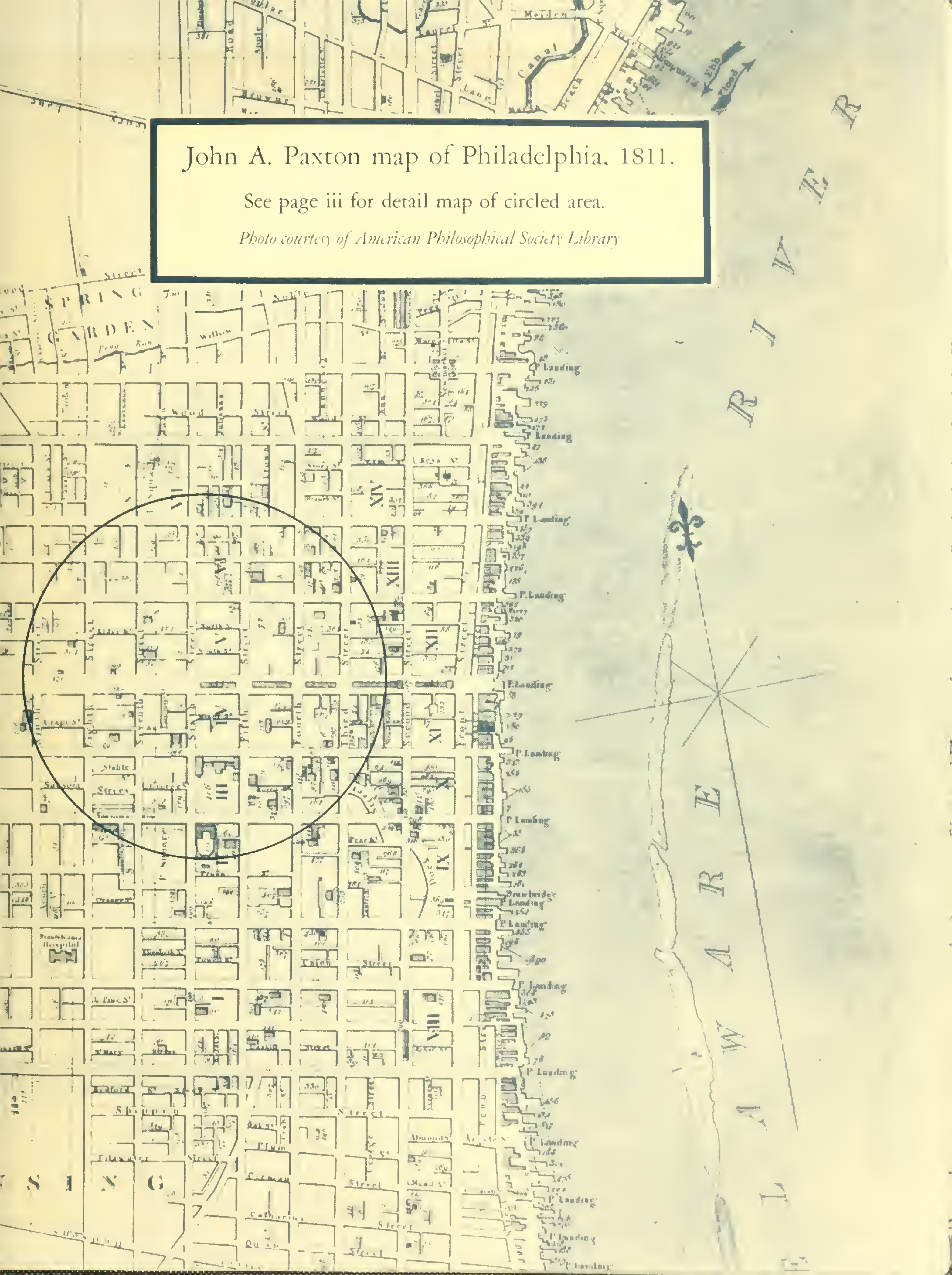

John A. Paxton map of Philadelphia, 1811.

See page iii for detail map of circled area.

Photo courtesy of American Philosophical Society Library

SMITHSONIAN INSTITUTION

UNITED STATES NATIONAL MUSEUM

BULLETIN 238

WASHINGTON, D.C.

1965

Publications of the United States National Museum

The scholarly and scientific publications of the United States National Museum include two series, *Proceedings of the United States National Museum* and *United States National Museum Bulletin.*

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 technical 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 sub-series *Contributions from the United States National Herbarium.* 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.

This work, brought to completion while the author was curator of engineering in the Museum of History and Technology, forms number 238 of the *Bulletin* series.

Frank A. Taylor
Director, United States National Museum

United States Government Printing Office, Washington, 1965

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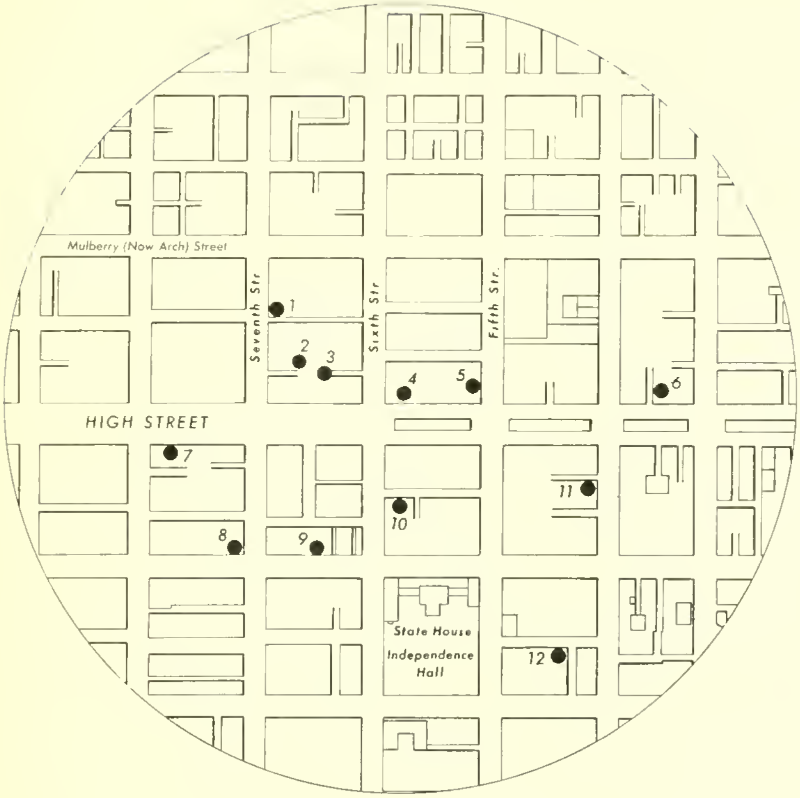

Area of Philadelphia circled on front end paper. Numbers identify a few places (mentioned in text) that were near George Escol Sellers's boyhood home:

1. First U.S. Mint.
2. Perkins and Sellers fire engine shops.
3. Birthplace of George Escol Sellers.
4. Shop and dwelling of Nathan Sellers at 231 Market St.
5. Friends School. Joseph Roberts taught here.
6. Isaiah Lukens's shop.
7. Diligent Fire Company.
8. City Hotel.
9. Philadelphia Arcade Building.
10. Matthias Baldwin's shop.
11. William Mason's shop.
12. Patrick Lyon's shop.

George Escol Sellers. Born November 26, 1808; died January 1, 1899. Portrait by George Giguere, after *Paper Trade Journal* (October 16, 1897), vol. 26, p. 104.

MUSEUM OF HISTORY AND TECHNOLOGY

Early Engineering Reminiscences (1815-40) of George Escol Sellers

Edited by

Eugene S. Ferguson

SMITHSONIAN INSTITUTION, WASHINGTON, D.C.

1965

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Preface

THIS BOOK DESCRIBES the development of machines and mechanical skills in the United States during the first half of the 19th century. It illuminates a facet of our technological heritage that is little known despite its essential importance to our understanding of the emergence of the United States as an industrial nation. Here the reader will meet many of the craftsmen and engineers who devised and developed the machines and techniques that made possible the growth of an industrial complex. He will find many fresh details of surprisingly sophisticated tools and skills that existed during an age that he has been taught was mechanically uncouth.

Before one can understand why progress occurred as it did, it is necessary to know what actually happened, who did what, and why. This is the kind of information that is presented in the pages that follow. Written with rare precision, perception, detachment, and good humor, these reminiscences have freshness and vigor that commend them to every interested reader.

The author, born in 1808 in Philadelphia, a block and a half from Independence Hall, was from early boyhood a constant visitor in and an alert observer of the many mechanical shops that were scattered about that part of the city. He knew, and tells us about, many of the leading mechanicians of the generation that spanned the administrations of Jefferson and Jackson. In these pages, the names of Philadelphians and sojourners in the shops of Philadelphia, as well as the names of other Americans whose paths crossed that of the author, take on qualities of flesh and blood.

Ranging farther afield as he grew older, the author made a visit to England in 1832 that enabled him to hold a mirror to the state of the mechanic arts in America, as he observed with a critical but kindly eye some of the great mechanicians of the Old World.

Most of the narrative included here appeared in a series of articles in the *American Machinist* between 1884 and 1893, which until now has been effectively buried in the stacks of the relatively few libraries that have preserved early volumes of this magazine. It was tracked down through an offhand reference that Sellers made in 1895 to his "valedictory," written "several years ago." A few additional episodes have been culled from two unpublished volumes in the Peale-Sellers Collection of the American Philosophical Society Library.

It is quite remarkable that the reminiscences of an old man—Sellers was 75 when he wrote the first article—of events that occurred more than 50 years earlier should stand up so well under careful testing of his factual statements against those contemporary with the events described. The reader will quickly note that Sellers had an uncommonly good memory; but occasional comments by the author show that he had also bales and boxes of papers, drawings, and artifacts of an active lifetime to refer to. Limited only by his failing eyesight, he used his reference materials with skill and candor. Even when his details can be disputed, which is seldom, his broader strokes paint a likeness that lets us see a real person where there would be otherwise only a name.

The reader can hardly fail to find new insights, previously unrecognized relationships amongst people and events, and occasionally—as when ebullient Jacob Perkins or sagacious Bryan Donkin step out of the page to confront the reader—sheer delight.

I have selected for publication those parts of the story that are pertinent to the history of technology, believing that they will be useful as source materials in the many studies that ought to be made of the technical history of this period. The articles describe events that the author had direct knowledge of. Second-hand narrative or historical summary are retained only when they contain information not otherwise available, or when editorial interpolation would do violence to the author's narrative. Family history, of which a great deal exists in the unpublished volumes mentioned above, has been left for biographers of the several prominent members of the Sellers and Peale families.

These reminiscences were written over a period of nearly 15 years, and for all their essential charm and freshness they were sometimes rambling and repetitious; no detectable plan or order was followed in their preparation. Therefore, the articles, and occasionally passages within an article, have been rearranged to give very roughly a chronological sequence.

Editing within each article has been held to a minimum, and changes and omissions have been noted in the text. Marks of elision have not been used generally to open and close passages from the typescript volumes in the American Philosophical Society Library because the typescript is made up of a series of letters that really has neither beginning nor ending.

Because the work is presented as source material, I have tried to preserve its meaning by not tampering with the author's style. I have spelled out abbreviations, corrected the spellings of names, and increased the number of paragraphs greatly, because the author paid little attention to such things. Grammatical changes, which have been made only when necessary, have been bracketed.

Footnotes that appear more bibliographic than interpretive are intended to suggest further studies. I have assumed the risk of annoying some readers by tedious annotation in the hope that others will make use of the information and will help to fill in some of the larger gaps in our knowledge of this field and this period.

I have been helped in every stage of the work by many individuals who have generously supplied encouragement, information, or pictorial materials, as the occasion demanded.

My first thanks are to Jo, my wife, who has submitted with patience and understanding to the tyranny of a work-in-progress in our home. Two former colleagues have been particularly helpful: Robert P. Multhauf encouraged me to undertake this work; John H. White put his extensive detailed knowledge and records of early railroads at my disposal, and he gave freely of his time in reading the manuscript, in discussing points not clear to me, and in locating materials for my use.

Charles Coleman Sellers, biographer of Charles Willson Peale and author of the monumental, definitive *Portraits and Miniatures of Charles Willson Peale*, has answered my many questions and has graciously opened doors whose existence I was unaware of. It was Charles Coleman Sellers' father, Horace Wells Sellers (1857–1933), who encouraged his uncle George Escol Sellers to expand his reminiscenses, and he assiduously collected, arranged, and transcribed the numerous papers that his uncle wrote.

John H. Powell, catalyst extraordinary of historical studies, furnished a summary of his work on Patrick Lyon that greatly expanded my knowledge of this colorful, competent mechanician. The kind assistance of Mrs. Gertrude D. Hess and Murphy D. Smith made my several visits to the American Philosophical Society Library both profitable and pleasant. Norman B. Wilkinson, John W. Maxson, Jr., and James L. Anderson have all responded with helpful answers to my unbidden queries.

My special thanks go to George Giguere, who drew the frontispiece portrait of the author. Mrs. Catherine Scott's patient work of typing, retyping, collating, and comparing the manuscript has helped to insure a faithful rendering of the author's narrative.

While I thank all of those who have lent aid and encouragement, I take sole responsibility for opinions, conclusions, and mistakes.

Eugene S. Ferguson

Ames, Iowa
September 28, 1964

FIGURE 1.—Coleman Sellers (1781–1834), father of George Escol Sellers. Portrait by Charles Willson Peale, 1811. Photo courtesy of Charles Coleman Sellers and Frick Art Reference Library.

George Escol Sellers

George Escol Sellers was born in Philadelphia on November 26, 1808, the second son of Coleman Sellers (1781–1834) and Sophonisba Angusciola Peale Sellers (1786–1859).

One of his grandfathers was Nathan Sellers, widely known in the United States and in England as a fine craftsman in the exacting art of making wire paper molds. Paper molds and machinery and, later, the actual making of paper were to engage much of George Escol's energy throughout his life. Coleman, his father, became involved in the building of fire engines, and this, with the general machine works that grew out of his various enterprises, provided training for George Escol over the whole spectrum of the mechanic arts.

His other grandfather was the renowned Philadelphia portrait painter and museum builder Charles Willson Peale. The boy's mother, like her brothers Rembrandt and Rubens and Titian, was named for an artist—in her case a female Italian portrait painter of the 16th century. George Escol was at home in the museum, as he was in the workshop. When lectures were held in the Peale Museum, the boy often assisted in preparing and cleaning up the apparatus used for demonstrations. He was, in fact, at home wherever there was something interesting to be

FIGURE 2.—Sophonisba Angusciola Peale Sellers (1786–1859), mother of George Escol Sellers. Portrait by her father, Charles Willson Peale, 1811. The child is George Escol Sellers's younger sister, Elizabeth Coleman Sellers, who was born in 1810. Photo courtesy of Charles Coleman Sellers and Frick Art Reference Library.

learned. He was accurately characterized by Jacob Perkins as "the boy who asked questions and would have an explanation of everything."[1]

His formal schooling started with his attendance at the "ABC" school of Mrs. Saul, who held forth in a second-story room on Chestnut Street at Seventh, about two blocks from his home. He recalled this "giantess with a terrific turban on her head" as having "not a particle of kindness within her skin and her greatest delight seemed to be in torturing the kids entrusted to her care."[2] Until he was 15 or 16 years old, he had various schoolmasters, remembering with particular gratitude and affection his term with Joseph Roberts, who taught in the Friends' School on Fifth Street and whose fourth-day afternoon lectures were open to all whom his students cared to invite. In Roberts's classroom, George Escol sat at the same table with Solomon and William Milnor Roberts, both to become civil engineers associated with the Pennsylvania Portage Railway, and with John Dahlgren, of naval ordnance fame. It was in the fourth-day lectures that Sellers met John C. Trautwine, whose civil engineering handbook was one of the earliest and most durable works of its kind.[3] Sellers attended a private class in mechanical drawing held by William Mason, machinist and instrument maker; and he drew with John Haviland, architect.[4] His practical training

[1] Peale-Sellers Papers, George E. Sellers memoirs (MSS, American Philosophical Society Library), book 4, pp. 13–14. Hereinafter referred to as Memoirs.

[2] Memoirs, book 4, p. 24.

[3] Memoirs, book 4, pp. 27–30.

[4] Memoirs, book 8, p. 9.

FIGURE 3.—High Street, Philadelphia, looking west. The "Market Street Store" of Nathan Sellers was similar to the building in the right foreground. From Charles W. Janson, *Stranger in America* (London, 1807). Library of Congress photograph.

began at home in his father's shop. Although he was bound to no particular master as an apprentice, he became certainly a competent machinist, profiting from association as a boy with such fine craftsmen as Isaiah Lukens, William Mason, his uncle Franklin Peale, and the itinerant German aristocrat known only as Henri Mogeme. Like most other engineers of his generation, the only advanced training that Sellers obtained was in the field or from such books as he was able to command.

George Escol Sellers was born less than a decade after the great federal period of Philadelphia's history, when President Washington lived across Market Street from Nathan Sellers's store and paper mold manufactory between Fifth and Sixth Streets, when Secretary of State Timothy Pickering lived next door, and when such luminaries as David Rittenhouse were of "the set that congregated about the stove of winter nights in the Market Street store." [5] He could recall personally the merchant

[5] Memoirs, book 1, p. 78; book 7, p. 6.

banker Stephen Girard, however, and he told of Girard's hurrying into his grandfather's store one morning to volunteer financial help for Nathan Sellers, without endorsers, when an erroneous report of his failure got abroad.[6]

Nathan Sellers moved about 1817 to a new home in Upper Darby Township, which he called Millbank; and Coleman's family, including George Escol, moved into the Market Street store. In 1828, an association by Coleman with John Brandt, of Lancaster, Pennsylvania—who had devised a particularly good machine for forming and setting the teeth in textile cards and card clothing—led to the building of shops that were named Cardington, near Millbank on the Marshall Road.

The Cardington shops grew rapidly. In addition to cards and carding machinery, Coleman Sellers and his sons George Escol and Charles (two years older than George) built a line of papermaking machinery.

In 1832, when he was nearly 24, George Escol spent several months in England to observe and learn whatever he could of papermaking machinery.

Shortly after returning from England, Sellers was married, in 1833, to Rachel B. Parrish. A house at Cardington was enlarged for their use, and during the several years that they spent in Cardington two daughters and two sons were born into their household.

After the death of Coleman, in 1834, the sons engaged in general machine work, building, among other things, two locomotives for the state railroad of Pennsylvania and steam engines and other machinery for the branch mints then being established in North Carolina and Georgia. In the depression that followed the panic of 1837, the enterprise failed and the Philadelphia chapters of George Escol Sellers's life were effectively closed.

With his elder brother Charles, George Escol then established in Cincinnati a plant to make lead pipe in continuous lengths from fluid lead. While he remained in Cincinnati, George Escol sold his interest in the lead pipe plant, organized the Globe Rolling Mills and Wire Works, and designed and promoted a grade climbing locomotive [7] that he preferred not to enlarge upon in his recollections.

In 1849, while they were in Cincinnati, George Escol and Rachel adopted Louisa Stockton Peale, the orphaned daughter of Edmond Peale, one of George Escol's many cousins. A last daughter, born to Rachel in 1852, survived only two months. During the ensuing eight years their second son and both daughters died, all three of them around 20 years of age. In the fall of 1860 Rachel died, leaving her husband with but one surviving son and an adopted daughter.

During and after the Civil War, Sellers spent several years in southern Illinois on the banks of the Ohio River, engaged in an abortive scheme to use the pithy swamp canes as paper stock, and pursuing as an avocation the study of Indian mounds in the vicinity of his home. The results of his speculations and experiments

[6] Memoirs, book 1, p. 42.

[7] Obituary in *American Machinist* (March 30, 1899), vol. 22, pp. 250–251. See also George Escol Sellers, *Improvements in Locomotive Engines and Railways* (Cincinnati, 1849) and *Observations on Rail Roads, in the Western and Southern States, and of the Introduction of the Pioneer System, for Their Construction* (Cincinnati, 1850). John H. White, curator of land transportation, Smithsonian Institution, will have a chapter on the Sellers grade-climbing locomotive in his forthcoming work on Cincinnati locomotive builders.

upon the flaking of stone for arrowheads and other instruments were summarized in a publication of the Smithsonian Institution.[8]

Upon his retirement from business, George Escol Sellers, his sister Anna, and his adopted daughter Lui took a house on Missionary Ridge in Chattanooga. There he wrote the series for *American Machinist;* kept up a correspondence with brothers, nephews, and cousins in order to straighten out obscure points and to reinforce his own memory; and wrote hundreds of unpublished pages of reminiscences concerning the very numerous Sellers and Peale clans.

Fascinated by his own memory, George Escol frequently speculated upon the mechanics of a brain's ability to store seemingly unlimited quantities of information. His prodigious memory was a source of wonder even within his own family. To one of his relatives he wrote:[9]

> I remember many little things when I was not over 2 years old. Once at Millbank Aunt Nancy was questioning me and telling me of little things when Mother asked, "What is the earliest thing you do remember?"
>
> "I can't go back of the great snowstorm of Nov. 26th, 1808."
>
> Mother sat a moment thinking when she exclaimed, "Why Escol that was your birthday."
>
> "Yes Mother I did not think it safe to go back of that."

Sister Anna, writing in 1893 to one of the Peales, called attention to brother Escol's article on the early U.S. Mint. "It reads like a story," she wrote. "My brother is an old man to write such long articles," she continued, "but he does it to bring in some money—this time to pay for painting his house outside—or to help towards it . . . . Escol is in his 85 year he does much carpenter work, and gardening yet is very lame in both knees—and gets very tired."[10]

There was more to Escol's writing than the money it brought in. It was his way of communing with the past and with posterity, leaving narratives and notes, in ink and in pencil, "from which some facts may be picked out after I have joined the majority."[11] In 1898 he was keeping a diary, noting daily occurrences, visitors, weather, and the like. He missed not a day throughout the fall, and half way through December. Each allotted space was filled with his easy scrawl up to his entry for Sunday, December 18. He died two weeks later, on January 1, 1899.

---

[8] "Observations on Stone-Chipping," *Annual Report of the Board of Regents of the Smithsonian Institution . . . 1885* (Washington, 1886), pt. 1, pp. 871–891.

[9] Memoirs, undated letter at end of book 2.

[10] Anna Sellers to Albert C. Peale, May 10, 1893 (MSS, Mills collection, American Philosophical Society Library).

[11] Memoirs, book 5, p. 22.

THE FAMILY OF GEORGE ESCOL* SELLERS

A PARTIAL GENEALOGY

Sources: Charles Coleman Sellers, *Charles Willson Peale*, 2 vols. (Philadelphia, 1947), and the following items in the Peale-Sellers papers in the American Philosophical Society Library: Charles Sellers genealogy of the Sellers family (no date, about 1826); George E. Sellers memorandum concerning his family (no date); and George E. Sellers memoirs, 2 vols., typescript.

- John Sellers (1728–?) m. 1749 Ann Gibson
  - Nathan (1751–1830) m. 1779 Elizabeth Coleman
    - Coleman (1781–1834) m. 1805 Sophonisba Peale (1786–1859)
      - Charles (1806–1898) m. 1829
      - GEORGE ESCOL (Nov. 26, 1808–Jan. 1, 1899) m. Mar. 6, 1833 Rachel B. Parrish (?–Sept. 14, 1860)
        - Frederick Harrold (Feb. 26, 1834–after 1900)
        - Eleanor Parrish (Nov. 23, 1835–1855)
        - Lucy (Apr. 3, 1837–Sept. 21, 1860)
        - Charles Henry (Aug. 26, 1838–1858)
        - Anna Frances (May 12, 1852–July 26, 1852)
        - [adopted] Louisa Stockton Peale, daughter of Edmond Peale, about 1849
      - Elizabeth Coleman (1810–?) m. Nov. 27, 1832 Alfred Harrold
      - Harvey Lewis (1813–1892) [dentist]
      - Anna (1824–1908?)
      - Coleman (1827–1907) [prominent engineer]
    - Nathan (?–?)
  - Samuel (1753–?)
  - David (1757–1813)
    - Samuel (?–?)
    - James (?–?)
    - David (?–?)
  - John (1762–?)
  - George (1768–?)

*Eshcol is a Biblical name. In *Genesis* (14: 13) appears an Amorite of that name; in *Numbers* (13: 23) Eshcol is the name of a valley, whence came the grapes of Eshcol.

Mark Twain, in his *Life on the Mississippi* (1883: chapt. 47), tells of his having used Eschol [sic] Sellers in one of his books as a name that he could not imagine ("without stimulants") as belonging to a real person. Shortly thereafter he met Escol, who sued him for libel; whereupon Mark Twain suppressed "an edition of ten million" copies of the book.

Part I

Early Philadelphia Mechanics

Philadelphia's rôle in the formation of the United States during and for a number of years after the Revolutionary War is generally well known. The Continental Congresses, sitting in 1775 and 1776, rallied the Colonies to a common cause, which was eloquently stated in the Declaration of Independence. After the war, the Constitutional Convention successfully wrought the document that gave the new nation direction and unity. Philadelphia was capital of the United States from 1790 to 1800, while the new federal city of Washington was being readied as the seat of government.

From the beginning of the Revolution until the final physical transfer of the national government to Washington in 1800, the great and near-great Americans of the age went about their business in that part of Philadelphia where George Escol Sellers was to grow up. The life in the city was carefully, often vividly, documented because these statesmen and political architects were there.

The picture of Philadelphia after 1800 is much less distinct, however. The city's part in the rapid development of the tools and skills that enabled the United States, within less than a generation, to end its dependence upon England for intricate or heavy machine work has been generally overlooked. Only the merest handful of observers were sufficiently aware of the importance of or had enough interest in technological pursuits to make a record of the mechanicians and their haunts; and those who wrote of the burgeoning industrial complex were generally so occupied with production machines, such as looms, and end products, such as steam engines, that little of their attention could be spared for the machine tools and techniques upon which depended the ability to produce the end products. It is to the task of capturing a record of this most elusive aspect of the city's culture that George Escol Sellers has so successfully addressed himself.[12]

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[12] The student of any aspect of early Philadelphia history should know of "Historic Philadelphia from the Founding until the Early Nineteenth Century," *Transactions of the American Philosophical Society* (1953), vol. 43, pt. 1, which contains 27 original papers and a carefully constructed map by Grant M. Simon showing historic buildings and sites. Each paper is detailed and specific. The collection provides a good survey, although it slights technological developments.

1. Fire Engines and Leather Hose

In the 18-volume American edition of Brewster's *Edinburgh Encyclopaedia*, published in 1832 in Philadelphia, three plates were added to the 400-odd engraved plates of the original work. One of these added plates exhibited the "Hydraulion," as the Sellers and Pennock fire engine was called, and the riveted leather hose whose development is described in this chapter. The plate is reproduced here as figure 8.

Volunteer fire companies, divided by their function into "engine" companies and "hose" companies, were exceedingly numerous when George Escol Sellers was a boy. Rivalry amongst the various companies, always keen, became at times so intense that the business of extinguishing a fire was subordinated to the business of preventing another engine company from getting the first stream on the fire.

Patrick Lyon (1769–1829),[13] a very able mechanician who is known today mainly because of artist John Neagle's vivid life-size painting of Pat at his forge, had been building fire engines and hose carriages since 1794,[14] many years before the Sellers family became involved in their manufacture. Upon returning in 1818 from a sojourn abroad, Pat stated flatly and characteristically, in an advertisement, that his engines (built for cash only) were "far superior to any imported or made here."[15]

Riveted "hose, or leather tubes" and riveted leather mail bags were patented by Abraham L. Pennock and James Sellers on July 6, 1818.[16] The firm of Sellers and Pennock, probably formed about the time of the patents, included George Escol's father Coleman, Coleman's cousins James and Samuel, and Abraham Pennock.[17] The author's later adventures in the Sellers and Pennock shops are recounted in chapter 7.

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[13] Coming to Philadelphia in 1793, after serving an apprenticeship in London, Pat Lyon was at 24 an honest, blunt-spoken man who prospered almost immediately as a skillful craftsman. Before his misfortunes of 1798 he employed four or five journeymen mechanics. In 1798 he was imprisoned and cruelly persecuted for a bank robbery that he was innocent of. Suspected because he had made the doors of the bank's cash vault, he was thrown into the Walnut Street jail in September, where he remained for nearly three months, even after the actual thief had been caught, the money had been returned, and the culprit had disclaimed Pat Lyon as an accomplice. Seven years later, in the Supreme Court of Pennsylvania, he won his suit for false arrest and malicious defamation of character against the mayor of Philadelphia and the bank officers. The verdict brought forth spontaneous cheers from a crowded courtroom. For events leading to and resulting from his incarceration, see PATRICK LYON, *The Narrative of Patrick Lyon* (Philadelphia: 1799); *Robbery of the Bank of Pennsylvania in 1798; and The Trial in the Supreme Court of the State of Pennsylvania* (Philadelphia: 1808) reported from notes by Thomas Lloyd.

[14] J. THOMAS SCHARF AND THOMPSON WESTCOTT, *History of Philadelphia, 1609–1884*, 3 vols. (Philadelphia: 1884), vol. 3, p. 1907.

[15] *Aurora* (Philadelphia), July 2, 1818.

[16] U.S. Patent Office, *List of Patents for Inventions . . . 1790–1847* (Washington, 1847), pp. 223, 298. Both patents were issued on the same day. No specification or restored drawings (restored after Patent Office fire of 1836) exist for these patents in the National Archives, where early patent records are preserved. However, litigation over the patents reached the U.S. Supreme Court. According to George Escol Sellers, the case established an important point regarding disclosure in patent law (*American Machinist*, July 3, 1886, vol. 9, p. 3). For seven references to records of litigation, see *Shepard's Federal Reporter Citations* [*Shepard's Digest*], 1938, vol. 1, p. 2319ff. For an amusing sidelight on the "exorbitantly high" price charged by Pennock and Sellers for riveted hose, see *Message from the President of the United States . . . Concerning the Purchase of Fire Engines, Dec. 13, 1820* (S. Doc. 20, 16th Cong., 2d sess.).

[17] *American Machinist* (July 3, 1886), vol. 9, p. 3.

At the time of these inventions [of riveted leather hose and riveted leather mail bags] I was a boy of about nine years of age, but like most boys of that period of life, I took great delight in running after "the machine" on every alarm of fire, and not unfrequently, at fires, dropping into line to pass the leather fire buckets, of course on the return line of empty ones.

To the present generation, who have become accustomed to our city fire departments with their steam fire engines drawn by horse power to the fires, accompanied by throughly trained and organized men that scientifically attack and conquer conflagrations, it may be interesting to take a retrospective glance at the organization and the performance of private volunteer associations, supported by the public spirit and zeal of their members, with but trifling pecuniary assistance from the public crib. For it is to these organizations with their great emulation and rivalry, and to the intelligent and ingenious men belonging to them, that the invention and introduction of riveted leather hose is due. It is the most important improvement of the times in the mode of extinguishing fires.

At the time I am writing of, Philadelphia had taken the lead of all other cities in America, and I might safely say of Europe, in improved fire apparatus. The old fashioned English Newsham side lever engines were still in use in New York. In Philadelphia they had given place to the more powerful end lever engines on which the men could more directly and effectively apply their force. The general plan of two single acting cylinders, with a center air vessel on the Newsham plan, had not been changed, except by increase in size, the end lever arrangements with their folding arms admitting of an increased number of men to man the engine.

This change in construction was mainly due to Patrick Lyon, a workman of extraordinary skill for the time. . . . The general plan of the long end lever, with the folding arms or handles, was originally suggested by Mr. Adam Eckfeldt, a sound, practical mechanic, and almost a life long chief coiner of the U.S. Mint. At that time he was a member of one of the volunteer fire companies—I think of the Diligent, but of that I am not certain—but it was for that company that Lyon built his first engine of that class.[18] It was substantially the same type of engine as afterwards built by Merrick & Agnew, until the time they were superseded by the steam fire engine.

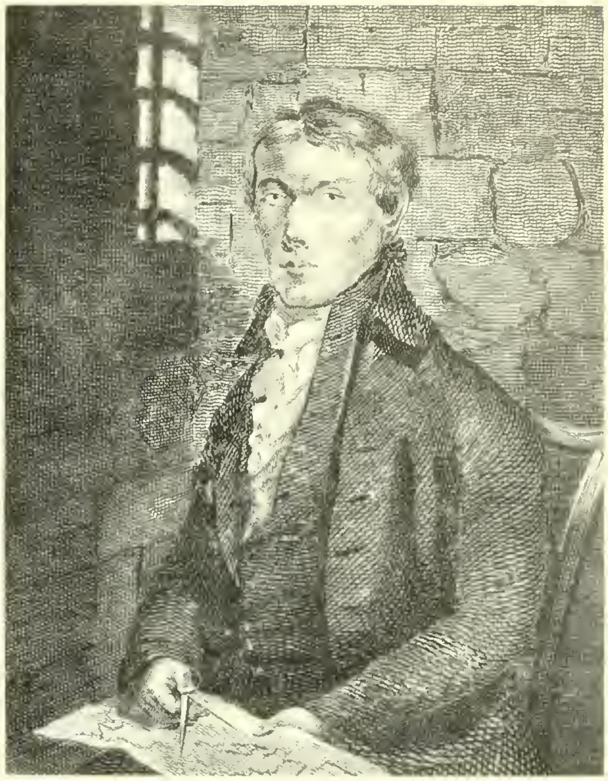

Figure 4.—Patrick Lyon, craftsman, at age 24 in 1799. This portrait is the frontispiece in Lyon's *The Narrative of Patrick Lyon, who suffered three months' severe imprisonment in Philadelphia Gaol; on merely a vague suspicion of being concerned in the robbery of the Bank of Pennsylvania with his remarks thereon* (Philadelphia, 1799). Library of Congress photograph.

[18] Eckfeldt was president of the Good Will Fire Company. The 1820 engine—which probably was not the first that Lyon built for the Diligent Fire Company, south side of Market, near 8th Street—is credited as Lyon's "masterpiece." (Scharf and Westcott, cited in note 14 above, vol. 3, pp. 1894, 1907, 1911.)

Pat Lyon had at his shop a little cubby-hole of an office, warmed by an old wood burning ten plate stove, around which he and his men would congregate of evenings to crack jokes, smoke their pipes and drink their grog. On a shelf in this office was a working model of folding levers with the long, wooden hand handles hinged to studs on crossbars between the side levers, that in an instant could be thrown open, grasped and firmly retained in clasps. They had additional out-riggers that on emergency could be attached, increasing the physical force by some twenty or twenty-four men. Pat never tired of working and exhibiting this model and expatiating on the great value of the arrangement, always attributing it to his friend Adam Eckfeldt.

The fire engine and hose companies were generally separate companies, but worked together. That is, hose companies, although professing to furnish water to the first engine on the ground, managed that their favorite one should be so considered. This often led to severe and sometimes bloody contests. Among these volunteer companies there were distinctive social grades. For instance, the Philadelphia Engine and the Philadelphia Hose Companies, having their houses next to each other, were worthy of the Quaker element. They were rich companies, and indulged in the finest kind of apparatus regardless of cost. Their great oilcloth coats and capes, and broad-brimmed japanned hats, were a peculiar and distinctive uniform. The Resolution Hose Company, a near neighbor, was mostly of the French element—sons, junior partners, and clerks of the large French importing firms.[19] All their equipments were the pink of perfection. The Phoenix Hose was another of the aristocratic companies, and had many of the younger generation of Quakers in its organization. The Diligent, the Assistant and others of the city proper companies were composed of solid men of the city.

The position of foreman of the companies was highly prized, as was also that of pipe men to the engine companies. Two of them on the gallery of the engine would direct the pipe to throw the stream of water onto the roof or through doors and windows of burning buildings—much of it to be dissipated in vapor without reaching the burning mass, and doing but little effectively towards extinguishing the fire.

The companies in the Liberties, or outside of the city, as then incorporated, had not the wealth to lavish on fine apparatus and show but what they lacked in wealth they made up with vim and zeal rarely equalled and never excelled. This produced a rivalry that frequently led to rather serious results.

Franklin Peale, at that time the manager of the Philadelphia Museum,[20] that had its home in the old State House or Independence Hall, arranged a system of bell signals to indicate the direction of a fire from the State House—one stroke on the great bell, repeated at intervals, for north; two strokes with regular intervals, for the south; and so on for the cardinal points and intermediates.[21] On an alarm of fire being carried to the State House, the great bell would call out the entire fire organizations. Then came the great rush, the madding races, the ringing of the bells on the engine and hose carriages, the bellowing "Fire" through speaking trumpets that every fireman was armed with; it was pandemonium broken loose.

The heavy fire engines or hose carriages, with their 1,000 or 1,200 feet of hose, were like a feather's weight to the string of men and boys who manned their long drag ropes. It was the fouling of the engines or carriages in these furious races—contests for possession of the nearest fire-plug or hydrant—that led to the most disastrous conflicts, in which costly apparatus was damaged, hose spanners and speaking trumpets playing a conspicuous part, as many a scalp wound could testify.

Philip Garrett, a prominent watchmaker and jeweler,[22] a member of the Society of Friends, was the foreman of the Philadelphia Fire Engine Company. He was in his element when fighting fires. I well remember that he was admitted by every one to be the *par excellence* of city firemen.

Often as a boy have I listened with great interest to conversations between him and my father as to the most effective mode of extinguishing fires. One point they were certainly agreed on; that was that by water the fuel or combustible matter and not the

[19] Confirmed in Scharf and Westcott, vol. 3, p. 1898.

[20] Franklin Peale was employed in the museum from 1822 to 1833 (Charles Coleman Sellers, *Charles Willson Peale*, 2 vols., Philadelphia, American Philosophical Society, 1947, vol. 2, pp. 345, 382).

[21] The bell signals for fire are given in "Regulations of the State House Bell in case of Fire," *Desilver's Philadelphia Directory . . . for 1829*.

[22] Later, but at least as early as 1832, builder of steam engines, small lathes, etc., and from 1835 to his retirement in 1840 partner of Garrett, Eastwick, and Harrison, locomotive builders (Scharf and Westcott, cited in note 14 above, vol. 3, p. 2258; Joseph Harrison, Jr., *The Iron Worker and King Solomon, with a Memoir and an Appendix*, 2d ed., Philadelphia, 1869, p. 119).

FIGURE 5.—"Pat Lyon at the Forge," by John Neagle, 1829. This life-size painting, owned by The Pennsylvania Academy of Fine Arts, is the artist's copy of his original painting of 1826. Photo courtesy of The Pennsylvania Academy of the Fine Arts.

flame must be attacked. My father was never an active member of any fire company, though his name stood on the rolls of several as an honorary member. I think these were companies he had built engines for.

Simple as the question is, as it now appears to us, of applying the water through a hose directly to the burning fuel, it was at that time the great stumbling-block. Hose companies suffered so much from the ripping of seams, or bursting of hose as it was called, when subjected to the force and pressure of the fire engine pumps that they refused to allow it to be used in that way. This led to the invention of what for many years was known as the "Hydraulion," a combination fire engine and hose carriage in one, and was designed by my father,[23] the Philadelphia Hose Company being the first to adopt it, and the "Phoenix" the next to follow. A large number of a smaller class of these were built for country towns and smaller cities, Richmond, Va., Washington, D.C., and Providence, R.I., taking the largest class.

The water supply of Philadelphia, in case of fires, was very deficient, the main supply being from the small reservoir [24] in the dome of the pump house in Centre Square (the present site of the new public buildings of Philadelphia). It was conducted through bored wooden logs of such small capacity that in case of fire citizens having hydrants were requested not to use them. Every block where the system extended was provided with a fire plug or hydrant, so poorly constructed that notwithstanding straw wrapping and wooden curbs they were apt to be frozen, and useless in cold spells; besides these fire plugs each square had a small wooden cistern sunk under the pavement, with a wooden hand pump for public use. These cisterns were kept full by a hollow copper floating ball, that opened or closed a common stop cock. Many of the old public wells had not been closed; their pumps were always of service.

The hook and ladder companies ran with them a fire-bucket carriage; some of the engine companies also had their bucket carriage. All public buildings and halls, as well as many entries of private residences, had their suspended rows of fire buckets. These were made of leather, stitched as hose was, stiffened by "jacking," or saturated with a mixture of resin and wax over a charcoal fire. They were fancifully painted with the names of the institutions or parties they belonged to, and they played an active part in supplying water to the fire engines. It was not an uncommon occurrence to see lines of bucket-passers of men and boys, and often women, slinging from hand to hand buckets of water from pumps as much as two blocks from the fire engine.

To understand the difficulties attending the use of sewed leather hose under heavy pressure, we must look at the manner of its construction. There were two plans. One was simply lapping one edge of the leather over the other, as is now done in the case of riveted hose, and sewing two lines of stitches from inside to out. The objection to this was serious. In dragging the hose when in use over the cobble stones of the street the outside stitches would soon wear off and the hose would rip. The plan generally adopted by the Philadelphia hose companies was to double or fold the leather so it would lay flat together, insert a strip of soft leather between, like a shoe welt, trim the edges straight, sew two rows of stitches through the leather and welt strip, exactly as harness traces are sewed. When the hose was opened this would present a ridge or rib from end to end, with the stitches protected from wear when dragging. The strain of head pressure was brought lengthways of the stitches as they passed through the leather. The soft leather strip was left to project slightly inside the hose, which, when wet and opened, was beat into the seam, tending to make it tight.

New hose when first made would stand the required pressure, but the hemp stitches would soon lose their strength. The dubbing of train or neatsfoot oil and tallow, which used to render the leather impervious to water and keep it soft and pliable, had the effect of destroying by a kind of rot the hemp stitching, so that its lifetime was very short. The stitches would give way while the leather remained in good condition. A stronger union than hemp stitches was not only desirable but was an imperative necessity, and

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[23] According to SCHARF AND WESTCOTT (vol. 3, p. 1896), the *Hydraulion* was built in 1814 by James Sellers. The *Journal of the Franklin Institute* (May 1827), vol. 3, pp. 286–287, credits William P. Morris, member of Philadelphia Hose, for the idea and James Sellers for the design of the *Hydraulion*.

[24] According to Latrobe, 7,500 gallons, which in 1803 supplied normal city demand for only 25 minutes, but which could be refilled in 6 minutes ("Manuscript Communications to A.P.S., Mechanics, Machinery, etc., no. 25, B. H. Latrobe Report on Steam Engines in U.S., read May 27, 1803," in American Philosophical Society Library). Latrobe's report was published in *Transactions of the American Philosophical Society* (1809), vol. 6, pp. 89–98, but this passage was struck out before the manuscript reached the printer. A capacity of 22,500 gallons was given in *Report of the Committee Appointed by the Common Council to Enquire into the State of the Water Works* (Philadelphia: 1802), p. 48, a copy of which is in Franklin Institute Library.

FIGURE 6.—Philadelphia-type fire engines of about 1800, displayed in Independence Hall group. The machine in the foreground is signed by Lyon, and the one in the background is of the same period. Detailed similarities suggest either that Lyon built the second one also or that he supplied the blacksmith-work for it. National Park Service photograph.

more minds than one were working at it. About this time there occurred a great fire in the heart of the city that spread with fearful rapidity and mastered all efforts of the firemen.

I was standing with my father on the curb looking at the fire, when Philip Garrett rushed up in a great state of excitement, seized my father by his arm, and said: "Coleman, if thee can dam the stairways and hatchways of the upper floors of those two warehouses (pointing), and I can get a foot of water on the floors, we çan stop the fire at that fire wall, but if we let it work down the walls will fall, and the whole block will go, and there is no knowing how much more." My father turned me over to some one to see me safe home, and left with Mr. Garrett. I learned afterward that my father, with board partitions that he tore down, succeeded with them and gunny bags in damming both stair and hatchways, making small crevices tight by having large quantities of bran thrown on the floors. The roofs were on fire and would soon fall in. Lines were formed for carrying up water by the bucketfull.

Instead of going home as directed, I for hours had my place in the empty bucket line. While this was going on Garrett was having section after section of hose attached to both the Philadelphia and the Diligent engines, only to burst before the water reached the upper floors. Fortunately the Resolution Company had a number of new sections of hose which were pressed into the service, and were attached next the engines where the pressure would be greatest. The floors were flooded, the attics and roofs fell into the water, and spreading fire was stayed. The success of this expedient was so complete that it turned the attention of all firemen in the direction of securing more reliable hose. . . .[1] [25]

At the time I am writing of the old firm of N. & D. Sellers, that dated back to the Revolutionary War, was carried on under the same name by my father, son of Nathan, and his two cousins Samuel and James, sons of David. James was an active member of the Philadelphia Hose Company, and was much interested in experimenting to find a substitute for the hemp or flax thread for sewing hose, not subject to their decay, and that would not be injured by the dubbing and have a lifetime at least equal to that of the leather.

He made a short section of hose sewed with annealed copper wire with a double row of stitching. To have the wire sufficiently pliable to draw the leather close and make a tight seam he was obliged to use a wire considerably thinner than the hemp or flax thread, and owing to the difficulty in inserting the wire in the punctured holes they were made larger, and the leather did not close tightly on the wire, which lacked the swelling property of the thread stitches which had aided greatly in closing the holes. This section was tried fully up to the required pressure, but not without considerable steeping through the stitch holes; at an increased pressure the thin wire cut the leather and the leakage increased. Yet the experiment was considered so far a success that the hose company agreed to bear the expense of further experiments, and Mr. J. Morris and Abraham L. Pennock were appointed a committee with James Sellers to assist him in prosecuting the experiments. Many were tried to render the wire-sewed seams more pliable and to stop the cutting and steepage, but unsuccessfully.

The next experiment was by nailing; this at first promised well. A workman, named Andrew Linkfelter, was in the employ of the firm [N. & D. Sellers], whose business for many years had been driving tacks in putting together hoops or rims of meal and grain sieves, and who prided himself on being able to so drive a large headed wrought tack, then called a "clout nail," so as to insure a certain and perfect clinch always in the same direction. To him was given the job of putting together the first sections of nailed hose. This was done by lapping one edge of the leather over the other as it is now done with the riveted hose, and driving two rows of clout tacks, clinching them on an iron mandrel. Several sections of 50 feet each of hose were so made, and subjected to very severe tests, showing no signs of yielding, but in after tests the clinches began to give way, and finally the seams ripped. This was mainly owing to the swelling of the leather when wet and shrinkage on drying tending to strain and loosen the clinch.

The next experiment was driving one row of tacks near the outer edge of the leather as it lapped over, clinching them on the iron mandrel as in the previous case; then a row of holes was pierced near the edge of the inner lap and the tack inserted from the inside with its head resting on the mandrel. The leather was then driven down around the tack by a hollow punch; a row of about a foot in length of these tacks being so arranged with their points exposed, they were turned by a pair of round-nose pliers, clinched and driven home by light hand hammer. This stood the tests well, but it was a tedious and costly process.

My recollection is that during all these experiments James Sellers devoted his whole time and attention to them. Mr. Pennock was almost daily at the shop for a short time, and Mr. Morris only occasionally. I recollect one day when all were present. My father asked if it would not be possible and better to put another head on the tack instead of clinching it. The next move that I remember was seeing my cousin James casting a hard pewter composed of tin, lead and copper into a single rivet or washer at a time in molds similar to the single mold used for casting rifle bullets. In this way the rivets and washers were made for the first section of riveted hose.

The next advance was in making long brass molds in which 15 or 20 rivets or washers in a row were cast at a single pouring. They were afterwards cut from

[25] Bracketed numbers refer to sources of text material for the preceding section. List of sources is given on p. 193.

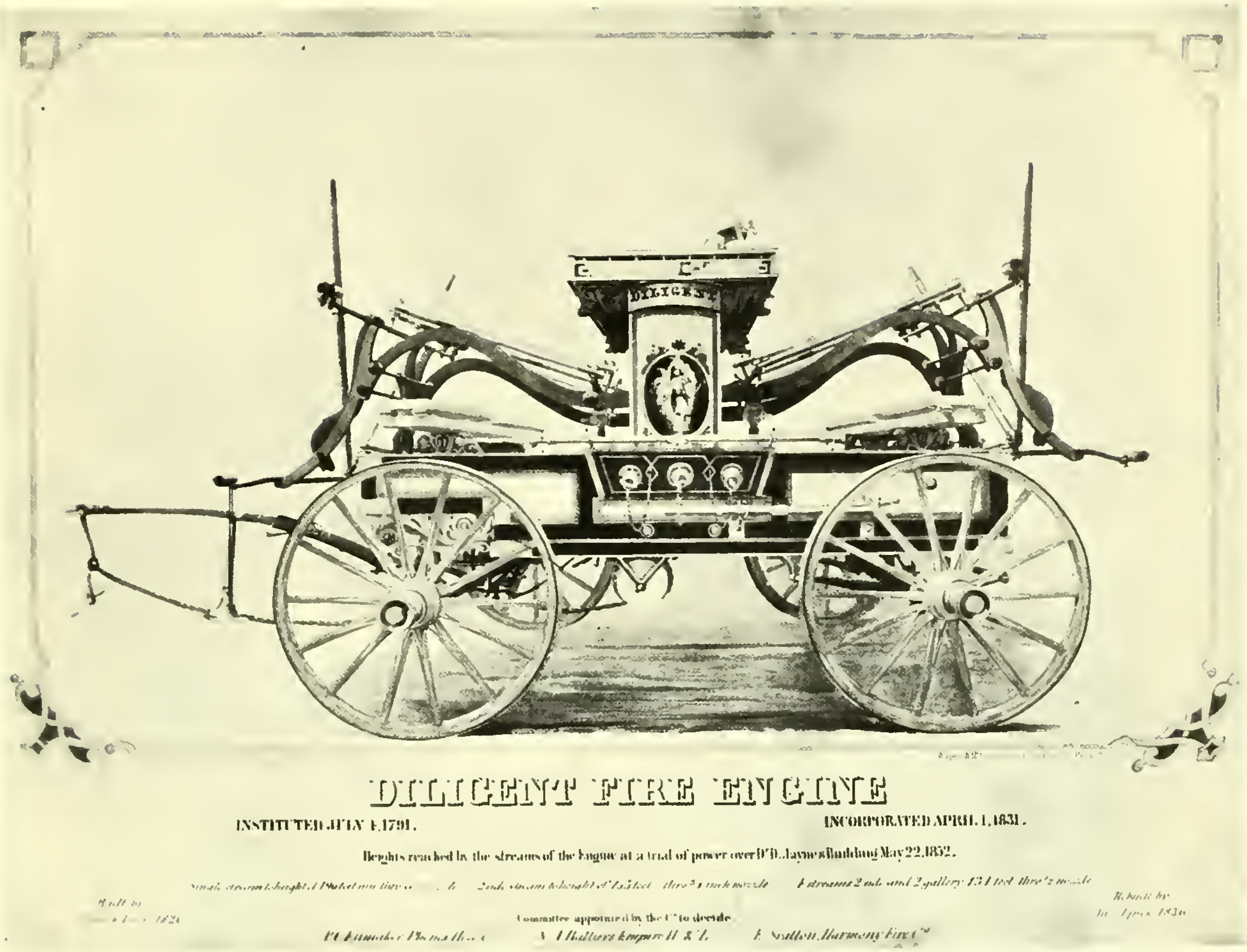

FIGURE 7.—Patrick Lyon's *Diligent*, 1820, as rebuilt by John Agnew in 1836. Lyon's engines employed vertical plunger pumps, located close to the central pivot of the levers. Lithograph published in 1852; photo courtesy of The H. V. Smith Museum of the Home Insurance Company, New York.

the gates with common hand nippers. A long series of experiments were tried to get a fusible metal hard enough to stand the wear of dragging the hose over the stone pavements, and yet not too hard and brittle to rivet well. The first cast rivets were very badly proportioned, the heads being 9/16 inch diameter and 1/16 inch thick; the shanks of the rivets a diameter equal to No. 6 Birmingham wire gauge [less than 1/4 inch], the washers the same diameter and thickness as the rivet heads. As to the length of time that these cast rivets and washers were used I am uncertain. My elder brother and myself of evenings and holidays cast and clipped from the gates many hundred-weight of them.

Next in order came copper rivets and washers. These rivets were headed by hand. No. 8 copper wire was cut into lengths by a machine turned by hand crank, then headed in half dies closed by a lever pressing together spring jaws that carried the dies. This lever was operated by a foot treadle (the old English wrought nail header) and the head was struck by two regulated blows of a four-pound flat-faced hand hammer.

The sheet copper for washers was cut into strips of a width that would admit of four or six washers being cut from them; this was fed by hand under two punches, a small one to punch the center rivet hole, the large one that followed to punch out the

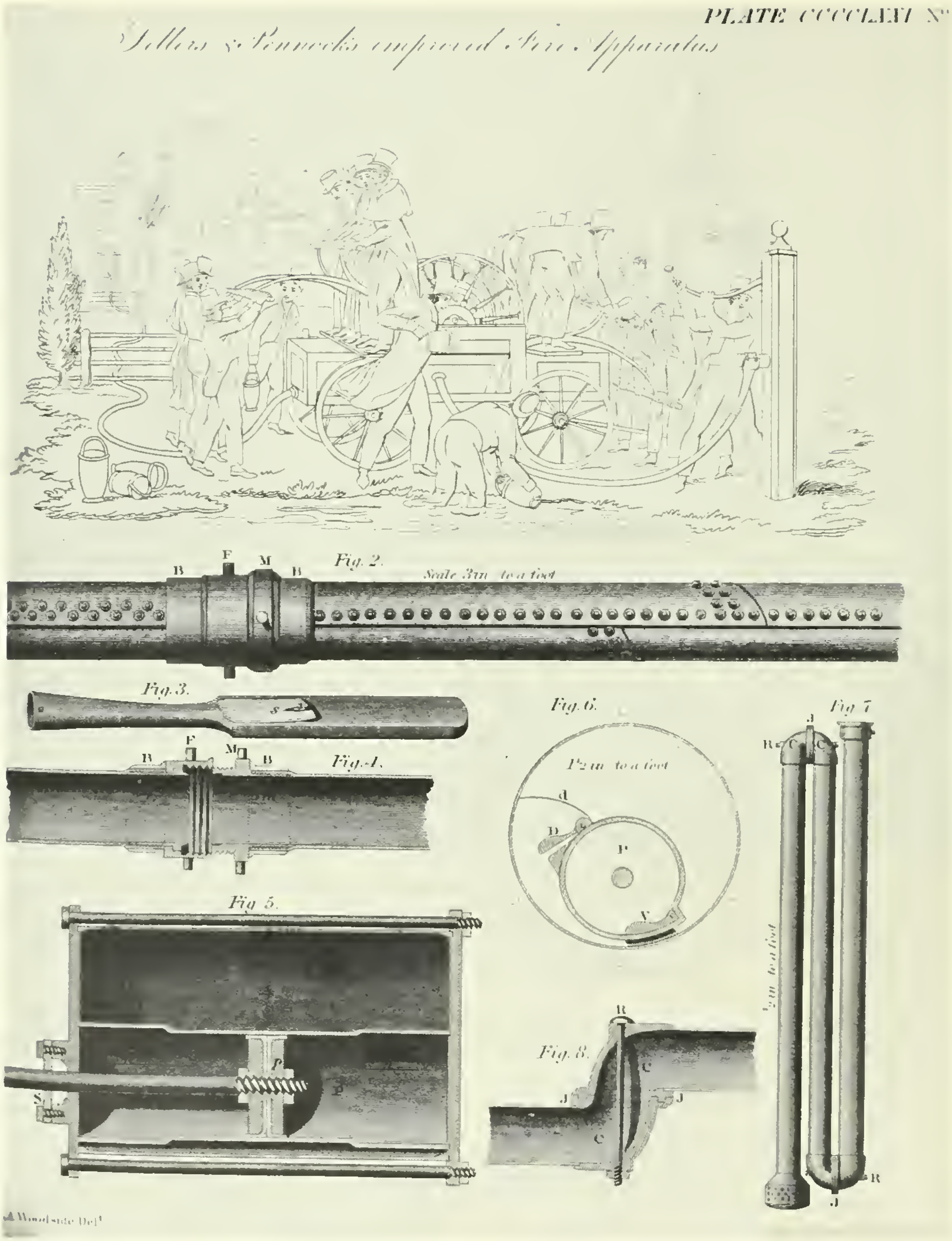

FIGURE 8.—"Hydraulion" fire engine and hose, about 1825. This engine, combining pump and hose reel, was "particularly suited for villages." "Fig. 2," riveted leather hose; "Fig. 3," rivet holder and back-up anvil for riveting hose (the anvil is attached to a wooden pole for insertion in the hose); "Fig. 4," brass couplings; "Fig. 5," longitudinal section of the horizontal pumps (piston was 7 inches in diameter and had a 9-inch stroke); "Fig. 6," a transverse section showing the inlet valve (v) on the lower side and discharge valve (D) on the upper side of the pump cylinder. "Fig. 7" and "Fig. 8," swiveling hose pipe for connection to water supply cistern. From *Edinburgh Encyclopaedia*, 1st American ed. (Philadelphia, 1832), vol. 16.

washer. The hand feed was against a stop precisely as the planchets or disks for coins are cut in the U.S. Mint. When for economy tinned iron rivets and washers came into use the same manner of cutting the wire and heading by hand was continued for years before a cutting and heading machine was invented and adopted, but for punching out the washers and using full size sheets of copper or iron my father invented and constructed a machine that left the sheets, from which the washers were cut, in a useful form for screens, or for covering cellar windows instead of woven wire, and for various other uses.

This machine, without any alteration as to plan, continues in use to the present time. It is also used for perforating sheet iron or steel for coal screens and for floors of malt kilns.

A wooden straight-edge; a shoemaker's leather knife; a rocker or templet, with points to mark the places where holes for the rivets were to be punched by a hollow leather punch; a hollow set punch to drive the washer home and to bring the leather in close contact were used. This set punch was made like a hammer, with an iron handle with a broad, flattened end; the face of the hammer portion, drilled out to go over the rivet, was faced with steel; the end on which the blow was struck, soft iron. When this set punch was grasped by the handle in the left hand, a turn of the wrist, after the washer was driven home, would bring the edge of the flat end of the handle on to the washer, and hold it down while the riveting blows were being struck.

A set punch, to round and finish the riveting; a riveting hammer, an iron mandrel to rivet on, were the entire outfit of tools when the first riveted hose was made. But soon labor-saving machinery had to be invented. First in this order came a ratchet arrangement to feed the strips of copper under the washer punches, instead of the hand feed. This soon led to the machine that I have above alluded to, in which whole sheets of planished copper, 30 by 60 inches, the size then imported, and iron sheets of much greater length, utilized what before was waste.

Before the machine was invented for cutting the wire into lengths, and by a plunger driven by cam and toggle, upsetting the head forming the rivet (the germ of all rivet and blank headers for wood screws of the present day), samples of hand-made copper rivets and washers were usually sent to England, and a large invoice imported from Birmingham. The washers were well enough, but the rivets were so rough and irregular in size as to be useless for riveting either hose or mail pouches, and they found their way to the brass founder's crucible.

Screw stretching frames to take the wind out of the sides of sole leather, after they were skirted, and before the hose strips were cut, that the hose in use would keep straight; machines for cutting and trimming, beveling and tapering the ends where the strips of leather were to be spliced together, and simultaneously punching the double row of holes for the spliced rivets; a machine through which the spliced strips of leather were fed, the rivet holes automatically laid out and punched; all these inventions were but the natural sequence of the invention of riveted hose, or leather water tubes, as it was called by our English progenitors . . . . [2]

2. Jacob Perkins in Philadelphia

Even a casual inspection of a list of his patents—21 in the United States, 19 in England, with only a few common to both countries—will convince a reader that Jacob Perkins's head fairly rattled with ideas.[26] Many of the ideas were good ones, but because he was forever developing new ideas and improvements on old ones, he never quite got around to demonstrating, in his impecunious lifetime, that some of them were economically sound.

When he came to Philadelphia to live, in 1815, Jacob Perkins was already in his 50th year. His inventions at this time ranged from nail cutting and heading machines to plunger pumps for freeing ships of water, and included a series on the engraving of banknotes so as to prevent forgery. There were two inventions for fire engines. Still in the future lay his abortive high pressure steam boilers, his fearsome steam gun, and his entirely sound vapor-compression refrigeration cycle; and still in the future lay his passage to London and his development there of the lively mechanical sideshows of his Adelaide Gallery.

As Sellers relates in this chapter, Perkins took as first partner in his fire engine venture Coleman Sellers, George Escol's father. The partnership was dissolved before the end of June 1818 when Perkins and Jones [27] commenced advertising their fire engines at prices ranging from $250 to $1,000.[28] This partnership was dissolved in turn within eight months, being succeeded by the firm of Perkins and Bacon. Bacon was a son-in-law of Perkins.[29]

Commodore Alexander Murray (1754–1821), Perkins's particular foil in the episodes that follow, was commandant of the Philadelphia Navy Yard from 1813 to 1821.[30]

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[26] The standard work on Perkins is by Greville Bathe and Dorothy Bathe, *Jacob Perkins* (Philadelphia: Historical Society of Pennsylvania, 1943), which is a compilation of pertinent data and many illustrations. The Sellers reminiscenses apparently were unknown even to the Bathes, whose searches were most diligent and far-ranging.

[27] Thomas P. Jones (1774–1848), lecturer at Franklin Institute, editor of the *Journal of the Franklin Institute* from its origin in 1826 until his death, Commissioner of Patents, 1828–1829, and one of the first patent examiners under the Patent Act of 1836 (Henry Butler Allen, "The Franklin Institute of the State of Pennsylvania," *Transactions of the American Philosophical Society*, 1953, vol. 43, pt. 1, pp. 275–279; "Outline of the History of the United States Patent Office," *Journal of the Patent Office Society*, centennial number, July 1936, vol. 18, p. 87.

[28] *Aurora* (Philadelphia), July 4, 1818.

[29] Bathe and Bathe (cited in note 26 above), pp. 69, 75.

[30] In a curious error, Sellers referred throughout this chapter to Commodore Barron rather than to Commodore Murray. Alexander Murray was commandant in 1813–1821; James Barron was commandant in 1824–1825 and again in 1831–1837. Barron was not in the United States during most of Perkins's time of residence in Philadelphia, which was from December 1815 to May 31, 1819, and he was not on active duty until 1824. See Paul Barron Watson, *The Tragic Career of Commodore James Barron, U.S. Navy (1769–1851)* (New York: Coward-McCann, 1942), pp. 81, 84; "A Brief History of the Philadelphia Navy Yard," unpublished typescript in Naval Records Section of the National Archives; and Bathe and Bathe (cited in note 26 above), pp. 59, 76. I have changed the text to read "Murray" throughout, being convinced that he was the man involved. Barron also was something of an inventor. A floating drydock of his is illustrated in *Journal of the Franklin Institute* (1827), vol. 3, p. 87ff.

My earliest recollection of Jacob Perkins was as associated with Murray, Fairman, Draper, Underwood, etc., as bank-note engravers. I think my father's acquaintance dated back of that, as I have heard him relate having been summoned as an expert in a suit for infringement of Perkins' tack machine for cutting and heading tacks in one operation, the ground of the defense being so imperfect a specification that no one could construct a machine from it.

After my father had answered that he had neither seen the machine nor read the specification, the latter was handed to him. After he had carefully read it, he was asked if he could construct a machine from it. His answer was, "Yes."

He was then asked to explain how he would proceed to do so. The deficiency in the specification was the want of describing the mode of transferring the cut tack to the heading tool. When my father came to that part, he went on describing how he should construct it, and its operation. When asked if he found that portion in the specification, his answer was, "No; but it would naturally suggest itself to any mechanic as the simplest mode; in fact there were only two ways of accomplishing it." He then described the other mode that would answer the purpose, but it was not so simple and effective.

Two machines then in the court were uncovered in which both plans had been adopted—the first described in the original Perkins' machine, the other in the infringing one. This testimony decided the sufficiency of the specification, and the Perkins company gained their suit. I think this was previous to Perkins coming to Philadelphia, and that an intimacy was at that time established.

Perkins had perfected the most important work or invention of his life—the annealing of cast steel, so as to substitute it for copperplate engraving, and rehardening the plates, transferring to soft steel rollers or dies, from which, after hardening, plates could be multiplied. This manipulation, together with the beautiful scroll-work of Spencer's ingenious geometrical lathe or rose engine, became, and still continues, one of the most important features of our American banknotes. [3]

Figure 9.—Jacob Perkins (1766–1849). From *Appleton's Dictionary of Machines, Mechanics, Engine-work and Engineering*, 2 vols. (New York, 1867).

Perkins prepared the plates and the firm of Murray, Draper, Fairman & Co. did the engraving, with Spencer doing the lathe work.[31]

[31] Bathe and Bathe (cited in note 26 above), p. 73n, give a very brief sketch of Asa Spencer (d. 1847). The Spencer geometric lathe is described and illustrated in British patent 4400, October 11, 1819, taken out under the name of Jacob Perkins. Lathe drawings are on sheets 1 and 2 of 6. A description of the machine and an example of the work produced by Spencer's lathe are in *Journal of the Franklin Institute* (1826), vol. 2, pp. 106–108 and plate. Short notices of George Murray and Gideon Fairman are in Scharf and Westcott (cited in note 14 above), vol. 2, pp. 1057–1058.

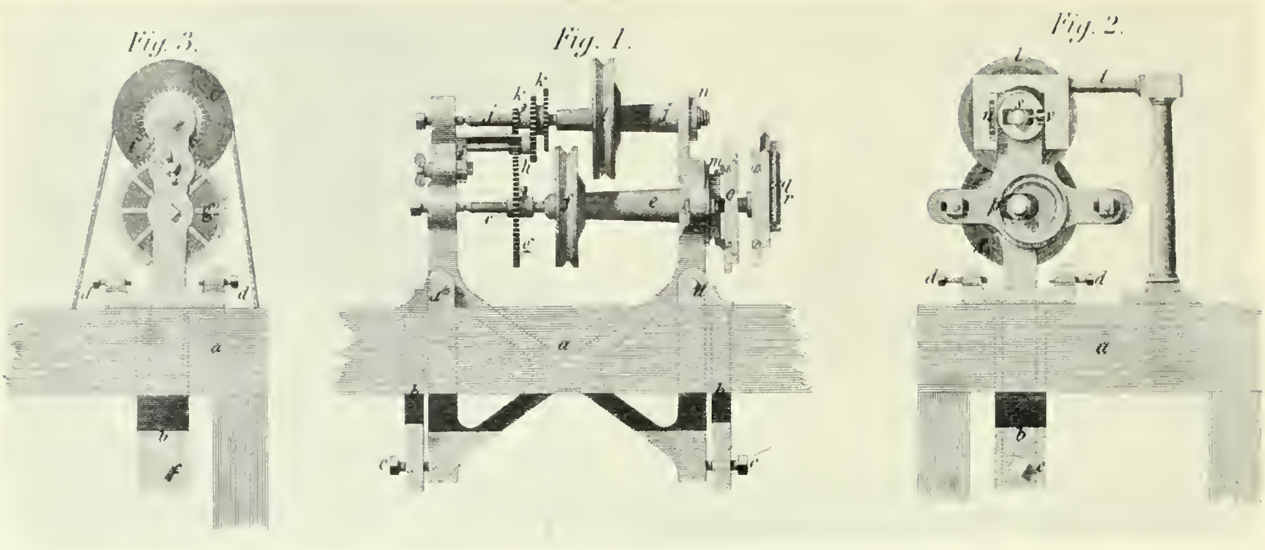

FIGURE 10.—Asa Spencer's "engine lathe for engraving oval or geometrical figures upon metal or other surfaces." "Fig. 1," elevation of swinging headstock, pivoted at *c*, *c*, with "oval chuck formed as usual" at right end; "Fig. 2," end view, with oval chuck removed (the adjustable cam *S* and follower—attached to arm *t*—are shown only in this view); "Fig. 3," rear end view. Tool carriage is not shown. From *London Journal of Arts and Sciences* (1820), ser. 1, vol. 1.

The steel plates were annealed in contact with oxide of iron in close retorts until soft enough to be engraved with the ease of copper plates, then they were recarbonized and hardened. I was too young at the time to fully understand the philosophy of the operation, but not too young to watch with great interest Mr. Perkins' manipulation. The care he took to have the water rapidly pass over his plates to carry off the heat forcibly impressed me.

He had small steel cylinders that he used in transferring the engravings. His mode of handling these in hardening them was very interesting to me. He heated them in what he called mufflers closely packed in with carbon which was made of wood charcoal, and about an equal portion of a coal made of leather scraps that he burned in crucibles. I have a clear recollection of what he called his muffler furnace and also of the mufflers themselves as I have carried them to him from Miller's pottery on Filbert Street to our shop. They were tubes flattened on one side ⌓ made of fire brick clay and about ½ inch thick. They were long enough to reach from side to side of his furnace over a charcoal fire made on a grate, charcoal being added from time to time so that the fire surrounded the mufflers.

It was a long heating process and to my boyish question of why he did not heat them in the open fire, his reply was that they would be ruined by scale if the air was not entirely excluded, and to the question as to why he was so long about it and so careful in watching the fire, he said it was necessary as a part of the hardening process.

I do not think the wood and leather coal dust were all he used in packing his cylinders in the mufflers, but I collected the leather scraps for him and when burned pounded them together with the wood coal in a great iron mortar. When Perkins was satisfied his cylinders were in condition for their cold bath, if from any cause they refused to be pushed from the muffler he never hesitated to break the muffle, seize the cylinder with heated tongs and plunge it into a gushing stream from a hydrant.

The hardening of steel by a quick running stream of water or by jets was a frequent subject of discussion between Father, Perkins, and visitors to the shops, to which I have listened with great interest and attention. Among the most frequent visitors that I remember taking an interest in the subject were Isaiah Lukens, Rufus Tyler and his partner Mason, Matthias Baldwin, Dr. Thomas P. Jones, Dr. Mease, but most frequently old Prof. Robert Patterson who at that time was director of the U.S. Mint and Adam Eckfeldt the chief coiner, who were almost daily visitors.[32]

. . . . It was the result of these early demonstrations [33] that so fixed on my mind the importance of quickly moving water or strong jets to rapidly carry off the heat that all of my after practice was based on it in some form or other. It was a common practice with Lukens and Mason and Tyler. I have a distinct recollection of seeing Lukens harden a pair of small steel rolls he had made for Charles Willson Peale to roll the gold plates for the artificial teeth he was then making. These rolls were less than 3 inches in diameter and about 4 inches on the face. He heated them with a charcoal fire in a muffle furnace, he placed them in V bearings under a hydrant jet and with one hand he regulated the jet and the other rotated the roll. [4]

While Perkins was engaged in the banknote engraving business in Philadelphia, he exhibited to my father drawings of his single-chamber fire-engine, with combined plunger and piston, the plunger filling just one-half the area or space of the chamber.[34] As the piston rises, the water, flowing in, fills the entire space of the chamber below it. On being depressed, the lower valve closing, all the water passes through valves in the piston, and, as the plunger fills just half the space, one-half the water is ejected from the nozzle, equal amounts being ejected on both rising and descending strokes. In its simplicity of construction, as arranged by Mr. Perkins, lay all its merits. He estimated that it could be constructed at a cost of fully 25 percent less than the common double-chamber engine. The plunger, the chamber, the surrounding cylinder that carried the water from its escape holes in the top of the chamber to the bottom of the surrounding air vessel, and the air vessel itself, were all to be made of *drawn copper tubes* or cylinders, and clamped between brass bottom and headplates by outside bolts, the same elongated bolts securing it to the bottom of the wooden engine-box or tub; he also showed the plan of a machine he had devised, and fully tested, for drawing, or rather forcing, these copper tubes or cylinders through dies.

At that time, owing to the smallness of the mains—in fact, all the street pipes were disproportionate to the number of hydrants—the city was very inadequately supplied with water. Good housewives, at night, when the hydrants would run, filled their tubs and buckets for the next day's supply. Almost every square had its street cistern and pump, around which, of evenings, hosts of men, women, and children would collect, waiting their turn to fill their buckets or garden watering-pots (Philadelphia was always a city of grass plats and small gardens); and Mr. Perkins argued that a cheap garden engine, that could be run to these cistern pumps like a wheel barrow, would have rapid sale. He planned an oval upright tub on two wheels, with wheelbarrow handles and legs, with one of his small single-chamber pumps in it. To build these and small village fire engines, my father joined him under the firm name of Perkins & Sellers. They located their works at the head of St. James', a little court or street that ran east from Seventh above Market Street. This was the germ

[32] Baldwin, Jones, Mease, and Patterson (father and son) are noticed in *Dictionary of American Biography*. William Mason, engraver in brass, etc. (1820) and philosophical instrument maker and engineer (1825), formed a partnership with Matthias Baldwin in 1825; they made book binder's tools and calico printing cylinders (Scharf and Westcott, cited in note 14 above, vol. 3, p. 2255). Rufus Tyler, machinist (1825), was partner of Mason through April 1827. Mason and Tyler were die sinkers and makers of "machines in general, particularly where great accuracy and excellence of workmanship are required; such as Rose-engines; Sliding-rests; fine Turning-lathes; Lever, Screw, and Drop-presses; calico engraving machines; machines for engraving and stamping Bank note dies, &c, &c." (*Journal of the Franklin Institute*, 1827, vol. 3, advertisement by firm of Mason and Tyler on back cover of each issue through April 1827; starting in May 1827, the advertisements appear under the name of Tyler only.) Lukens and Eckfeldt appear again in later chapters.

[33] The omitted passage (1500 words) just preceding this note described Perkins's demonstration of the varying effects of water in small and large quantities upon a very hot surface—say 1200° F. This was by way of preparation for a demonstration of Blind Hawkins's high pressure steam generator, mentioned in the next chapter.

[34] No records exist in the National Archives of Perkins's fire engine patents of August 6, 1812, and March 23, 1813, listed in U.S. Patent Office, *List of Patents . . . 1790–1847*, pp. 221, 224. However, a description and cut are in John Nicholson, *The Operative Mechanic and British Machinist*, 2d American ed. from 3d London ed. (Philadelphia: 1831), vol. 1, p. 284.

from which sprang more important works. I will, *en passant*, state that on my father's retirement his place was taken by Dr. Thomas P. Jones, who afterward became Commissioner of Patents, if I recollect right, succeeding Col. Thornton. [5]

The gateway from the Mulberry Court yard into the yard of the fire engine shops was still free to us boys and we made use of it nearly as often as when Father was there. As a boy I was on most intimate terms with Dr. Jones for about that time he frequently took the place of my Uncle Rubens Peale in the popular experimental lectures he was delivering in Peale's Museum in the State House. On these occasions I was always called on as Dr. Jones's assistant. I turned the crank handle of the electrical machine, handed him magic lantern slides, washed chemical glasses, bottles, and such like. [6]

The business for a short time was conducted under the name of Perkins & Jones, when Perkins decided on going to England. Samuel V. Merrick, at that time a dry goods merchant, bought his interest, as well as that of Dr. Jones, and associated with him a Mr. Agnew, under the firm name of Merrick & Agnew, so long and well known as successful fire engine builders.[35]

It was in these shops, during Mr. Perkins's connection with them, that I learned the peculiar traits of this remarkable man, and which I can no better exemplify than by relating some incidents that therein occurred . . . .

Perkins's original idea, as carried out, was to build a large number of these garden engines before offering them for sale. For this purpose, shops for carpenters, wheelwrights, blacksmiths, finishing, and setting up were started, and as the engines were finished they were stored away, and when first offered the novelty as playthings for the boys caused a rapid sale for a short time; but it was a case where

> "The best laid schemes o' mice an' men
> Gang aft a-gley."

For, while these engines were building, the city authorities were relaying their water mains and pipes with cast iron of full capacity, and a screw nozzle to the hydrant and a garden hose became the successful rival of the Perkins' garden engine, and a large portion of the stock on hand had to find a slow sale in suburban villages or country seats.

The Perkins machine for drawing the copper tubes was simple, crude and ingenious. For the small engines their length did not exceed 12 inches, the diameter varying 2 inches to 10 inches. The sheet copper was shaped and brazed in the usual way; it was then slid on a mandrel, which, for the small sizes was solid, for the large hollow, with one end closed for the plunger to press against. The enlarged collar for the tube to be pushed by was less in diameter than the die, so that it could pass through it.

The press was a simple toggle joint. The leaf of the toggle next to the plunger or push end was elongated beyond the center joint as a hand lever. By this lever one man could raise the center joint and work the toggle sufficiently to give a thrust that would force the tubes of 3 inches or less in diameter through the die about 1 inch at each rise and fall of his pump handle lever; but on larger sizes the toggle required to be worked at a less acute angle, and it took two men to force the 10-inch tubes through the die from ¼ to ⅜ inches at each stroke. As the handle was raised and the plunger drawn back, a suspended wedge would by its own gravity fall and fill the space, ready for the next thrust. These wedges were of a size that when they had fallen their length they would occupy a space of about 5 inches. They were then raised and blocks dropped in, and so on until the pipe was passed through the die, and came out beautifully smooth and planished.

There was a frequent visitor to the shops who would stand for hours watching this operation, often repeating aloud, "The power of the toggle is amazing; if we could only apply it to the ship's capstan it would be grand." This man was Commodore Murray, then in charge of the Philadelphia Navy Yard. He was fond of mechanics, though not grounded in first principles; would be and fancied himself an inventor.

Before relating what grew out of his watching the operation of the toggle, I cannot better show Perkins' quickness and some of his peculiarities than by relating what I witnessed with Murray's latest invention, his ship pump. He talked a great deal very mysteriously of it, never explaining, but always promising to bring one he was then having made at the Navy Yard, as soon as perfected, and exhibit its great effectiveness.

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35 As noted in Bathe and Bathe (cited in note 26 above), pp. 69, 75, the partnership passed from Perkins and Jones to Perkins and Bacon. This is the only reference I have found to this version of the origin of the Merrick and Agnew firm. However, the notice of Samuel V. Merrick in *Dictionary of American Biography* gives the date of his partnership with Agnew as 1820.

FIGURE 11.—Engraving produced from siderographically prepared plate. The scroll work was done on a Spencer lathe. The original designs and medallions were first transferred to soft steel rolls. These rolls, after hardening, were used to impress the final plate, also of steel, which was then hardened for final use. The ability of the siderographic roll to impress the same design several times in the final plate is here demonstrated. From *London Journal of Arts and Sciences* (1820), ser. 1, vol. 1.

The day at last came that the Commodore with his pump on a dray made his appearance. It proved to be a flapper piston, working in about a ¼ section of a cylinder; he called it his wing piston. This had a valve on it with one below, as in the common lifting pump. This flapper or piston, was worked by a handle on the end of its axis, that came out of the chamber through a stuffing-box; in fact, it was a single acting section of the old Rowntree fire-engine. The misfortune of the Commodore was the lack of published records accessible to him, and no doubt the invention was original with him. He could not have known that he had been anticipated.

The pump was put in the cistern, and the Commodore himself worked it, expatiating largely on the volume of water delivered, the flapper being large in proportion to the suction and ejection pipes, and the lift of water not over four feet, consequently the pump worked lightly. Perkins bustled around in his quick way, often taking hold of the handle and working it, repeating, "It works well, Commodore; it is a capital thing."

Had he stopped there the Commodore would have gone away delighted, but Perkins, like some other great men, always had a story ready for illustration on every occasion, and was often his own hero.

This time he could not keep it in; he began: "Plank, good plank, a side or two of leather, plenty of spikes, nails and rivets, and you always have at command pumps, safety pumps. Why, once I was going from —— to —— on a heavily laden schooner, in a storm. She sprung a leak; the water gained on the pumps; it was evident she could not float over an hour. Water-logged as we were it would take several hours to make the nearest port with favorable winds. I took the matter in hand. All I had to work with was a couple of planks 1½ inches thick, 9 or 10 inches wide, and one plank 12 inches wide, all over 9 or 10 feet long. I set the carpenter to ripping the 12-inch plank into two. While he was doing this and spiking them together into a 6-inch square spout and squaring them to a length, I was making a bottom board to nail on the lower end. I made a hole through its center 3 inches square, put on it a leather flapper, hinged wooden valve weighted with a bent bar of lead nailed on it. I cut the blade off a sculling oar, and to the lower end of its handle I nailed a conical leather bucket, made out of a couple of boot tops. The bucket was square, to keep it from crushing down with the weight of the water. I had straps from its top nailed to the oar handle through its upper end. I bored holes at right angles, drove through them a couple of deck broom-handles so that four men at a time could take hold. I cut a square hole in the deck, sounded the depth of the hole, nailed a strip on the side of my *ex tempore* pump to rest on the bottom, secured the top with nails to the deck, and caulked around it with oakum. There was over 5 feet of water in my pump, so the bucket was deep in it. Four men seized the handles and lifted each lift about 2 feet; they averaged fully 50 lifts per minute, each lift spewing on the deck a column of water 6 inches square by 2 feet, which ran off through the scupper holes. We rapidly gained on the leak, and made port, saving the vessel and cargo."

While Perkins was telling this in his quick, enthusiastic manner, he became more and more excited, and concluded by turning to Murray and saying: "I will bet you an oyster supper for a dozen that I can myself make in less than half an hour a pump that will with one man throw more water than that pump of yours does."

The Commodore very good humoredly said he would take the bet, and insisted on an immediate trial. Perkins went into the office, and in a few minutes returned, coat off, and an old boot in his hand, and said he was ready. (I presume he had been looking up materials and placing them handy.)

The company of lookers on, who by that time had increased to a dozen or more, adjourned to the shop, many with watch in hand. Perkins gave the signal when ready to start. His first operation was with his pocket knife, to cut a section of about 6 inches off the top of the boot leg, then another of about 3 inches. These he threw into a bucket of water, while his eye wandered as if hunting materials; then rapidly turning over some strips of inch boards standing in the corner, he selected four of them, two of them 3 inches wide, no two of the same length. He was but a few minutes nailing them into a 3-inch square spout, and sawing off its ends square, closing the lower end with a block, through which he bored a 2-inch hole. He doubled the strip of leather for valve fan and hinge (wooden valve), weighted it by boring a hole through it and putting in a ½-inch bolt that lay on the carpenter's bench. Then to a sweeping-brush handle he crimped in and wired his boot-leg section, roughly squaring its upper end with hammer, tacked with copper tacks, clinching their sustaining straps from the handle. While this was doing the cock was open and the cistern was filling with water. The pump was put

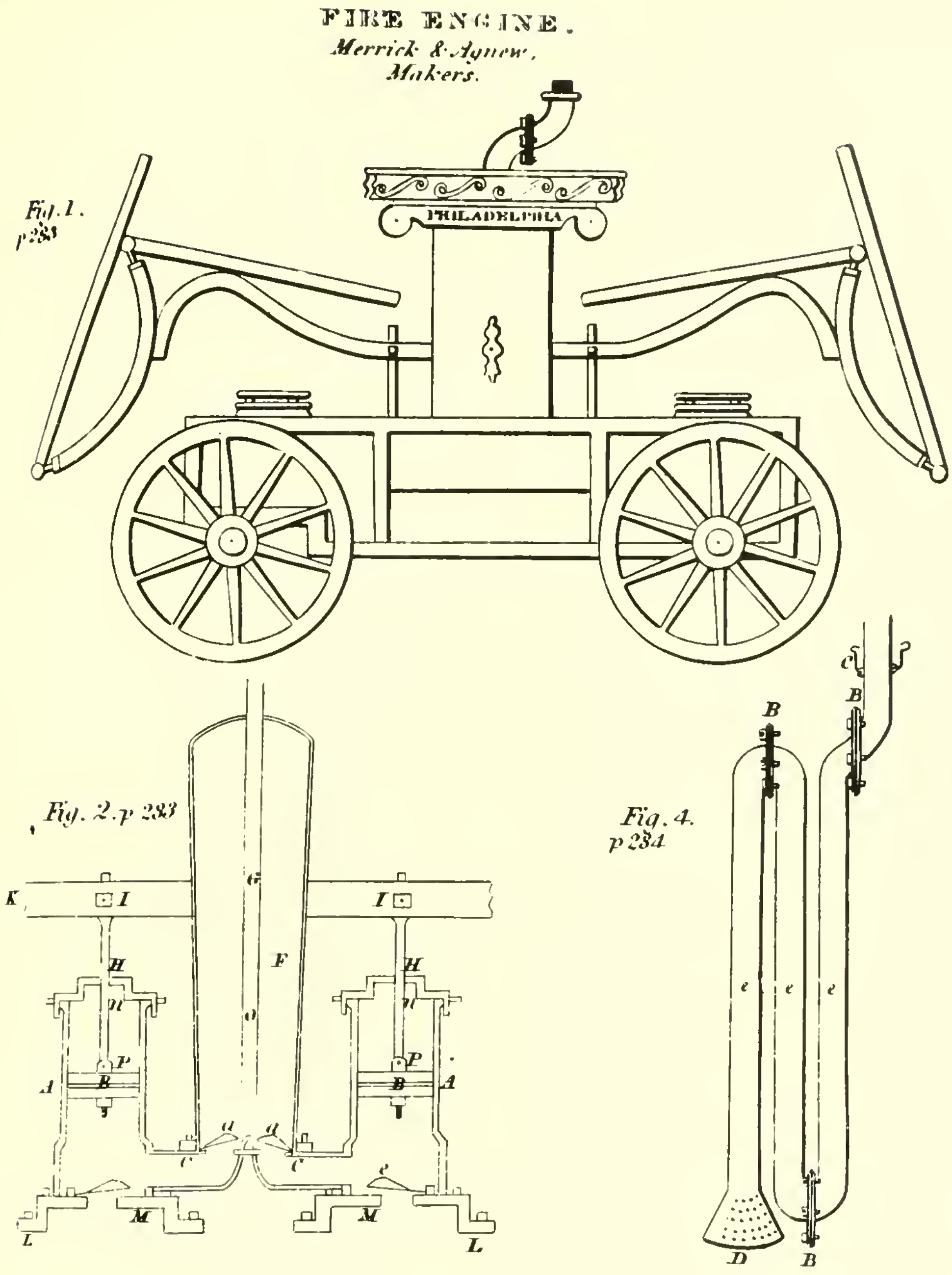


FIGURE 12.—Merrick & Agnew fire engine, showing vertical pump arrangement and folding handles at the lever-ends, after Patrick Lyon's designs. In "Fig. 2" the surge tank (F) is located between the two pump cylinders. "Fig. 4" shows the flanged swivel joints mentioned by Sellers. A single-bolt variation of this joint is shown in figure 8 (p. 10). From John Nicholson, *The Operative Mechanic and British Machinist*, 2d American ed. from 3d London ed., 2 vols (Philadelphia, 1831), vol. 1, opposite p. 284.

in at such an angle as to bring the upper end outside of the low curb; the crudely-made boot-leg bucket was some two or three feet under water.

It was just twenty-four minutes after Perkins stuck his knife into the old boot-leg that he had the water pouring over his legs and feet from his extemporized pump. The Commodore declined going into test of quantity pumped, acknowledged himself beaten, said the supper should be at Rubican's; that Perkins should name the time and invite the guests.

Out of little things do great ones grow is true, and it is always interesting to trace their course. Among the lookers on at this trial were two of father's friends, who happened in, Josiah White and Erskine Hazard, who at that time were engaged in their effort to float anthracite coal down the Lehigh and Delaware in small barges. Mr. White was so well pleased with the plan of these box pumps with leather buckets, that he adopted them for their barges, from which they found their way to the flat boats of the Susquehanna, and finally to the Ohio river, and the Mississippi and its tributaries, and now there is not a coal barge or shell that descends the Ohio with its millions of tons of coal, or a flat boat carrying millions worth of produce from all the tributaries of the mighty "Father of Waters" that has not two or more of these simple box pumps, worked by spring poles and man power, and on which the safety of its cargo depends, and the leather buckets, or suckers as they are technically called in the West, are to be found ready made for sale in all the supply stores on the rivers. It is just that Perkins should have the full credit of the invention, for small as it appeared at first, it has proved of great utility and vast importance.[36]

Up to this point the Commodore had taken his defeat good humoredly, remarking "that the United States can have any number of my safety pumps on all their vessels, but they cannot find a Jacob Perkins for every man of war." This was the kind of flattery that Perkins liked and never forgot, and he referred to this when I saw him in London in 1832.

As the Commodore was having his pump placed on a dray to return it to the Navy Yard, a couple of men came up the court; one remarked to the other, "That is the biggest beer pump I ever saw; it is a whopper."

The Commodore hearing this asked the man what he meant; if he thought it would answer to pump beer from one vat into another. The man, who was foreman of a brewery near by, replied that he meant just what he had said, and if the gentleman would wait a few minutes he would show him. He left and soon returned, carrying an English wing beer pump, such as had been used in England time out of mind for pumping beer from the barrel into the glasses or mugs.

This was too much for the Commodore; to think that his great pump that he had spent so much thought and labor on, should have been in common use for probably more than a century for such an ignoble purpose, and that he should not have known it. Father tried to satisfy him that his credit for the invention was as great as if he had not been anticipated, as he did not know of it; that the invention had so long stood the test of use should encourage him; that with him invention was not a necessity but a pleasure, and that he should persevere, but advised him when any new idea occurred to him to use every endeavor to learn what had been done in the same direction. [7]

I do not know anything of the oyster supper, as I was too young to be of the party, but I do know that it was a long time before the Commodore again came to the shops.

One morning I found him sitting in the office, both Mr. Perkins and father being absent. He was playing with a two-foot rule. He held one end on the table, the middle joint being up. He was sliding the other end back and forth, watching the rise and fall of the toggle. I told him father and Mr. Perkins would soon be in; he said he would wait. He then asked me to observe that, at the angle he held the rule, that when he moved the end he held in his right hand one inch, the middle joint would rise over two inches, but when he lowered the middle joint a push of ¼ inch would raise it the two inches, but it took a much greater force. He said he had by trial found the angle to place it at, to raise it the distance required with the greatest ease. I could not understand what he was driving at.

When Mr. Perkins came in he told him that he had perfected the application of the toggle joint to the capstan, and that it worked to perfection; that he had a carriage waiting to take Mr. Perkins and my father

[36] This pump, patented on March 23, 1813, two years before Perkins came to Philadelphia, was adopted by several U.S. naval vessels before and during 1816. The plan was also submitted to the Royal Society of Arts in London on January 10, 1820. (Bathe and Bathe, cited in note 26 above, pp. 49–50, 189–190.)

to the navy yard to show them the operation of what he considered his greatest achievement; that this time he was certain he had not been anticipated. I was taken along with them.

In the second story of a frame carpenter shop was an old horizontal capstan; on each end a strong ratchet wheel; the capstan rested on a couple of long beams, into which its journals were let about half their diameter. These beams formed the foundation for his contrivance, which consisted of two long-leaved toggles, from the center joint of which hung hooked pawls to operate on the ratchet wheels. One end of the toggles was securely hinged to the beams, the other to a movable guided plunger; these were connected by pitmans to crank arms of a rockshaft that extended from one beam to the other. This shaft was provided with sockets to receive handspikes, one of the crank arms being above, the other below the shaft. There was an arrangement to extend this shaft entirely across the deck of the vessel and give an increased number of sockets and handspikes, by which this shaft was rocked, and as it rocked by its crank arms and pitmans alternately pressed against the ends of the toggles, which, by the rising and falling of their center joints by the hooked pawls, continuously rotated the capstan.

As soon as Mr. Perkins' eye took in the arrangement he said: "Commodore, you are taking hold of the wrong end of the lever."

"No," replied the Commodore; "you see what immense leverage I have with my handspikes and the short arms of my rockshaft; I work at short stroke to the best possible advantage of my men, and that wonderful multiplier of power, the toggle joint, gives me so long a lift."

"But," said Mr. Perkins, "you are taking hold of it in the wrong place. You had better throw it away and attach your pawls directly to your rockshaft arms."

"What!" asked Murray, "give up all the advantage of the toggle that I have seen prove its great power in forcing your copper tubes through the dies?" Father took the Commodore aside, and kindly, with rule and pencil, endeavored to make him understand the principles of the toggle joint leverage, and so let him down as gently as possible.

While this was doing, Perkins was busy attaching a rope to the raised center of the capstan, it being what is called a double one, the center being larger in diameter than the end ratchets. This rope he passed through an opening in the floor under the capstan into the carpenter shop below. He gave this to two men, with directions to hold it steady, and not allow the capstan to turn if only the power of one man was applied above. He arranged signals as to when they were to throw their entire weight on.

Murray seemed to understand father's explanations, and he looked very much crestfallen, but, turning to the capstan and taking hold of a handspike, he said: "You see how easily I turn it." But it would not turn. He threw more and more weight on the lever, finally resting his chest on it. When Perkins gave his signal the Commodore was lifted from his feet, struggled for an instant, lost his balance and fell, sitting on the floor as the lever flew up, as completely *hors de combat* as ever was a naval officer. It was a pitiful sight that I have always thought of as a cruel trick; but it has served me many a good turn by relating it to would-be inventors that have come to me with marvelous works, to impress on them the necessity of making themselves acquainted with first principles.

I will give an instance showing the quick working of Perkins' active brain. There was a certain Professor, full of mechanical notions, who was in the habit of coming to the shop to be helped out when in difficulty.

One day father saw him coming, and said to Perkins, "Here comes Doctor, brim full; I will leave him to you."

The Doctor explained his difficulty. Perkins said, "Pooh! pooh! that is nothing; do it so," and he rapidly sketched a plan.

"That is the very thing. I wonder I did not think of it," said the Doctor, and off he started. But before he had closed the door Perkins called, "Come back, Doctor, and I will show you a better plan." This time the Doctor was delighted, and again started, sketch in hand, but had not got out of the yard before he was again recalled to be shown a still better plan. But this was not the end, for Perkins followed him to the gate, calling after him: "Doctor, if you don't find that to work right, come back, and I will show you a d—d sight better plan than either, which I have this moment thought of."

Perkins' favorite expression on the conclusion of any argument was, "Well, we shall see; time proves all things."

One of his peculiar traits was, that if any new idea was started, or new thing suggested, that at the time he did not fully comprehend, he would work it into shape and then show it to the suggester as an entirely new thought, not as one perfected by him, but of his own creation. I will relate an instance.

After the failure to make a business of the garden engines, a class of engines called "village engines" were built. These carried a suction hose, to be thrown into cistern, creek, or pond, as the case might be. He had returned from delivering one of these engines, and in the evening came to father's house. He complained of having had great trouble from leaks in the leather suction hose. My father proposed substituting folding metallic pipes, and sketched a swivel ground joint, with a single bolt clamping the parts together. He proposed three or four folds, just as is shown in the plate facing page 284 in the second American edition of "Nicholson's Operative Mechanic," [see fig. 12, p. 19] with the exception that that is shown with the screw flange to clamp the joint. It is also illustrated with the single clamping bolt as one of Nasmyth's inventions in his autobiography.[37] Father's sketch was complete in all its parts.

As Perkins was leaving, according to his common custom, he gathered up all scraps of paper from the table and thrust them into his universal receptacle—the crown of his rather broad-brimmed plug hat. The next morning he came hurriedly into father's office, saying: "Coleman, I have worked out my suggestion of last evening."

"What was that?" asked father.

"Why, have you forgotten already? Folding copper pipes, instead of our leather suction pipes that have given us so much trouble." He dove into his hat, turning out a lot of sketches; and taking up the one father had made, he explained how simple it was; a single bolt to clamp the joint together.

I saw by father's smile that he was more amused than annoyed, but I could not help remarking, "That is the drawing father made last evening."

"Is it?" said Perkins; "Why, bless me, can I have made a mistake?" He then rummaged over the contents of his hat, and produced a sketch with the joint made with clamp ring and bolts, evidently his own work. "Coleman, when last evening I proposed folding metallic pipes, you certainly did make this sketch, but it don't look like your work. In the night I thought of using a single bolt, and it is strongly impressed upon my mind that I got up and sketched it, but I have had so much on my mind lately, that at times I don't know what I am at; but we will say no more about this." He crammed the papers into his hat and was off.

This was not a solitary case. I know many more like it, yet still believe he was honest and sincere; but on the subject of originating he was not far from being a monomaniac.

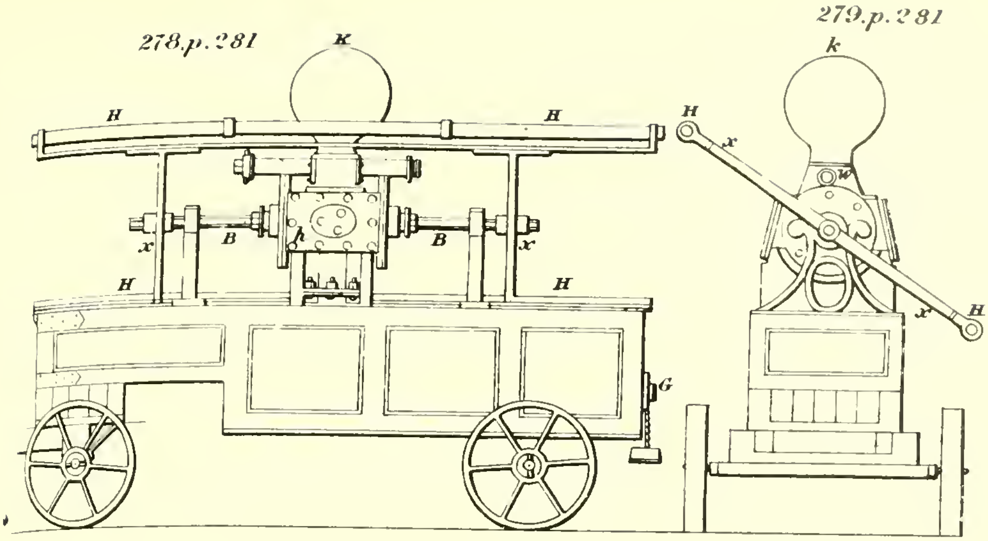
When father became connected with him he was engaged in other business, and it was agreed that Perkins was to conduct the engine building, father only acting advisory and giving such time and attention as he could spare.

I will now relate what led to his retiring and transferring his interest to Dr. Thomas P. Jones. Patrick Lyon had brought out his greatest fire engine—I think it was called the "Diligent"—with double cylinders, if I recollect right, of 9 inches diameter and 11 or 12 inches stroke, with folding levers and outriggers, and it could be manned with about 60 men. Perkins had seen this engine on its trial, and was seized with the idea that he could excel it.

Father was opposed to that kind of rivalry. He had always taken great interest in the independent volunteer fire companies, whose engines Pat Lyon, with hard knocks, had done more to improve than any other man. Any one visiting the Pennsylvania Academy of Fine Arts can see almost the living Pat Lyon in Neagle's great picture, as he stands with bare arms and leather apron in the glowing light from the fire on his forge. Father urged that this uneducated workman, having with his own hands, skill, and energy accomplished so much, should rather be helped than competed with. Mr. Perkins remarked that would put an end to all improvements.

The matter was supposed to be dropped, but it was not long before it was again opened by Mr. Perkins in a rather singular manner. His ever-active mind had been dwelling much on it. He began by saying that at the trial of Lyon's engine he had observed when the engine was only about two-thirds manned, the stream of water from the nozzle wet the ground to a greater distance than when fully manned. This he attributed only in part to the increased velocity of the water meeting the resistance of the air, separating it into spray. But he had noticed with the increased velocity the crackling noise as the water escaped from the nozzle also increased. He was satisfied that it was caused by expansion of compressed air taken up by the water in its great commotion in the air vessel. To prove this, he had put a bent glass tube from top to bottom of the air vessel of one of his garden engines,

[37] *James Nasmyth, Engineer, An Autobiography*, Samuel Smiles, edit. (London: 1883), p. 426. In justice to Nasmyth, he claimed as novel only the packing ring of the joint.



in which he could see by the rising of the water how rapidly the air was taken up, and he was surprised to see how soon all the air was exhausted, and the stream became irregular and jerky on the moment of the return of the strokes. He said he had a way of remedying this. He would throw away the air vessel and put in its place an open-top cylinder, with piston and rod and crosshead, with rods extending from it to a series of springs under the engine box.

Father asked, why not put a floating piston in a cylindrical air vessel to separate the air from the water, and still use the air above it for the spring to maintain a steady stream?

He said he had thought of that, but the piston would be out of sight, and always out of order: the leather cup packing would become dry, the water would pass it, and the spring soon be lost. He said he proposed using a 9 inch plunger, with a cylinder double its area, and give from 16 to 18 inches stroke; then, with the same number of strokes per minute, he would throw 50 per cent more water than Lyon's "Diligent."

Father asked him how he proposed to arrange levers to man them to give so great a length of stroke.

His reply was: "Bless you, I don't intend to use levers at all. I have been blamed enough for using Lyon's or rather Adam Eckfeldt's, folding levers on *my* village engines. I shall dispense with them altogether, and in doing so with a great weight." He then went on, saying: "Imagine a bell crank with a pendulum arm and a shorter arm at right angles that takes hold of the pitman that is attached inside

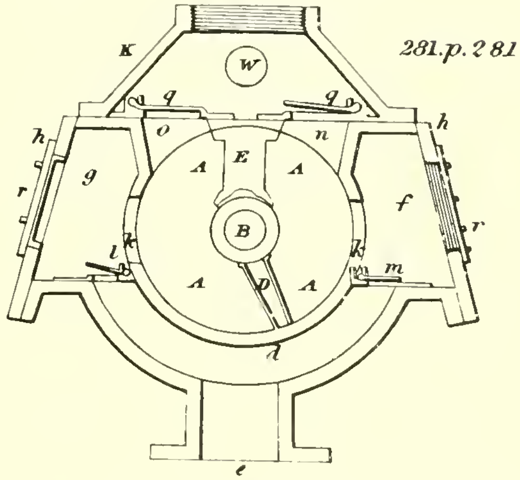


FIGURE 13.—Rowntree fire engine. Side and end views are above. The lower figure shows a transverse section through the oscillating-vane or wing pump. From John Nicholson, *The Operative Mechanic and British Machinist* (cited in legend for fig. 12), vol. 1, opposite p. 282.

to the lower end of the plunger; to the pendulum arm ropes that could be manned with any number of men."

He only gave this as an illustration, for he did not intend directly to take hold of the pendulum, but on each side of its axis he would have a cylinder or drum, whose radius should be equal to its length; on these drums he would coil ropes having wooden cross-handles about three feet apart, so that the rope would be manned with two men at each handle. When sufficient rope was let out, the drums would be clamped to the pendulum arm, the ropes running out, one at each end of the engine, and from the bottom of the drums alternate pulls would swing the pendulum and operate the pump. In places where there was not sufficient room to run out these long ropes, a single-tree attached to it, with ropes at each end, would give three ropes, with six rows of men to man them.

On being asked how he expected to take from the crowd men and boys who would make the alternate pulls in harmony, he replied: That was easy. In the first place the members of the company would be trained; besides that, he proposed to have a stand or a seat, alongside of the gallery on which the men stand to manage the branch pipe, for a foreman, leader or conductor in sight of all the men manning the ropes; this leader would wave a conspicuous baton, and at the same time have a ringing call, like the boatswain's call to the men when hauling a line, that would soon bring the alternate pulls in harmony . . . .

My father, who had not the most distant idea that Perkins was in earnest, laughed, and said he had expended much ingenuity, and he would like to know how he expected to hold his engine with all his pulling and tugging?

Perkins replied: That is provided for by radial bars from each axle, with shoes or scotch blocks that would be dropped, wedging under and securing all the wheels; besides this, he should have an extending steel-pointed rod from each corner of the engine against the ground.

On father bantering him on the waste of thought on such a picture, Mr. Perkins very triumphantly drew from his hat a contract signed between Perkins & Sellers and a newly organized fire company, in which P. & S. agreed to build, within a certain time, a fire engine that would throw more water than the new "Diligent," and so much farther as to completely wet the ground where, on competitive trial, the Diligent's last drop should fall; and on these conditions being complied with the company were to take the engine, paying a certain price.

This put a serious face on the matter, and decided father to retire, which he had a right to do at the expiration of a year, or sooner, on finding an acceptable person to take his place. Dr. Jones was such, but he could not take hold before the expiration of the year, and before that time the great engine was completed.

Its high-arched gallery and uncouth shape had, among the boys, got it the nickname of the "hunchback," that soon settled to the "Perkins Dromedary." When everything was ready for the trial, Perkins, baton in hand, mounted his perch. The ropes were drawn taut, and the signal given; a few slow pulls followed the motion of the baton, when the pressure of the escaping water at the nozzle began to be felt.

The fun grew fast and furious; the men and boys, shouting, tugged at the ropes; the engine reared and jumped about; the men at the branch pipe fell on their knees, grasping the sides of the gallery; Perkins shouted and screamed to the men to stop; but he was neither heard nor heeded. In less time than it takes to tell it he was thrown from his perch and badly bruised; but he was a man of indomitable will and perseverance, and would never acknowledge defeat. He said that on that day week he would have another trial; that by that time everything would work right.

He had already conceived the changes he would make. He would attach a square pole a little longer than the engine body at its center to the lower end of his bell crank pendulum. He would make arrangements to carry on the engine eight poles, each twelve feet long; these he would connect by socket and key, four at each end of the engine; these, with his cross-handles, he could man with 100 men. Each pole was provided with a pair of spreading steel-pointed supporting legs, jointed to the pole, the motion to be like a standing rower. By this arrangement the men would be compelled to work in concert, the same as with common levers. The advantage over the ropes would be that every man could exert some power to push as well as pull.

The changes were made; the day of trial came; a great crowd collected to witness it; a few swings of the poles and pendulum and a solid stream of water came from the nozzle, looking like a stick of black glass, without any of the ordinary crackling noise, and the ground was thoroughly wet fully 20 feet beyond any previous record from the same size nozzle.

Perkins was almost beside himself; urged the men who partook of his enthusiasm, and they thrust and pulled with all their power, lengthening their stroke until the engine jumped its chocks and was jerked back and forth so furiously that the two men at the branch pipe lost their hold, which, by the force of the stream and bend of the goose neck, went flying around, deluging with water the crowd of lookers on.

In the excitement of the men at the pole one end of it was jerked up, and with it the rocking supporting

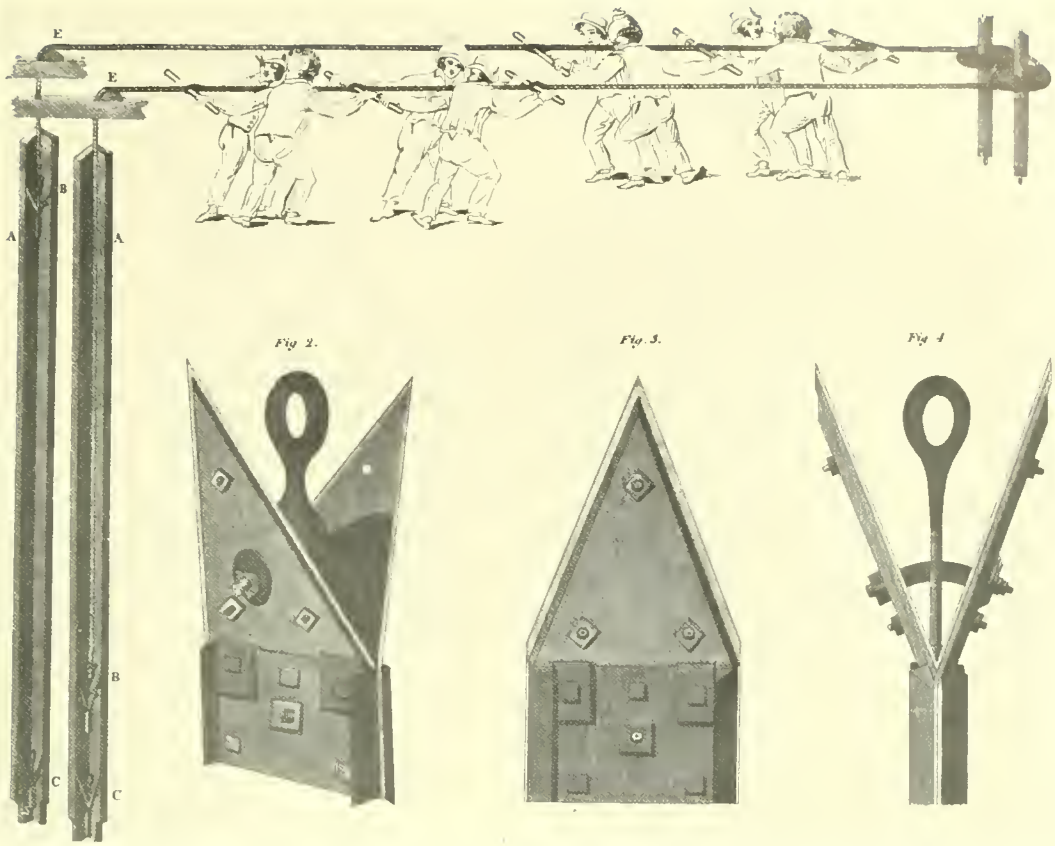


FIGURE 14.—Perkins's triangular-valve ship pump. Lower figures show various views of the plunger. From Abraham Rees, edit., *The Cyclopaedia*, American ed. (Philadelpia, 1822), plates vol. 3, "Hydraulics."

legs, one of which, steel-pointed, as they went down pierced through a boy's foot, pinning it to the ground. This mishap had more effect on Mr. Perkins than a total failure of his engine would have had, for he was a kind, tender-hearted man. The boy was a novitiate, who swung the censer in one of the Roman Catholic chapels, and who, years after, when a priest in Cincinnati, spoke to me feelingly of Mr. Perkins' great kindness and attention to him while laid up with the wound that had lamed him for life.

The "Dromedary" was run under a shed and never brought out again. It was finally dismantled, a regular air vessel replacing its spring piston. It was sold as a stationary mill engine to a cotton factory, to be worked by water-power. [8]

3. Old Blind Hawkins

The ideas concerning high pressure steam that Jacob Perkins spent several years of his life in England trying to promote probably originated with the blind man who is the subject of this short chapter. Perkins hinted as much when he mentioned in his 1822 British patent for a steam generator "communications made to me by a certain foreigner residing abroad . . . ." [38] This is not to say that Perkins made direct use of Hawkins's scheme. Perkins, like a Fourth-of-July sparkler, needed only to be lit, and that was what Joseph Hawkins did. While in Philadelphia, Perkins knew also Oliver Evans, a high pressure steam advocate, and talked with him frequently; [39] but Evans's use of steam in his engines represented a courageous departure from, not (as in Perkins's case) an abandonment of, the main stream of steam engine development.

During the entire time that Mr. Perkins was connected with these shops there was an almost daily visitor; sometimes he would come feeling his way with a cane, at others led by a boy. He would sit for hours apparently conscious of all that was going on around. Among the workmen he was known as *Old Blind Hawkins*, although under fifty years of age. His blindness, stoop and long iron-gray hair gave him the appearance of a much older man.

He usually carried with him one or two small volumes, which he offered and from the sale of which he derived his main support. From these we learned all we knew of him; his name was Joseph Hawkins, born in Kingsbury, Washington County, New York, in the year 1772, and when about twenty-one years of age he sailed from Charleston, S.C., as super-cargo of the *Charleston*, a Guinea trader of 400 tons burden.[40] He sailed December 1st, 1793, and had a prosperous voyage to the coast of Africa. He was sent inland for a cargo, got a large number of slaves and much ivory and gold dust. On the homeward voyage the ship fever broke out; he took it and lost his eyesight. When or how he ever attained any mechanical knowledge, I do not know. [9] He was always a welcome visitor to the shops so far as my brother and I were concerned, not only from his enthusiasm in explaining the merits of his invention, but for the long yarns he used to spin of his adventures in Africa. [10]

Being a good penman, and having command of the pencil as a sketcher before he lost his eyesight, he never lost the power of using them. With his left hand to hold the paper on the table in a manner that he could use his thumb to indicate where to start the lines, with a pencil he wrote very freely, keeping his lines straight, and at all times he was ready with pencil to sketch with sufficient accuracy to aid him in explaining whatever he had to present.

Besides the volume, the history of his early life, he often had with him a portfolio filled with rude drawings of his own make, from which he would illustrate

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[38] British patent 4732, December 10, 1822. There is no surviving record in the National Archives of Joseph Hawkins's U.S. patent of June 14, 1816. It is listed in U.S. Patent Office, *List of Patents . . . 1790–1847*, p. 156.

[39] Bathe and Bathe (cited in note 26 above), p. 97.

[40] Hawkins went to Charleston to make his fortune, "hearing it frequently said that a young man of moderate education and industrious habits, with a good recommendation, would be sure of an eligible and constant employment in the southern states . . . ." (Joseph Hawkins, *A History of a Voyage to the Coast of Africa, and Travels into the Interior . . . and Interesting Particulars Concerning the Slave Trade*, Philadelphia, 1797, p. 11).

his plans. No one hearing him explaining and seeing him pointing out the parts would, if they did not see his sightless eyeballs, even suspect his blindness. It was a remarkable case of the cultivation of other organs to supply the place of lost ones.

He had evidently tried, or had tried for him, many experiments with steam; his whole thoughts were on that subject. He said he had satisfied himself that the greatest economy was in using steam at very high pressure, and also the greatest safety from explosion; he even talked of using steam of 1,000 lbs. pressure to the square inch, of the great reduction in the weight of furnaces, boilers and steam engines for ocean navigation that he should make, and that by his system dangerous explosions would be an absolute impossibility, as the steam for every stroke of the engine would be generated as used. He claimed to have demonstrated that the spheroidal state of water, when thrown on heated metal, was entirely prevented by using highly-heated tubes of great strength, and maintaining in them an attenuated vapor at a pressure of not less than 175 lbs. This was done by the escape valve being loaded to that pressure.

His plan was to inject into these tubes just the quantity of water required to generate the steam at the pressure wanted and required to fill the cylinder and make the stroke. He had another modification that had grown out of the difficulty of regulating the jets of water with absolute certainty. This was to keep his heavy, strong and highly-heated tube-generators full of water, and to allow just so much highly-heated water to escape and flash into steam as was required for each stroke of the engine. I do not recollect the exact mode he proposed to accomplish this.

Toward the latter part of the time father was connected with Mr. Perkins, Hawkins had succeeded in getting, by subscription, what he thought would enable him to demonstrate his theories. This subscription was headed by two retired merchants from Charleston who had settled in Philadelphia, and had known Hawkins in his early days; part was by shops in the shape of work; a brassfounder subscribed the brass castings; a coppersmith the steam pipes, etc. Hawkins was given the use of bench and tools in the P. & S. shops, and there he brought the different parts of his engine together, which he erected under a shed in a yard in the vicinity.

Perkins took great interest in the work as it went on, and, no doubt, gave him much aid.[41] On the first trial of this engine the soft solder of two wiped joints of the small copper steam pipe melted, and it blew apart in a few minutes after the engine was started. Here Hawkins' trouble commenced. For these copper pipes he substituted musket barrels, joining them by conically counter-sinking one and tapering the other to fit into it, drawing them together by clamps and bolts.

There did not seem to be any serious trouble with his generator, but the great heat of his high-pressure steam burned out the hemp packing of his piston and piston rod. Then came a long series of experiments with metallic packing, which at the high heat, for want of lubrication, fastened to the cylinder. Then followed a most ingenious device. He put on a larger steam cylinder to work with lower pressure, a condenser to give him hot water from the escape steam; simultaneous with the flash of highly-heated steam, or water flashing into steam, hot water was injected, reducing the temperature and increasing the volume of steam at a lower pressure.

He had a scheme of open and single-stroke engines, with a plan of lubricating, that I do not remember, nor do I recollect to have ever heard him allude to using high steam for rapid shooting, as was exhibited by Perkins with his steam gun in London. But he had a vision that he liked to dwell on and talk of for protecting such harbors as New York that I cannot better describe than by using his own words as near as I can recollect them.

He would say that: "Ascertaining the narrowest part of the channel, I choose the position for my battery of generators, always kept heated ready to be

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[41] An account of the demonstration by Perkins of the Hawkins boiler, before Charles Willson Peale, Robert Hare, and several others is in the Memoirs, book 20, pp. 5–11. Mention of further developments in Philadelphia of the Hawkins boiler, involving the dentist Plantou, is made in SCHARF AND WESTCOTT (cited in note 14 above), vol. 3, p. 2263, and in CHARLES COLEMAN SELLERS (cited in note 20 above), vol. 2, pp. 397–398.

forced to the required pressure on the approach of an enemy's fleet. Now, imagine a row of great mortars, each loaded with a shell of not less than a ton weight. I know the exact capacity of my steam engines and pumps to eject the highly-heated water; I know to a certainty its effect on flashing into steam; I also know to a fraction the quantity of water to produce the required effect; I hurl this immense shell into the air; it is no guess-work; it is all a certainty; it falls from 300 or 400 feet on to the deck of the frigate at its weakest part. What would be the effect?"

Jacob Perkins, with Col. Fairman, Mr. Spencer, and some of their workmen, went to England, expecting to contract with the Bank of England to furnish their plates; they failed in this, but in connection with Heath, of London, they furnished the plates for the Bank of Ireland and many private banks. About the time they were leaving, Mr. Hawkins expressed himself as confident that Mr. Perkins would interest parties in England, and induce them to send for him to put his system to a full and fair test.

From this time I lost sight of Hawkins until after Mr. Spencer's return from England. It was supposed that he [Spencer] was doing well in London, and on being asked the reason of his return, he replied that he was doing well enough. But Perkins, with his steam engine and steam gun, had been so flattered that he had lost balance and imagined himself to be the inventor of the universe. He had never heard him put forth a claim to have invented his (Spencer's) scroll lathe, but almost always when explaining it to their swell visitors, it was done in a way to convey the idea that it was one of his *slight* inventions, and this so annoyed Spencer that he returned to America.

About this time Hawkins came into father's office with a letter in his hand from Mr. Perkins, in which he said he had been using his best endeavors to bring *our* steam engine favorably before the public, that he had met with great difficulties not only in doing so, but in successfully working an engine he had constructed; but he hoped in the end to overcome them all. The word "*our*" greatly excited the blind man; he stamped his foot, exclaiming, "*It is mine, mine only!*"

He had a London paper giving a glowing account of Perkins' new steam engine and Perkins' steam gun. If the published accounts of the first engine in London are correct, it differed but little from Hawkins' Philadelphia engine. It proved a failure. Had

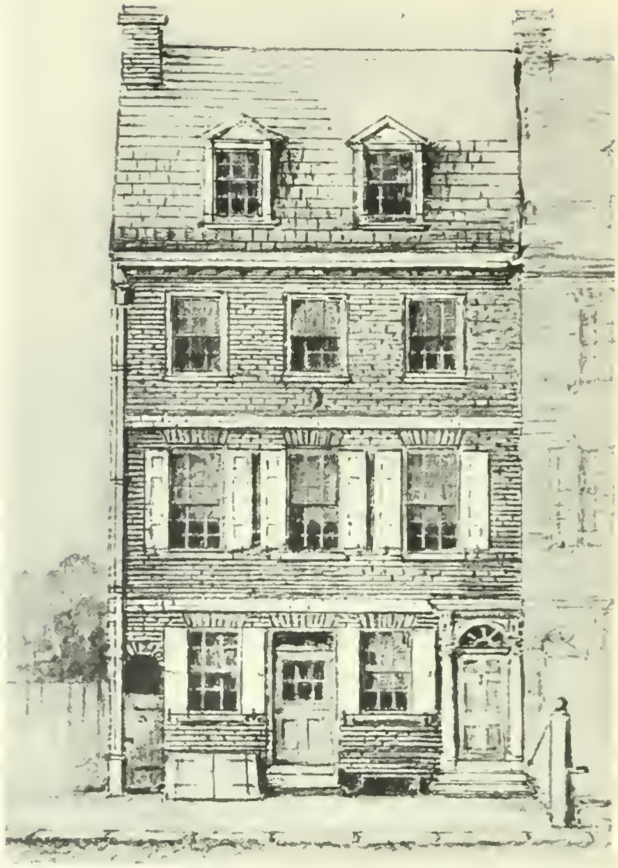

FIGURE 15.—231 High Street, the "Market Street Store" of Nathan Sellers located near Sixth Street (see end paper map). Home of George Escol Sellers from about 1817. From drawing by Horace Wells Sellers. Courtesy of Charles Coleman Sellers.

it been a financial success, I have no doubt but Hawkins would in that particular have had justice done him. After the first failure, Perkins labored for years on improvements, with no better practical success. Hawkins disappeared from Philadelphia, or I should most probably have again seen him. I should be pleased if this notice would bring out from some one what became of him after leaving Philadelphia. What will ever eventuate out of his ideas, elucidated as they were by Perkins, must be left to his [Perkins's] favorite maxim, "Time proves all things." [11]

4. An Adventure in Learning

George Escol Sellers was born into a Quaker household in which his father's work, and indeed his workshop, was part of the daily family experience. The house in which he was born was in Mulberry Court,[42] which opened onto the west side of Sixth Street above Market, and just around the corner from his grandfather Nathan's store, shop, and dwelling, the second door east of Sixth on Market. When Nathan Sellers in 1817 or 1818 built the home that he called "Millbank" on the Sellers tract in Upper Darby Township, Delaware County, the author's family moved into the place he vacated. This is the "Market Street house" referred to below.

As TO MY EARLY SHOP practice, it had a very early start but no regular apprenticeship on any one branch. It did not begin exactly at my birth but so soon after that I cannot fix the date nearer than that it was immediately after our removal into what we called the second house in Mulberry Court. It was a curious old fashioned wainscoted house, the cellar having a series of brick arches and a foundation adequate for a fortress. Open fireplaces were in every room with tile facings and high wooden mantels and all these fireplaces opened into separate flues of great size that united formed a stack that passed through the centre of the garret room and out of a gambrel roof. The garret had dormer windows opening on the Court, as well as the rear and a single gable window to the west which was directly opposite the stack of flues, the space between which and the windows was much less than the space on the east side owing to the house entries being on that side. The size of this stack of flues might have had something to do with the boys' first outfit in way of a work shop, for the carpenter's bench father made for us stood against the south side of the flues and in length was exactly the width of the great stack. His own carpenter bench was on the north side of the same stack, its stop and screw vise end extending some two or more feet beyond the stack to the east. This put his daylight work in a bad light but father said boys must have the best light, for their work was in the day time and his mostly by candle light, and he wanted the best daylight for his turning lathe which stood by the west gable window.

This lathe was rather a primitive affair; its pulley head was made of wrought iron; wooden shears; tail head, a wooden block; crank wheel, wooden, and a long treadle ran lengthwise of the shears with another at right angles which ran nearly across the garret floor. Primitive affair as this lathe was, father used to do some very beautiful work in hard wood and ivory on it and on it he gave Charles and me our first lessons. This was at a time when no good carpenter tools of a size to suit boys were to be bought and father himself made most of ours, or helped us make them for ourselves. It was while with father we occupied this joint garret shop and that he got possession of the fine set of carpenter tools that had belonged to David Jones. I never can forget the glee of us boys when helping carry the tools up to the garret shop and to see the then empty tool chest hoisted up outside and taken in through the gable window. It was the advent of these tools that gave us our first lessons in the importance of system and order. With care and under father's watchfulness we were allowed to use some of these tools. It was an adage with father, "That an indifferent workman

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[42] The author describes, in the present chapter, the "second house" in Mulberry Court. Elsewhere, however (in chapter 9), he establishes his birthplace as Mulberry Court.

might do tolerably good work with good tools, but that it took a skillful one to do so with bad tools." He used to tell us never to say "can't" but to try and keep on trying until we could.

Jacob Pearce was the first male teacher we ever went to. His school was back of Friend Edwards' house at the northwest corner of 5th and South Alley, now Commerce St. Adjoining the school room he had a little work shop in which he made cases and trays for his minerals and cylinder electrical machines and their fixtures. To encourage us boys to work he gave us a small glass cylinder conditioned that we do all the work of mounting without assistance. We were at a loss to know how to turn the parts—cups and journals for the ends of the cylinder, as father's lathe was too high for either of us to do the turning and at the same time tread the treadle, but a small stool was made for one to stand on while the other worked the treadle. While we were pegging on in this way, I recollect father coming up and offering to help, meaning by that to do the turning, but that was not the bargain. Then father said the time had come when the boys should have a lathe of their own, and long discussions came as to the ways and means of accomplishing this. The crank wheel seemed to be the greatest trouble. Father finally concluded to make one of wood and to get weight for the rim by drilling auger holes in it cast full of lead. This wheel was made in the garret shop and I have an idea that it is still in existence.

When we moved to the Market Street house just as I was entering my 10th year and Charles was 12 years old, a fourth story had been added to the back buildings of the Market Street house for a private shop for father and the boys' sleeping room. The shop was lit by two windows and a skylight. Isaiah Lukens had a set of patterns and father got him to finish a set of lathe heads and rest carriers. He had the crank wheel cast and fitted up at Oliver Evans' shop at the junction of Ridge Road, 9th & Vine Streets. This new lathe was put up in the new shop at a height that we boys could use . . . . [Another] crank wheel was made at which we boys helped, and if my recollection is not entirely at fault the rim was glued up out of mahogany that had been rejected for paper mold frames. This was used to run a watch-maker's lathe which was mostly used for light drilling and for boring [and] polishing . . . .

Among the tools most prized by the boys when in the Mulberry Court garret shop was a miniature axe, a present from Beatty the axe maker. Something was to be done on the roof of the woodshed—I don't recollect what—probably a boy's weather cock or windmill. Some things for whatever it was were thrown on to the roof before we climbed to it. Charles told me to throw up the little axe which I had in my hand. This was done but the roof was too steep for it to stay there and it slid off and in falling struck one of Charles' upper front teeth breaking it square off close to the gum. This was a sad affair for it was a second tooth and the only remedy was a false one. I do not recollect what dentist killed the nerve and reamed out a tapering hole for a wooden plug by which the false tooth was affixed. The tooth would sometimes twist around and Charles had frequently to make new wooden plugs. [12]

5. John White's Press-Screw Manufactory

The remarkable feature of this chapter, which describes a screwcutting lathe and its operation that the author first observed when he was under 10 years of age, is the exactness and entire plausibility of the detailed information concerning it. Within my knowledge, there exists from this period no American lathe for heavy work in iron, nor have I discovered any contemporary document that shows a useful picture of one. For example, the patent drawing of the 1798 screw-cutting lathe of David Wilkinson, of Providence, is a restoration, made after the Patent Office fire of 1836, and in view of Wilkinson's later attempts to obtain compensation from Congress for inventing a machine (the lathe) that was then in wide use in government arsenals, the detailed resemblance of the restored drawing to the original machine is open to question.

It should be noted that the making of large iron screws was possible without either an engine lathe or one like John White's, described below. Records of the U.S. Mint mention the purchase of screws for coining presses as early as 1792,[43] and the surviving press from this period, now on display in the Philadelphia Mint, indicates that a rugged screw with a long pitch and deep square threads was within the capability of early shops. It is probable that many of the screws made at this time in Philadelphia were, like those made in England, hogged out of the solid by a judicious combination of cold chisel, hammer, file, brawn, and skill.

John White's shop was on Market Street, west of the Permanent Bridge over the Schuylkill.[44] The remoteness of the location, a mile and a half from the author's home, no doubt accounts for Sellers visiting it only during summer vacations.

I REMEMBER THE TIME when every boy must possess an original Barlow knife.[45] At that time the same may be said of the Southern tobacco grower and cotton planter. They must have screws for their presses, and these screws must be of John White's make; no others would be accepted if these could be obtained, not even imported screws.

I now propose to describe, as well as I can, without the help of drawings, White's mode of operating, and the tools he used in making his screws. I can fix the date at 1816, from the fact that I watched with great interest his entire process at various times during my summer vacations of 1816 and 1817. Engine lathes with gearing to cut screws of various pitches were unknown at that time. The screws he cut for cotton-presses and paper mills were of two kinds—one called the lantern head, a large globe head with holes through it, crossing at right angles for wooden press levers; the other with a square body slightly tapered to receive a trundle or lantern wheel of four bars,

[43] The sum of $21 was paid to George Breining for cutting a screw in 1792; $50 to Reynold and Sharpless for cutting a screw and nut in 1795; and in 1797, Adam Eckfeldt built a screw coining press on contract (FRANK H. STEWART, *History of the First United States Mint*, Camden, N.J., privately printed, 1924, pp. 75, 82, 179).

[44] Philadelphia city directories give this location for John White, blacksmith, through 1820, lending weight to Sellers's impression that White died before 1821. John White, blacksmith, of 54 Frankford Road, appeared later, but it seems likely that this was another man.

[45] A discursive account of the Barlow knife is in LAURENCE A. JOHNSON, "The Barlow Knife," *Chronicle* (Early American Industries Association), (June 1959), vol. 12, pp. 17, 20.

between which and the body of the screw the press lever was thrust; this latter was at that time coming into use, being less liable to break than the lantern head. The large diameter of the trundle enabled the pressman to use it as a hand wheel to run the screw down and give considerable pressure before using the lever and windlass. This class of press screws were made of cast iron, and rarely exceeded 6 inches diameter. They were cast at the foundry of Rush & Muhlenberg,[46] Philadelphia, and turned ready for cutting the screw thread on a lathe got up by Cadwallader and Oliver Evans. This lathe was the nearest approach to our present engine lathe that I can recollect in Philadelphia at that time. It was a wooden shear lathe with cast-iron slides for the poppet head and tool-carrying rest, which rest was moved by hand wheel with crank-handle operating a pinion attached to the rest and working into a fixed cog-rack on the front shear.

Screws for tobacco and other small presses were of wrought iron and varied from about 2¾ to 4 inches diameter, and in every case made of piled charcoal iron, nine square bars being used to each pile; the object being to have a solid center bar. These pile rods of hammered iron of the required size were made at some one or other of the Pennsylvania charcoal forges. The piles were heated in a hollow fire of imported bituminous coal, at that time known as Liverpool coal, or an open hearth by a blast from a couple of wooden tubs about 4 feet diameter, their pistons alternating by a wooden walking beam, worked through a connecting rod by a crank on the end of the shaft of a breast water-wheel. There was a third tub with weighted piston to regulate the blast.

The forging was done under a couple of trip hammers, one for roughing, the other for swedging, driven by an undershot waterwheel, with tappet wheels on its shaft, regulated in their diameters and number of tappets so as to give twice the number of blows to the swedging hammer. The heads of the screws with lever holes at right angles and one above the other were shaped and finished on an ordinary anvil, with hand hammer and sledges. On the end of the screw bolt was forged a square tit not over half an inch long and of such a size as to come within the diameter of the bottom of the screw-thread when cut; the object of this tit will be explained further on.

The turning and screw-cutting lathes were of the most primitive construction. The bed or shears were two white oak timbers about 12 or 14 inches square, about 6 inches apart, securely bolted to stone foundations. The lathe head was two pieces of timber the same size as the shears boxed into and crossing them, with a space of about a foot between them; into these the boxes that carried the mandrel were let, the overhanging center-carrying end of the mandrel was square on which the face-plate, or rather cross, was keyed; the entire end thrust was taken by the boxes by collars on the journals, the back end of the mandrel was also square and overhung sufficiently to carry a spur wheel about 4 feet diameter, with 5- or 6-inch face with wooden cogs in which a trundle pinion worked as the driver; part of the pinion shaft was square, on which part slid a ratchet clutch, which fastened by a corresponding ratchet on the iron hub of a loose, deeply grooved wooden pulley, driven by a twisted rope belt made of raw hide; the ratchet clutch was so arranged as to be shoved into gear or disengaged by a foot treadle in front of the lathe shears, giving the operator instant command both in starting and stopping.

The back or poppet head was similar to the main head only differing in its timbers not being so heavy and being set closer together, and on their under sides connected by a piece of wood fitting and projecting into the space between the shears, to act as a guide for the back head; the mandrel was square let into and screwed on its angle to the head blocks, the end of this back mandrel carrying the center overhung the blocks about 3 inches and was accurately turned to a collar, which, besides its especial object, prevented the mandrel sliding back on the head blocks. There was no arrangement to move this mandrel forwards or back; the head was clamped to the shears in the usual way, and the center held to its work by wooden wedges driven between the head block and a piece of scantling that lay across the shears, held in its place by iron pins in holes in the top of the shears. There were rows of these auger holes about 1½ inches in diameter and 6 or 8 inches apart. The tool rest or rather rests, for they were the lengths suited to the bolts to be turned and screws to be cut, were flat bars of wrought iron secured to wooden rests; the only way to regulate the height of these long rests was by the thickness of the wooden supports. Close to the edge next the work of

[46] An outgrowth of the Oliver Evans Mars Works. Rush and Muhlenberg, both sons-in-law of Evans, established their foundry and machine works in 1816 on the site of the present U.S. Mint, on Spring Garden Street west of Broad. (Greville Bathe and Dorothy Bathe, *Oliver Evans*, Philadelphia, Historical Society of Pennsylvania, 1935, p. 232 and passim.)

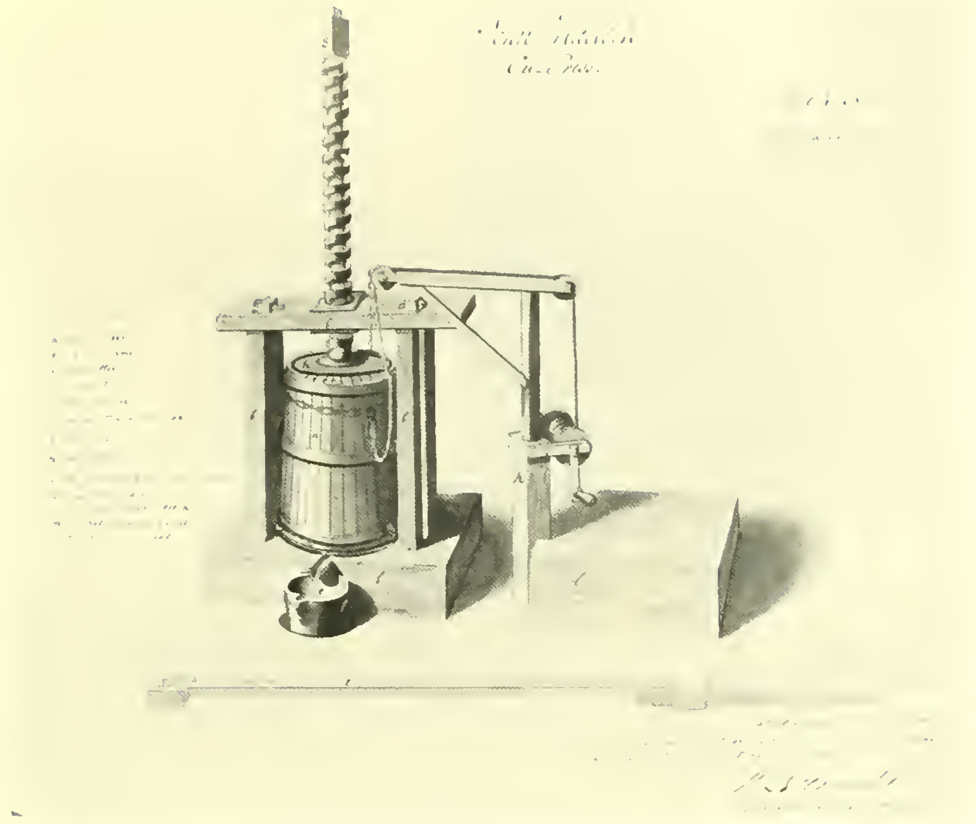


FIGURE 16.—Screw press, 1822, for expressing vegetable oils, such as linseed. Restored patent drawing in Record Group 241, National Archives.

these wrought iron rest bars, was a slight groove. From end to end in this groove was rolled a button end hand tool with so long a handle that the operator could rest it on his shoulder. I was often astonished at seeing the long curled shaving turned off in this primitive manner, and at the accuracy of the bolt turned, when tested by straight edge and calipers. [13]

After a number of bolts of the same size had been turned, came the thread cutting, and this may be considered an advance or evolution from haphazard hand chasing and die cutting to the present engine lathe work, and even at this day will be looked at as an ingenious device. On the 3 inches of the overhanging back mandrel was slid up against its collar what Mr. White called his "screw guide"; it was a template screw of the diameter and pitch of the screws he was about chasing, of about 4 inches in length on its thread; the portion projecting beyond the 3-inch overhanging mandrel was closed to a square hole in its center, into which the tit heretofore described on the end of the screw bolt would loosely fit. The carrying center of the back mandrel was a round steel rod about 8 inches long, perfectly straight beyond its pointed end. This center rod fitted in the center of the back mandrel, and was driven forward and held to its work by a wedge-key through a slotted hole in the mandrel. When the bolt on which the screw was to be chased was put in the lathe, the back head was driven forward by the wooden keys so as to bring it and the template firmly together; the back center was then driven forward by the key through the mandrel. By this arrangement the guide template was made to revolve with the screw bolt.

The chasing tool—or, rather, tool carrier—was wrought iron, in form of a cross, with very short, broad arms—in fact, they did not project more than half an inch beyond the body. These arms were grooved to carry the cutting tool and guide. The end of this carrier next the work was much lighter than the body, and was shaped so as to pass under the bolt to be cut and press against it opposite to the cutting tool. Both guide and cutting tool were firmly clamped to the carrier, and pressed forward and held in position by set screws through longer arms than the tool-carrying cross. The handle of the carrier was wood, about five feet long, with a drop handle of some 18 inches or two feet. When the chasing was to be done, a steel bar with a narrow edge for the carrier to slide on was substituted for the iron bar-rest used in turning; this was well lubricated. The guide tool was shaped to fit into the thread of the template, both guide and cutting tool being adjusted in its thread. This generally placed the guide and the cutting tool about 3 inches apart. The cutting tool was what might be called a stubby hook tool. In the first adjustment, the guide was set just as deep into the thread of the template as experience had taught the first cut could be made. The operator rested the long handle of the carrier on his left shoulder, grasping it in his left hand, steadying it by the drop handle in his right. The first cut required considerable skill on the part of the operator; the following not so much, as less care was required to adjust the guide and cutting tool. When the depth of required thread was cut, the screw was finished by a toothed comb that smoothed the work and gave a slight taper to the thread; the final polishing was done between dead centers. The brass nuts on all the wrought iron screws were cast on them, the screws being heated and well coated with rosin and lamp black over an open charcoal fire.

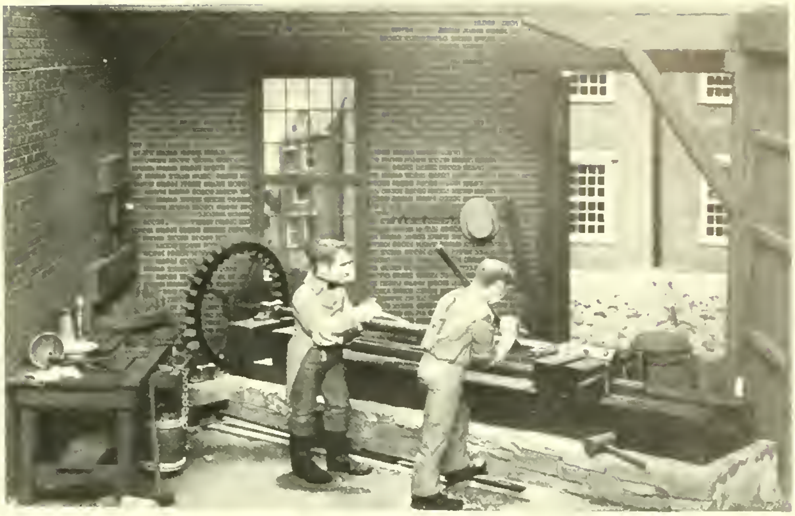
In chasing the large cast iron screws, the template or screw guide was not carried by the square tit, as in the case of the wrought iron screw, but simply by a steel pin in coinciding holes in screw bolt and template. The cutting tool also differed, as both guide and cutting tool were carried by a deep collar that was slid in to the template, fitting both it and the screw bolt; this collar had an arm that held it from turning by the lathe rest on which it slid, the guide tool being on the collar next the poppet head, the cutting tool on the opposite or advance side, and, as in the above described hand[tool,] the cutting tool going in advance of the guide—in fact, a screw cutting die with a single cutting point. When this die had traveled to the end of its cut, the cutter and guide were withdrawn and the die or collar slid back by hand, the tools readjusted and again started.

I recollect on one occasion my grandfather asked Mr. White why he did not adopt this simple plan to cut his wrought iron screws. The reply was, because it has *no feeling*; that no two bolts of wrought iron were ever alike in texture. He then expatiated largely on the necessity and advantage of a piece of ham skin, the fat side next the screw, that he placed in the lower part of the bend of his tool carrier that clasped the back of the screw. By bearing down the long handle of the carrier, this ham skin was pressed up against the bottom of the screw being cut, and, as he expressed it, so increased the sensitiveness of the touch that with his eyes shut he could detect the slightest dulling of the cutter, or, should a corner break off of it that might interfere with the guide, he was notified of it before the eye could possibly have detected it: again, he claimed that considering he could take a heavier cut when he could feel his work, and the time lost in backing the tools, sliding the collar carrier and again readjusting the tools, that he had an advantage that nearly doubled the amount of chasing per day.

On a simple plan being suggested to him of reversing the lathe and automatically starting and stopping that would run the tool back rapidly ready for a fresh cut, his comments were very characteristic of the man, and, no doubt, many other hand workers opposed to innovations. He had listened very attentively, and after what appeared to be due consideration, he said: "Nathan, I have no doubt what thee proposes would act just as thee suggests; but when I hire a workman I hire his brains as well as his hands. They are naturally careless enough, and if thee would save their thinking and give part of it to the machine, it would only make them more heedless, and I would be the sufferer. If I were to spend money to adopt thy jimcracks, I would still be obliged to have the man to watch them, to set the tools and keep them sharp and in order, and why not let him do the work? It is better for him than to stand with his hands in his pockets; they would soon be in mine."

The heavy cast iron nuts for the cotton press and paper mill screws were bored by head and cutters on a vertical boring bar, guided both above and below the nut, which was clamped on a wooden platform, the boring bar and head being worked capstan fashion by men walking around pushing levers. For cutting the thread, the boring bar had a screw thread the pitch of that to be cut, on which was clamped a two part nut secured to the upper guide of the boring bar. When a cut was run through, the cutting tool was brought back by the men reversing the direction. At the time I am writing of, this primitive mode of

Figure 17.—John White's screw-cutting lathe, about 1817. The chasing tool is attached to the long wooden handle which rests on the operator's shoulder. The advance of the tool along the workpiece is initiated by the "screw-guide," located at the right-hand end of the workpiece. However, the operator had to possess skill as well as brawn in order to chase a uniform thread. The model shown here was built for the U.S. National Museum from the description given in the present chapter. Smithsonian photo.



boring was followed by Patrick Lyon, the then celebrated builder of fire engines in Philadelphia, for boring his brass engine cylinders.

As to how long this primitive process of press screw making was carried on after the time I am alluding to, I have no way of knowing with certainty. I have an impression that Mr. White died before 1821.

I recollect a curious incident connected with these screws: The house of which my grandfather was head received through the Spanish Consul resident in Philadelphia a letter of inquiries as to the cost of a large number of wrought iron screws, a peculiarity of which was they were to be forged solid, then bored out, leaving a certain thickness of shell, the hole closed by a well fitted plug secured by a screw tapped half in the shell and half in the plug. Other peculiarities were explained by the Consul as a necessity to secure lightness, as they had to be transported long distances either on ass or llama backs. The order came, the screws were made, and shipped through a Philadelphia drug house having extensive commerce with South America. At the same time was shipped by Cadwallader and Oliver Evans machinery for a flour mill. Some years afterwards, when the old United States Mint on Seventh Street was being dismantled, the machinery broken up and sold as old metal, I noticed among the rubbish some old rusty, battered, hollow screws, that reminded me of the screws made by White. I stated the circumstance of that order to Mr. Adam Eckfeldt, the then coiner. He smiled, and said he could tell the sequel. It was like a sermon of three divisions and finally: Firstly, when the screws were made, from some cause mercury was cheaper in Philadelphia than either Spain or South America. When produced, the hollow screws were filled with mercury, and in that condition reached the gold mines. The secondly was, after the mercury was run out, the hollow body was made to take the place of an ingot mould and cast full of gold, the plugs returned and securely riveted, some bent and broken, all badly rusted, and with other pieces of machinery were safely transported to the seaboard shipping port, having offered no attraction to brigands who infested all the roads. The thirdly was, as old machinery and waste metal they passed the Custom House and evaded a heavy export duty levied on all gold shipped to any other country than Spain; they also got cheap transportation and safety by vessel to Philadelphia. The finally was the golden harvest at the old United States Mint. They had answered the purpose of the projector, had brought into our country over $150,000 that otherwise could not have reached it in a direct way. They had left their maker's hands at a cost probably not exceeding $30 each, and returned after their long travel by water and by land, each carrying within its old, battered, rusty shell over $5,000 of pure gold. Some of these old screw shells should have been preserved as relics of Yankee ingenuity, for it was all the work of an American who had found his way to the gold mines in the mountains of South America. The humor of the thing was making the Spanish Consul, probably an innocent party to the fraud against their customs, act as a go-between in the entire transaction. [14]

6. The Philadelphia of Oliver Evans

Oliver Evans was 53 years old when George Escol Sellers was born, and he died before Sellers was 11.[47] However, the author in this chapter delineates a profile of Evans considerably sharper than the standard one constructed at second hand from written and printed sources.

Evans had a really first-rate mind. He was original and generally sound in his conclusions. His high-pressure steam engine represented a courageous departure in practice from the low-pressure engine pioneered by Boulton and Watt. His system of materials handling in a flour mill, using vertical bucket and horizontal screw conveyors, was fully set forth in his *Young Mill-Wright and Miller's Guide*, first published in 1795 and republished through 15 editions, the last appearing in 1860. His high-pressure steam engine took form after 1800, and in 1805 he issued his *Abortion of the Young Steam Engineer's Guide*, whose title reflects the frustrations that beset him as he sought support for a pioneer work on the steam engine.

For several years prior to the organization of the Franklin Institute, of Pennsylvania,[48] there was great interest and activity in what at that time was considered a rapid advance in mechanics, both in America and Europe.

The problem of ocean as well as land transportation was occupying the minds of many thinking men. Steam power was looked to, but was ridiculed as chimerical by the world at large. Our own Oliver Evans, from the time of his first high-pressure engine in 1785 or 1786 [49] to the time of his death in 1819, never lost an opportunity to impress on any listeners he could hold the feasibility of not only navigating our rivers, but crossing the ocean and continents by steam power.

As early as 1786 he petitioned the Legislature of Pennsylvania to grant him the exclusive right to use his improvements in flour mills, and also for *road wagons propelled by steam*. The act passed in 1787, granting him the right so far as flour mills were concerned; but no notice was taken of that part of his petition relating to steam wagons. In 1787 the Maryland Legislature granted him, his heirs and assigns, the exclusive right for fourteen years for his improvements, including the steam wagon. The term "locomotive," as now applied, had not at that time been suggested.

As a boy, I have often listened to Mr. Evans' earnest predictions as to land travel by steam. He said he had lived to see part of his prediction verified in steamboats—that high-pressure steam and light engines had made it practical on our western rivers, and would in time on good turnpike or tram road.

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47 Most of what is known of Oliver Evans has been brought together by Greville Bathe and Dorothy Bathe, in *Oliver Evans* (cited in preceding note), a quarto volume of 362 pages, profusely illustrated.

48 Founded in 1824. A brief outline of the Institute's history is in Henry Butler Allen, "The Franklin Institute of the State of Pennsylvania," *Transactions of the American Philosophical Society* (1953), vol. 43, pt. 1, pp. 275–279.

49 These dates apparently were derived from those of his petitions to the various state legislatures. While he asked in 1786 for a patent, or privilege (the U.S. patent system began in 1790), for his steam wagon, his first steam engines were built after 1800 (Bathe and Bathe, cited in note 46 above, pp. 66–69).

In speaking of the Pennsylvania Legislature, he called them "the assembled wisdom of the State, that could not see beyond their noses." They could see the grain go into the mill and come out flour, but as to a wagon being moved by any other power than the slow-moving ox, the horse, or mule, or being dragged by man power, was beyond their comprehension. He had asked no aid other than protection in case of success. It would cost them nothing, yet he had been treated with contempt little short of insult.

Of the grant from the State of Maryland he said the Hollingsworths, the Ellicotts, the Tysons, and others, were men of enterprise and progress, more so than the average of the time.

He was very severe in his denunciations of Benjamin H. Latrobe, whom he blamed for a report on steam navigation he had made, in which he alluded to him (Evans) as a visionary, seized with steam mania, in conceiving and believing that boats and wagons could be propelled by steam to advantage; while he (Latrobe) demonstrated by figures that could not lie that the entire capacity would be required to carry the engines and fuel, leaving no available tonnage for freight and passengers.[50] The B. H. Latrobe referred to was the father of the very eminent engineer, B. H. Latrobe, Jr., who carried to a successful termination one of the greatest of American enterprises—the Baltimore and Ohio Railway, and other important works. The elder Latrobe was an accomplished English architect and engineer, who designed and erected the first water works of Philadelphia, by which a steam engine on the Schuylkill River raised the water into a brick underground conduit, through which it flowed nearly a mile into a cistern in Centre

FIGURE 18.—Oliver Evans (1755–1819). From *Appleton's Dictionary of Machines, Mechanics, Engine-Work, and Engineering*, 2 vols. (New York, 1867).

Square, the site on which the new public buildings are now being erected. Over this cistern was the engine house, on the top of which, covered by a dome, was the reservoir or basin, to give head to supply the city with water through bored wooden pipes.

Mr. Evans frequently referred to his blasted hopes. He had succeeded in obtaining indorsements of Prof. Robert Patterson, David Rittenhouse, C. W. Peale, Nathan Sellers, and a number of others whose names I cannot recall, as to the feasibility of his plans. He was meeting with success in interesting parties of means, and was full of hope of demonstrating to the world that he was no visionary, when Mr. Latrobe's report proved too much for him to overcome, and he was obliged to abandon the project of demonstration by outside aid.

It is now about 66 years[51] since I rode with my father and Oliver Evans from Philadelphia to a mill

[50] This is the report on steam engines in America that Latrobe made in 1803 for transmittal to the Rotterdam and Batavian Societies (*Transactions of the American Philosophical Society*, 1809, vol. 6, pp. 89–98).

[51] This article was written in 1884. That would make the date of the ride 1818, when Sellers was nearly 10 and Evans was within a year of his death at 64.

in Delaware county, Pa., in which the latter was putting in a set of his elevators, hopper boy, and flour press. Yet much of the conversation I listened to both in going and returning on that never-to-be-forgotten trip, is as fresh in my memory as if it had occurred but yesterday.

Mr. Evans had much to say on the difficulties inventive mechanics labored under for want of published records of what had preceded them, and for works of reference to help the beginner. In speaking of his own experience, he said that everything he had undertaken he had been obliged to start at the very foundation; often going over ground that others had exhausted and abandoned, leaving no record. He considered the greatest difficulty beginners had to encounter was want of reliable knowledge of what had been done.

Even at that early day Mr. Evans suggested and urged the formation of a Mechanical Bureau that should collect and publish all new inventions, combined with reliable treatises on sound mechanical principles, as the greatest help to beginners. He did not believe it could at that time be made self-sustaining, but it would be to the interest of mechanics, manufacturers and merchants to subscribe to its support.

Another subject discussed was the importance of a school to teach mechanical drawing. Mr. Evans made all his drawings full size on chalked boards; he had no confidence in working to scale with the character of labor to be had at that time. His drawing instruments consisted of a two-foot rule, straight edge, square and compass. His first designs were rough pencil sketches, not drawn to scale. To combine and reduce these full size working drawings and put them in shape to exhibit, he depended upon Frederick and John Eckstein, then copperplate engravers in Philadelphia. I think he named at a later date William Kneass,[52] who was also a copperplate engraver, and a good draftsman, but of this I am not quite certain.

Mr. Evans gave an instance of the advantage, in fact, the importance of artistically finished drawings to the mechanic, by citing the Philadelphia water works. He said it was Latrobe's fine drawing he exhibited of the Boulton & Watt steam engine and pumps, and above all the exterior of the pumping house, with its Doric columns and pediments, both front and rear, its center dome-shaped building covering the reservoir, with the novel expedient of the stack and chimney, terminating on the apex of the dome, vomiting its wreath of black smoke, that caught the eye of the members of the city council that adopted the plans and gave to Latrobe the superintendence of the work. Mr. Evans called it the city plaything on which to expend money; more for ornament than utility, barely calculated to supply their wants without provision for a growing city, but he said that notwithstanding Latrobe had classed him among the visionaries, he would give him credit for having introduced a higher standard of mechanical drawing that would stimulate our native mechanics, and in that respect they owed him much.

Boy as I was at the time, it did not occur to me that there might have been a dash of satire in Mr. Evans' allusion to Mr. Latrobe, or that he might have been a competitor with him in plans for the water works. I do not now know that he was or was not. Beside the Boulton & Watt condensing engine and pump in the old Centre Square Water Works there was an engine known as the "American Engine," a vertical cylinder, lever-beam engine, the original Oliver Evans engine, and I presume built by him or under his supervision. This engine, if my recollection does not deceive me, was oftener seen running than the "great English engine," as it was then called.[53]

In speaking of the water works, Mr. Evans said Philadelphia had paid dearly for rejecting a proposition of Nathan Sellers, who was then a member of the council, for the city to purchase the Fairmount hills and reserve them as a site for reservoirs when the wants of the city should require an extension of its water works, and he believed Mr. Sellers had spoken prophetically when he said to the council that he expected to live to see the Centre Square Water Works torn down. Mr. Evans said that about that

[52] John Eckstein and William Kneass are noticed in *Dictionary of American Biography*. Eckstein died about 1817; Kneass became engraver at the U.S. Mint in 1824.

[53] Sellers has confused the Center Square Water Works with the Fairmount Water Works. The former, built in 1799–1801, contained one steam engine, 32 inches by 6 feet, to pump water into an overhead reservoir. The engine was built by Nicholas Roosevelt in his Soho Works near Newark, N.J. Another similar engine, 40 inches by 6 feet, also by Roosevelt, was located at the Schuylkill end of the supply tunnel, to supply the Center Square pump. The Fairmount pumphouse, however, answered to Sellers's description. Built in 1812–1815, the works contained one locally built engine on the Boulton and Watt plan and one engine, a Columbian, built by Evans. Evans's engine was slightly more economical. (BATHE AND BATHE, cited in note 46 above, pp. 65, 211–213, 227, 246–247.)

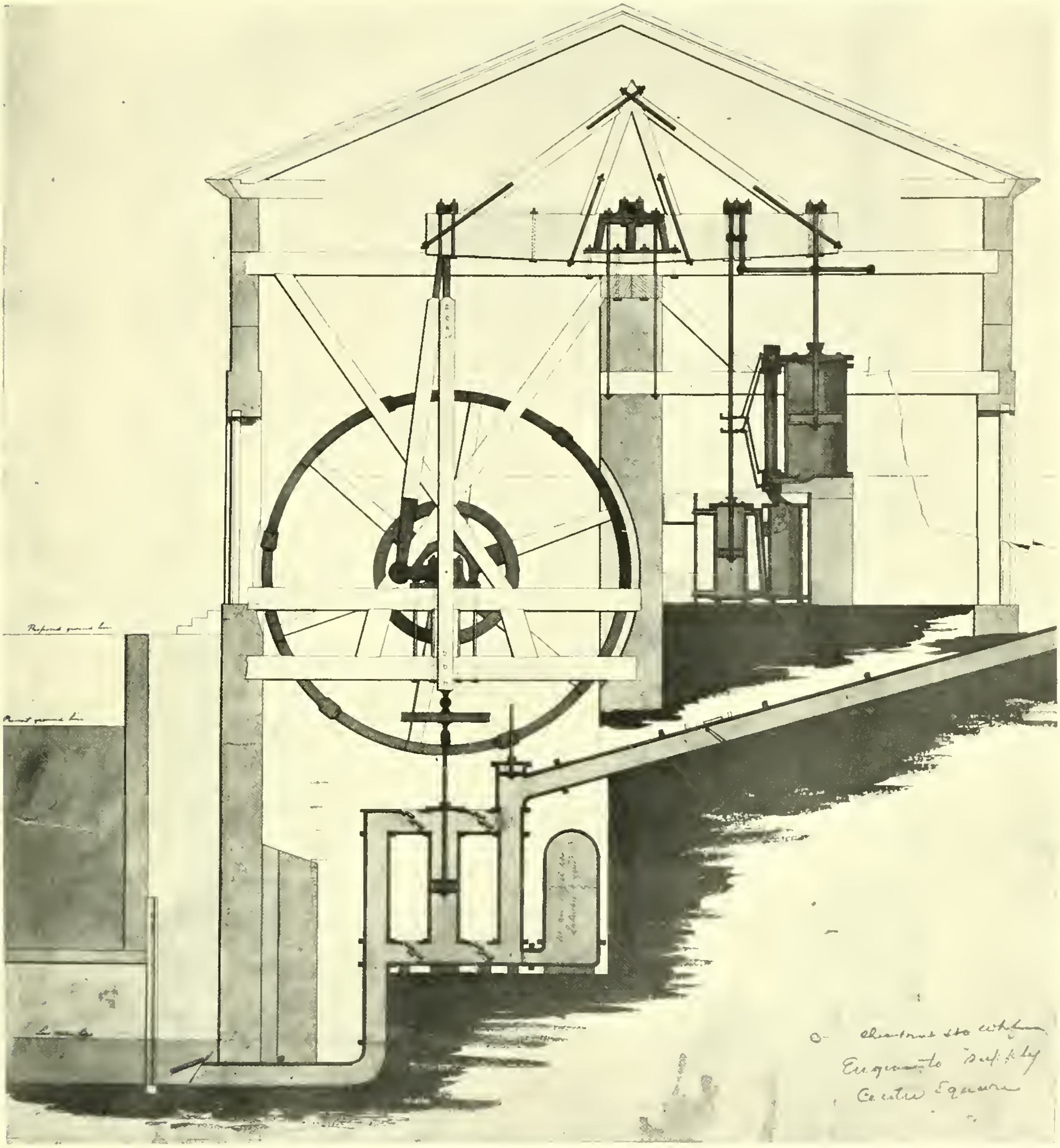

FIGURE 19.—Pumping engine of Philadelphia Water Works, about 1801. This engine, built by Nicholas Roosevelt and located in a pumphouse on the Schuylkill River at Chestnut Street, pumped water to the Center Square Works where a similar engine pumped it into a small reservoir above the engine. Original wash drawing in the Frederick Graff Collection. Photo courtesy of The Franklin Institute Library.

time he was called before a committee of the council, and that he said to them: "As sure as there is a Heaven above us, it will not be long before the city must own the Fairmount hills regardless of cost." I infer from this that Mr. Evans must have had plans in connection with these hills that were not approved at the time the "Centre Square plaything," as he always called it, was adopted.

I will here add that one of the last visits Nathan Sellers paid to Philadelphia after his retirement in his old age to his place in the country, was to see the first stone removed in the destruction of the Centre Square building that he had so earnestly opposed erecting—not from any mechanical defects in the plan, but for inadequacy in supplying the requirements of a growing city.[54]

The want of published mechanical works that Mr. Evans complained of so much did not begin to be supplied until some years after his death. It was not until 1825 that *Nicholson's Operative Mechanic*, so long a standard, was published in England, and the second American edition bears the date 1831.[55] I do not know the date of the first. As late as 1831 I could not find on sale in either New York or Philadelphia a copy of Dr. Alexander Jamieson's *Mechanical Dictionary*,[56] then considered a standard work in England, and was obliged to import a copy through Carey & Lea, who ordered with my copy some extra ones, which they held a long time before finding purchasers.

I have dwelt longer on Oliver Evans than I intended, for I look back with pleasure at having been privileged to listen to the plans and predictions of so far-seeing a man.

A good style of mechanical drawing was taught in Philadelphia long before the want of a mechanical publication was filled.

William Mason, of the firm of Mason & Tyler, makers of philosophical instruments and small tools, taught a private class which I attended.

William Strickland, as an architect, was always ready to lend a helping hand to young beginners. He would lend them drawings to copy and give kind advice. I recollect his once saying to me, "Come often and study the plates of my Stuart's *Athens*;[57] copy them and recopy them; they are the foundation of sound principle and true taste."

Some really fine mechanical drawings of my earliest remembrance were made by a divinity student, at that time acting as draftsman at what I think was called the Eagle Foundry and Machine Shop. It was located on the Schuylkill River, near the foot of Callowhill Street. I do not remember who operated it, but it must have been short-lived, as for many years the great stone building stood vacant and idle.[58]

This student was an accomplished and rapid pencil sketcher of machinery. That and music were passions with him. He spent two or three evenings a week at our house, kept a violin there, and joined my mother and others, of whom I may yet speak, in home concerts. He frequently brought his drawings to show to my father. On one occasion a finished colored drawing of a pair of bevel cog-wheels in gear, drawn in perspective, to my boyish eyes was a most wonderful piece of work, and, as a matter of course, I had many questions to ask. He then proposed, if I would devote my half-holidays (our Quaker schools gave two—one on meeting day, the other Saturday), he would teach me all he could. On this my father went with John, as we familiarly called him, and selected my fine case of drawing instruments, and with them, proud enough, I trudged away out to the foundry. I say "away out,"

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[54] The Center Square structure was removed about 1828 (Scharf and Westcott, cited in note 14 above, vol. 3. p. 1844). Nathan Sellers died in 1830.

[55] The first English edition was published in 1825. The first American edition, from the second London edition, was issued in Philadelphia in 1826.

[56] Alexander Jamieson, *A Dictionary of Mechanical Science, Arts, Manufactures, and Miscellaneous Knowledge*, 2 vols. (London: 1827). The 7th edition carries the date 1832.

[57] This is repeated, but not from this source, in Agnes Addison Gilchrist, *William Strickland, Architect and Engineer, 1788–1854* (Philadelphia: University of Pennsylvania Press, 1950), p. 31. The influence of Stuart and Revett's *Antiquities of Athens* on Strickland's work is mentioned several times by Mrs. Gilchrist in her book.

[58] The Eagle Works furnished cannon during the quasi-war with France in 1798–1800. In 1799 a contract with the U.S. Navy called for cannon to be cast solid and bored out "at the boreing Mill on Schuylkill" (*Naval Documents Related to the Quasi-War Between the United States and France, 1797–1801*, 7 vols. [U.S. Naval Records and Library Office, Washington: 1935–1938], vol. 2, pp. 205–206). The Eagle Works was operated in 1799, and as late as 1810, by Samuel Foxall. Under the direction of Samuel Richards, in 1820, water pipes of 22-inch diameter were cast in 9-foot sections (Scharf and Westcott, cited in note 14 above, vol. 3, p. 2251). James Mease, in *The Picture of Philadelphia* (Philadelphia: 1811), p. 77, says: "All kinds of castings are also made at the Eagle Works, on Schuylkill, belonging to S. & W. Richards." Sellers apparently was unaware of the earlier history of the works, which is surprising.

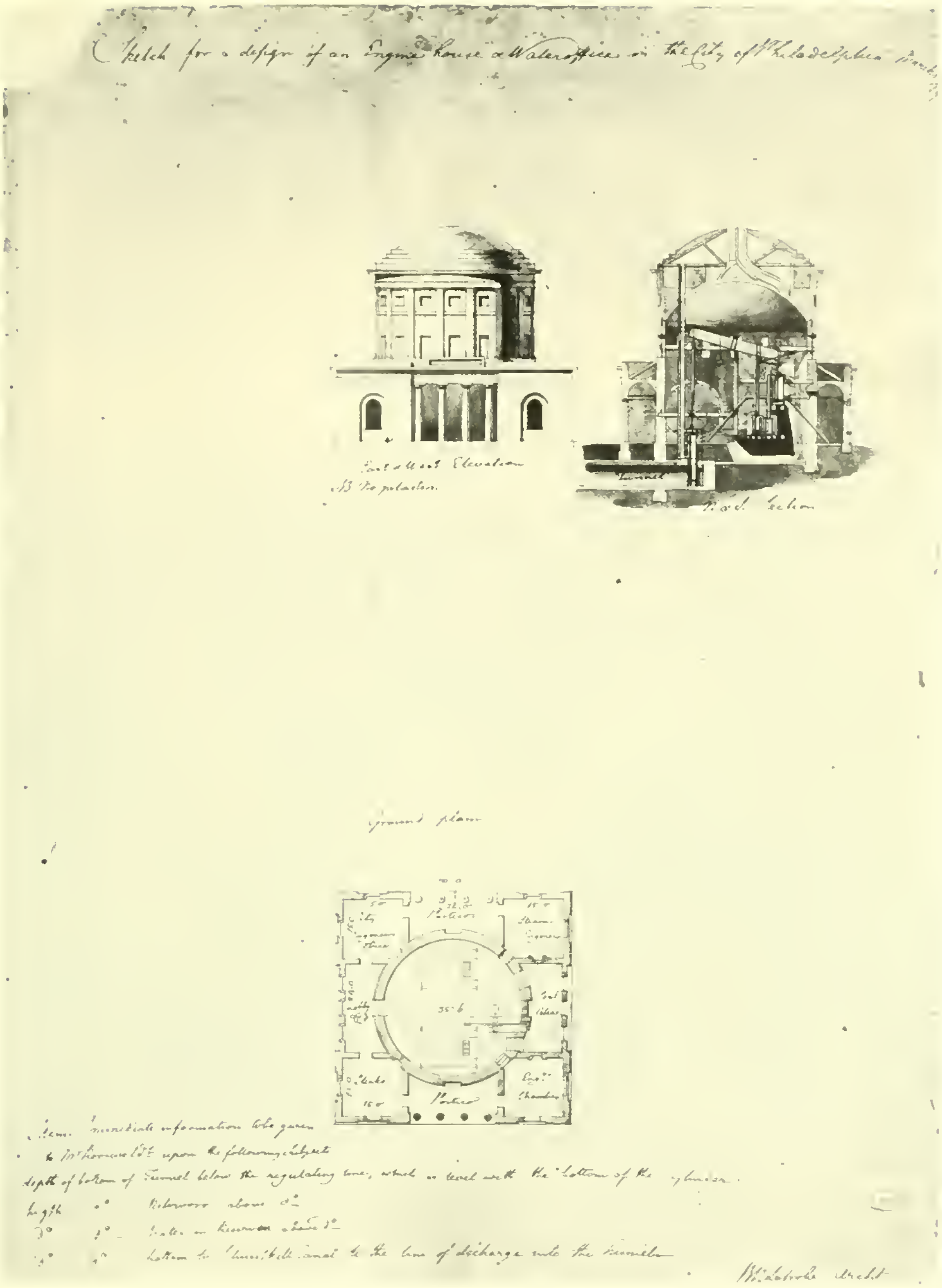

FIGURE 20.—"Sketch for a design of an Engine house and Water office in the City of Philadelphia March 1799." The ink sketch is signed by B. H. Latrobe, architect. Engine, pump, and boilers were located in the central rotunda. The surrounding spaces were designated (counterclockwise, starting at upper left corner of Ground plan): "City Engineers office, Lobby, Clerks, Portico, Engrs. Chamber, Coal Cellar, Steam-Engineer, Portico." In Latrobe Collection; photo courtesy Maryland Historical Society.

for at that time it was through the suburbs and by the brick-ponds, on the margin of which I have more than once put up snipe and woodcock in what is now one of the best-built parts of Philadelphia. I profited by these lessons, for he was certainly the best mechanical draftsman of the time, and bid fair to make his mark as a mechanic had he not left its walks for what he considered a higher one—the Church. I was present at his ordination by Bishop White and heard his first public sermon. He was a loss to the mechanical world, but not a case of "spoiling a good mechanic to make a bad preacher," for he became eminent and world-wide known as John Henry Hopkins, Bishop of Vermont.[59] He made no mistake in choosing his profession, whatever he may have done by his advocacy of domestic slavery, and his claim that it was justified by Holy Writ. [15]

[59] Born in 1792, Hopkins was George Escol's senior by 16 years (*Dictionary of American Biography*).

FIGURE 21.—Center Square Water Works, Philadelphia. From Charles W. Janson, *Stranger in America* (London, 1807). Library of Congress photo.

7. Sellers and Pennock Fire Engine Works

A cousin of George Escol's father, James Sellers, was in the fire engine trade for several years before the short-lived partnership of Jacob Perkins and Coleman Sellers was formed. It was James Sellers who developed, perhaps as early as 1811, riveted leather hose as described in an earlier chapter. It was not until 1818, however, that he took out a patent for it, in collaboration with Abraham L. Pennock.

The date at which the partnership of Coleman, his cousins James and Samuel, and Pennock—doing business under the name of Sellers and Pennock—was formed to carry on engine and hose making is thus uncertain. However, the "regular fire engine shop" at 16th and Market Streets that the author refers to in the following passage is that of Sellers and Pennock.[60]

Samuel Morey's visit to Philadelphia occurred sometime during the 1820's. The explosive vapor vacuum engine, one of the earliest internal combustion engines to be developed in the United States, was patented in 1826.

The sojourn of the titled itinerant German craftsman, whom we know only as Henri Mogeme, apparently occurred in 1823.

Charles Sellers, the author's elder brother, took charge of the shops in 1826. Two years later, Coleman withdrew from this partnership, moved to the Sellers lands in Upper Darby Township, Delaware County, and built the shops that gave their name to the section of Upper Darby now known as Cardington.

Before we quit school, I made all the working drawings for the Hydraulion. It is curious how, before the establishment of the shop at Market & 16th Streets, the first engines were gotten together. I have already told how the brass cylinders were bored in the garret of Market Street,[61] the patterns from which they were cast being made in father's shop and the castings being made by John Wiltbank.[62] The air vessels and other copper work was done by Israel Morris. I think this was the man, he lived on the corner of 3rd and New Sts., his shop being in the rear on New St. I think this was the name of the street, a street from 3rd to 4th opposite the Catholic Church above Race or Vine.[63] Joseph Oat was his foreman and after he went into business did the copper work for Sellers & Pennock until they established their own shop.[64] The cast iron cylinder heads were cast and turned and the stuffing boxes filled at

[60] In an 1828 Philadelphia directory, "Sellers & Pennock patent rivet hose and fire engine manuf." was located at 231 High (the Market Street store), and also at Schuylkill Seventh (16th Street) on the west side, one door south of High.

[61] I have found no specific description of Coleman Sellers's cylinder boring operation, which was no mean job at the time. It can only be assumed that the boring was done on a foot-driven lathe, however, from which I should guess that the cylinders were not larger than 4 or 5 inches in diameter.

[62] John Wiltbank, of 262 High Street (Philadelphia directories of 1828 and 1838), who bought the Cardington property upon the failure of the Sellers brothers machine works in 1838 or 1839 (Memoirs, book 5, p. 17).

[63] This was St. Augustine's Church, on North 4th Street, between Race and Vine. New Street is correct; it was also called Story Street.

[64] Joseph Oat was a coppersmith at 12 Quarry Street for some time before taking his son, in 1843, into the partnership of Joseph Oat and Son (Nicholas B. Wainwright, *Philadelphia in the Romatic Age of Lithography*, Philadelphia, Historical Society of Pennsylvania, 1958, p. 159).

Oliver Evans' shop corner of Vine and Ridge Road, the levers were forged and fitted up at his blacksmith shop on Cherry Street,[65] the ash wood handles were turned by Hansell,[66] the wheels and running gear at a carriage shop at Hestonville (I cannot recall the name) and the box or body for the first engine was built in the back shop on Market St. and afterwards in the new building on 6th Street[67] until the advent of the Market & 16th Streets shop. I must not forget the painting, which was done by Woodside the sign painter.[68] With all this scattered work you can form some judgment of the amount of leg wear to a boy old enough to run errands. Samuel Meredith and George Rawlings built the first engine bodies.

After the advent of the regular fire engine shop, things were consolidated and systemized and a much better character of work was turned out. To do that with the character of tools then in use the highest character of skilled labor had to be employed, which they were very fortunate in securing.

The only labor saving machines for wood work were a small circular ripping saw driven by a hand crank wheel [and] a pattern maker's lathe driven by the same crank wheel. In the finishing room were plenty of vises, cold chisels and files. There was one hand lathe for metal which had a Maudslay slide rest that belonged to father who had purchased it from a workman who brought it from England. I recollect that he paid $40.00 for it. It was too tall for the lathe in the little home shop without blocking up. There was also a small wooden shear (iron slided) slide lathe for turning piston rods, etc. All drilling not done in the lathe was done by a hand crank with a weighted jointed overhead lever or with ratchet drills.

The blacksmith shop was the best equipped of any part of these works—it had four regular fire hearths and a small one for tool dressing. The bellows for the large hearths were home made and as I think father designed them they may be worth describing. They were oblong square boxes the size of which, as near as I can recollect being 3 x 6 feet and 12 or 14 inches deep. There were double flap valves in its solid bottom and the lower leaf, the size of the box, was hinged at the travel end and leathered in the usual manner. The box was the air chamber and between its upper edge and a float plank was a space of about 6 or 8 inches leathered so slack as to allow the plank to sink to within a couple of inches of the bottom of the box. To keep this floating plank central there were a couple of upright round rods that passed loosely through holes in cross bars above the box. This float was loaded to the pressure of the required blast.

The first work that I recollect in the shops was the making of a number of what they called village engines. These were made for sale without regard to special orders. Then followed a larger class on which taste was displayed in the design. They were mounted on springs with galleries for goose neck and branch pipes, as well as for the hose attachment at the side and with suction to take water from ponds or cisterns.

Though still a school boy I was actively at work on the fancy designs. I have some of these sketches but do not know where to lay my hands on them. Playing from the gallery and through the hose from the side attachment was what made Pat Lyon dub them as "D. D. Cholera Morbus Machines." I think the first of these large fancy engines was built for the Philadelphia Hose Company, then followed the Phoenix, and at this time a first class engine was being built for Providence, R.I., and another for Richmond, Va., also one for Washington, D.C. I think the last built by the firm was the Assistance and it had father's floating piston in the air vessel, and on a trial with the "Diligent" thoroughly wet the ground several feet beyond the "Diligent's" last drop.[69] On one of my visits to Philadelphia after the burning of the Theatre opposite the Girard House I was told by an old member of the Assistance that after the steam fire engines had failed to extinguish the flames on the high cornice of the Girard

[65] Oliver Evans's Mars Works were at 9th, Vine, and Ridge Road. I know of no Evans shop being on Cherry Street.

[66] Thomas Hansell, turner, next to 41 North 8th Street (Philadelphia directory of 1817).

[67] Perhaps 10 North 6th Street (Memoirs, book 4, pp. 66–67, book 17).

[68] A favorite of the Philadelphia fire companies, John A. Woodside is mentioned frequently in the account of fire companies in SCHARF AND WESTCOTT (Cited in note 14 above), e.g., pp. 1053, 1898, 1900, 1901, 1902; see also JOSEPH JACKSON, "John A. Woodside, Philadelphia's Glorified Sign-Painter," *Pennsylvania Magazine of History and Biography* (1933), vol. 57, pp. 58–65. Woodside is the artist who drew the picture in figure 8 (p. 10).

[69] It should be noted that this followed *Diligent* of 1820 by several years, perhaps seven or eight.

FIGURE 22.—Great wheel lathe (foreground, 1765–1800) and pole lathe (right background, 1750–1765) from the shop of the Dominy family of East-hampton, Long Island, and now installed in the Henry Francis du Pont Winterthur Museum. Note the two spring poles (one in use) at upper right. Photo courtesy of Henry Francis du Pont Winterthur Museum.

House which had taken fire, that the old Assistance was got out and did it. . . . [16]

I was going to tell of Mr. Morey's[70] efforts to have one of his interesting engines attached to a hydraulion but in detail it would be too long a story.

[70] Samuel Morey (1762–1843). GEORGE CALVIN CARTER'S *Samuel Morey, the Edison of His Day* (Concord, N.H.: Privately printed for G. C. Carter by the Rumford Press, 1945) is an inexact, uncritical, and slight work. More solid information is to be found in *Dictionary of American Biography*. A sketch of Morey's steamboat enterprises is given in GREVILLE BATHE, *An Engineer's Note Book* (St. Augustine, Fla.: 1955), pp. 123–144.

I think the old gentleman came from Hartford, Conn., bringing a working model of what he called by so long a name that I cannot recall it, but the substance was that it was an explosive vapor vacuum engine. The machine he brought had two single acting cylinders about 10 inches in diameter and he used turpentine or any substance that would, at a low temperature, give an inflammable vapor. He claimed that for fire engines, his engine could be put in operation in less than a minute after lighting his lamps under the vaporizer.

He exhibited his model propelling a bateau on the Schuylkill and it was then brought to the fire engine shops. I do not recollect that he had any plans to attach it to the fire engine pump; I think he only proposed to furnish the driving power.

Finding a set of light small wheels, I think those that had been used on the Perkins garden engine, he proposed to demonstrate the practicability of running the engine to a fire without the aid of men with the long ropes. For the purpose he mounted a kind of buckboard carriage and to prevent firing of this board he placed under his vehicle cylinders a pan containing water. When the explosion took place in the cylinder a flame would shoot through a clap valve at the bottom of the cylinder into the water. At every explosion he would get a vacuum about equal to what was got by the doctors in the old fire cupping process. On the up stroke of Morey's engine, atmospher[ic] air and vapor were drawn in, the valves closing before the piston had quite reached the end of its stroke, in doing which it forced a small hole opposite to which a lamp was burning, the flame of which was drawn into the cylinder and its inflammable mixture exploded and the piston descended by atmospheric pressure into the vacuum.

After Mr. Morey had made what he thought satisfactory yard tests, he had the gate onto Market Street opened that he might mount the seat he had provided, guide the machine and run out Market Street which was then a common road not having been paved with cobble stones although the side gutters were paved with brick, but the narrow paved sidewalks were not curbed.

In starting the machine, somehow Mr. Morey when about mounting his seat lost his hold, tripped and fell flat. As he gathered himself up calling "Stop her, stop her," which no one seemed ready or knew how to do, the thing ran across the street, through the gutter, over the sidewalk and turned a sumersault into the brick yard where the clay had been cut away several feet lower than the sidewalk, a complete wreck. This was the end of the vacuum engine. [17]

There were some incidents connected with Sellers & Pennock's fire engine shops that, as they had a bearing or influence on my mechanical education, it may be well to relate. Charles was more at the shops at that time than I was for I seemed to have found my place in the Market Street store weighing and putting up card teeth, giving them out with the leather to the setters, keeping the accounts, taking in, inspecting and paying for the work done. As near as I can recollect, the average number of workers was considerably over 200. There was a great register book with names and residences, this book had been kept from an early time, and I recollect once having counted over 3,000 entries in it. Charles about that time had begun mould making, and the frequent drawings that I was doing for father led me to the engine shop as often as I could get there.

I recollect on one occasion seeing a short thickset man walking about the shop looking at the work going on, and he seemed to be explaining what he saw to a smooth faced young chap who was with him. Their dress showed them both to be foreigners and when I got near enough to hear him, it was in German that he was speaking. Somehow I became interested in watching the man and when father came in I reported the man's actions to him. Father asked if he interfered with the work and when I replied "No," father then said, "Let him amuse himself."

Soon after I again met the man and was surprised when he spoke to me in good English and said he was a workman looking for a job, that he had been looking around and thought he would like to work in the shop and asked me to whom he should apply. I took him to father who was then in the office and after he had made his application father asked him his trade or what branch he worked at. His reply was, that it did not much matter, he had been looking around the shops and he could do anything he saw being done there. At this reply father had a very quizzical look and asked him what trade he had learned.

None in particular: in the Polytechnic he had learned how to use tools and he had been working around in different shops for over two years. Father asked where, to which he replied London, Manchester, Liverpool, five or six months for Kemble at West Point and his last place had been in Allaire's shops in New York.[71] Father made some remark about his wandering habits and told how long some of the hands had been with them.

"Yes," said the man, "but the more move the more learn and the better work do." Some allusion was made to the young man with him and it was asked if he wanted work too. "No, he go to school when I go to work."

[71] Gouverneur Kemble, "The West Point Foundry," *Proceedings of the New York State Historical Association*, (1916), vol. 15, pp. 190–203. James P. Allaire (1785–1858) is noticed in *Dictionary of American Biography*.

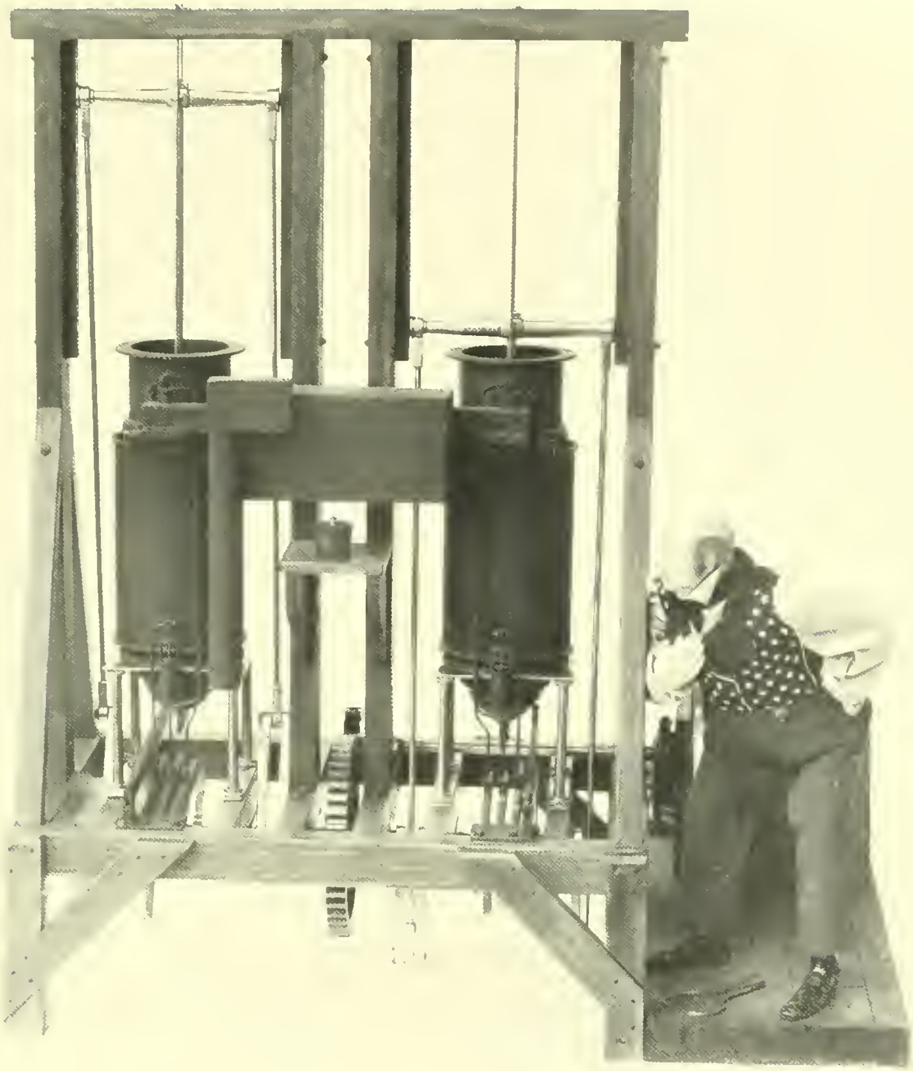

FIGURE 23.—Model of Samuel Morey's turpentine engine, 1826–1828, the earliest recorded American internal combustion engine. The turpentine vapor carburetor was in the large box between the two cylinders. After explosion of the vapor, water was injected into the cylinders to produce the vacuum which caused the pistons to descend under atmosphere pressure. *USNM* 314668; *Smithsonian photo* 43888.

Father asked the place of his nativity and to what Polytechnic he went. To the first question I think his reply was Bavaria, and to the second Heidelberg, but of this I am not quite certain. There was a good deal more talk and among other things Father asked what wages he expected to get when he told father he left that entirely to his employers. Father told him that at present he did not see an opening for him, and to this his reply was "No matter; any time." When asked to leave his address he wrote "Henri Mogeme" and the name of a tavern that was in the next block east on the south side of Market St. next to Wiltberger's iron foundry. It was a frame building with a long range of back buildings, stables and stock yard—a kind of drovers tavern. On some remark of father's to its being close at hand, he said, "Yes, I always like to be close to work." Father told him if there was any opening he would let him know, but instead of leaving the man stood, then said as if talking to himself, "I see no coppersmith's bench or tools."

Father said, "We have that work done out."

"Better work, better fits if done here."

When father told him that there was not work enough to warrant starting a coppersmith's shop the man said he had a tool chest and only some mandrels were wanted and went on to say that the little waste scrap room adjoining the blacksmith shop was big enough for all the copper work and to cast the brass. He was then told that there was but one brass founder in the city that could cast the cylinders and that the air furnace in which the brass was melted was almost as big as the little room by the smith shop.

"No want air furnace, one big pot, or two next big better—no blow holes to cast up no plugs to put in cylinders (he had seen this being done)—good cylinders, no bad castings. Only one little *chimbly*, two grates, bricks, one man to help mix cement and I build him in two days." Father seemed a good deal amused at the idea of starting two branches of business with one man in the little scrap room and he said he would have to talk with his partners about it. The man on leaving asked when he should come again and was told any time after tomorrow.

After he left father said that man was a puzzle to him. He might be a very useful hand or a very mischievous one, but that he was certainly a better educated man than any foreign workman they had ever employed and that he certainly had a good conceit of his ability.

All the coppersmith work being done at the shop on New St. so far away from the engine shop made it necessary for Joseph Oat to be sent for if any small change was to be made or any brazing or soldering to be done and this was not only troublesome but expensive and to have it done in the shop was certainly more desirable.

It was not many days before Henri Mogeme was installed in the waste scrap room fitting it up for his copper work. As I have always considered Mogeme's advent at the shops as the most important step in my mechanical education . . . I have gone into the detail of the matter. I do not claim a recollection of the various conversations verbatim, but have put it in this shape as the easiest to be understood as well as what will follow. I never went into his shop that I did not learn something. He was always ready to answer my questions and mostly with some illustration. I will give an instance:

I once found him tugging at a bellows with a small crucible on a blacksmith hearth, and I asked him what he was doing. He told me to look on and he would show me. He said he was making solder to braze fine finished brass to copper without melting or hurting the brass. He told me the exact weight of clean copper he had in the pot (a little pile of pieces): he also told me the weight of the spelter, which he said we called zinc, and also of a piece of bismuth. All these must be put in after the copper was melted. I could only see something sparkling as if burning in the crucible . . . .

Mogeme explained to me that what I saw sparkling in the crucible was charcoal brays, to prevent the oxidation of the melted copper; while talking he kept blowing the bellows. After a bit he said, "Now he is melted." He scraped off the charcoal, dropped in the zinc piece by piece, stirring all the time, and finally put in the little piece of bismuth, then the whole was poured out on a flat plate of iron, broken up with a hammer as it cooled. When done he said all right, that he could now braze the finished brass coupling screws to the copper pipes without hurting or melting the brass. Then to show me why he had melted the copper first he put a piece of zinc in an iron ladle and told me to watch him melt, then he get red, then he grow littler and littler and go off all in smoke. He said we called it "sublimating."

Mogeme was a capital teacher: when explaining anything to me it would be as if I was entirely ignorant. He would say, "No understand without beginning right." At the time I refer to he gave the formula for solders for brazing iron and steel, copper to copper and copper to brass, and he was very particular to see that I had put them right in the memoranda book I carried.

He had learned that in a boyish way I was interested in mineralogy and he gave me many fine specimens which I could never learn how he obtained. At the time of the solder making he gave me some fine specimens of the Franklin ores from New Jersey, one or two of which I still have. At this time he told me that when coming from New York to Philadelphia he had gone to see Dr. Franklin's Dead Furnace. He said it was choked to death. In the bottom (the hearth) was salamander, iron, cinder and charcoal all mixed up and massed. The top of the furnace also choked—the harder they blow the more he choke. He then said he would show me how. He pounded up a piece of the ore and separated the specular iron ore from the zinc and put some of the zinc on a plate of iron, laid it on the fire and told me to see it smoke. He held a cold iron shovel in the smoke and scraped together the white deposit that was soon on it and said, "that is what chill and choke him up."

Up to the advent of Henri Mogeme all the copper pipes were jointed and the coupling screws attached by soft solder by sweating as it was called: first turning well, slipping one within the other then over an open charcoal fire soaking in soft solder and piling over the joints a mass of solder wiped into shape like the plumber's lead pipe joints. Henri's brazed joints got rid of these unsightly ones.

There were no regular foremen at the shops. I think Daniel Cullom was the name of the leading wood worker in making the engine bodies with Samuel Meredith and George Rawlings working with him. I think I have before said that there were four blacksmith fires and work was given out through the man at what was called the first fire or smith and the same plan was carried out in the finishing and erecting. If they could be considered foremen they were also workers.

Among all the hands employed I think I can safely say that not a single one had become on friendly terms with Henri. When speaking of him it was always as that mean, stingy, dirty Dutchman. As to dirty and unkempt they were not wrong when about his work. Cullom once said to me that he had tried to make up to him and had offered to treat him at the bar, but he said he never took anything. Cullom went on to say that he knew it was only stingy meanness—he was afraid he would be obliged to return it.

I said I did not think a man who had the two best rooms at the tavern, who regularly paid his board and gave the boy (as his companion was always spoken of) the best private teachers and had him always look like a gentleman could be called mean and niggard, that for my part I could not see how he did it on his wages of $9.00 per week.

That is just it, said Cullom, there is something wrong and we are bound to find it out. We know he is mean and stingy, he chews the vilest tobacco, dries the quids and smokes them in his nasty black pipe, uses the ashes for snuff and picks his nose to grease his shoes and a lot more of the same kind of stuff. I told father of this and he said he feared that trouble was coming, he had heard of a good deal of grumbling among the hands and he thought that Henri's evident partiality to me and the fact that I was so much in his little shop might have something to do with it. He did not know what the men suspected but he did know that they were shadowing Henri's every movement. Every Saturday the men were paid off, their wages being put up in envelopes and they had learned that sometimes Mogeme did not call for his for several weeks.

There were no drawings to scale in use at that time but full size drawings on boards were in common use. Father was very ready with the pencil and was one of the best offhand sketchers I ever knew and he made good use of me in making the full size drawings. In the smith shops were two great boards or boards jointed together. On one of them was half of the set of levers drawn to full size for the large engines and on the other were the levers for the village engines which the blacksmiths worked to for the curves. In making these drawings part of the time I was obliged to lie on my belly and use my arm as radii for the curves with father standing by directing the changes of the trial marks I made.

No rolled iron was used; all the iron came from a charcoal forge on the Brandywine near Coatesville, I cannot recall the name. Wooden patterns were sent. In order that the main lever bars might be drawn to the proper taper and the centre piece or drop from the fulcrum to give the motion to the horizontal pump chamber, patterns were made.

The two principal welds were to connect the arms to the centre drop. They were scarf or top welds and for the large levers when finished would be about 5 or 6 inches $\times$ 1 inch. There was a great deal of hammer and flattening work done on these after they came from the forge. A lever on a large engine (I think it was the Philadelphia Hose Co.) gave way at one of these welds. Externally it looked to be perfect but there was a considerable cavity internally showing that in welding cinder had been enclosed. Father had given directions to the head smith to be very particular in shaping the bevels to be welded so as to have them so shaped that the first blows should be effective on the centre and drive the cinder out if there should be any.

An engine had been shipped to Richmond, Va. It went on the deck of a schooner, I think on a line called Hands Line for Norfolk and Richmond, and George Rawlings went along as caretaker. Father followed by the Steamboat and Stage routes via

Washington and Fredericksburg and expected to be absent some two weeks. Cousin James Sellers was to be at the shops with Charles, who acted as time taker, etc. Cousin James was taken sick and Charles was there alone. I went out to the shops to see how he was getting along and as I went in Mogeme signalled that he wanted me in his shop. He told me that Jack—I do not remember his last name—was getting his hollow fires ready to weld up a set of levers and that if I would go and look I would see that the bevels for the top were not made with the care father had directed.

I went into the shop with a carpenter's rule in my hand and as I knew Jack was a very touchy fellow I spoke to him pleasantly and laying my rule on the end of the piece that was then resting on the anvil ready to be put in the fire I saw at once that if the other piece was not better, that if not perfectly clean, cinder would be wrapped in. I said, "Jack you are going to take a heat and shape these as father directed."

He said, he knew his own business, they were all right and that he was not going to take any orders from a boy who knew no more about it than a cow.

This got my back up and I said, "Jack, if you make that weld without doing as father directed I will tell him when he returns."

Jack worked himself into a rage, blustered and talked loud enough to be heard all over the shop and roared out, "that I might tell and be d—d for all he cared he was not going to be bossed by a boy." He took off his apron, threw it down and went talking to the other men, evidently trying to induce them to join him in a strike against being bossed by a boy.

I started to hunt for Charles and have him try his hand at getting rid of the fellow and prevent his making trouble with the other hands, but Henri beckoned me into his shop and said that fellow had told me I didn't know any more about it than a cow and that I should go back into the blacksmith shop, take hold and show him if he was still there and the other hands that I did know something. He said that the smith who had the fire next to Jack was a good workman and could be relied on to help and that he did not think he had much love for Jack. His helper was a German called by the other men Dutchy.

The idea of my attempting to make the weld, only a school boy not yet 15 years old who had never welded two pieces of metal together, was absurd and I told Mogeme so. His reply was characteristic of the man: "Does the leader of the music band make the music? No, his baton only keeps time. Does the little hammer make the big weld? No, it is the baton; the two big hammers they do the work." He then rapidly told me what I ought to do, that he would attend to the proper heat, that he and Dutchy would be strikers, that I must have Jack's helper at the bellows and to handle the drop piece as it was too heavy for me and the second smith must handle the long bar and that he, Henri, would attend to the proper placing before a blow was struck.

After everything was arranged and fully understood between him and me, no one to know of this consultation and he not to be called until everything was in readiness, when I was to direct what I wanted him to do. The first man I spoke to was Jack's helper whom I asked if he wanted to quit, and his answer was No. Then I told him to get his fire in order and take a heat on the drop bar and I would try and see if I couldn't shape it as it should be. Then to the man at the second fire I told to take the long lever bar and shape its end as I should direct ready to weld and to get his fires ready for a welding heat. At that time Liverpool coal was used for hollow fires.

I then sent for Mogeme and when he came (as it had been prearranged) I told him that I was going to make the weld and show Jack, who was still there, that I did know how to do what I had directed him to do, and asked if he would strike for me with Dutchy as I was not strong enough and that Jack's helper and the second smith would have to handle the bars for me. Of course Henri agreed to do his best. He also attended to having the heats right and clean. It may have been for the fun of the thing or for a real desire to help me that he did these things.

The second smith and helper brought the bars properly together on the anvil and I with a pair of tongs had hold of the drop piece, more to steady myself than anything else for the maneuvering was left to those who understood it and could better manage. I got my first tap with my hand hammer which was quickly followed by Henri and Dutchy, but at first so lightly that I thought the job would be a failure but they knew better, increasing the force of their strokes, and in less time than it has taken me to write this the weld was made and I took up the planishing swedge, unfortunately by a firm grasp of the handle and the first stroke sent a shock up to my shoulder that made me wince, which Henri must have seen for he said, "Hold him loosely to find his own flat." When the planishing was done I took up a handled chisel to do some trimming when Jack pushed in and took it out of my hand (in welding there had been considerable spreading that had to be trimmed off).

He said, "Let me finish it. I take back all I have said, I have been making a blasted blustering d—d fool of myself and I promise not to do so again." I was glad of the relief for I was near giving out. I no doubt deserved credit for my pluck but not for making the weld which I got, for it really belonged to Henri Mogeme and the helpers. The object was gained and before father's return from Richmond there were some well made levers finished . . . .

One day, I cannot say how long afterwards, I was in the Market Street store giving out cards to be set and there were a number of girls between the desk and the counter when the front door opened and a man dressed in black with a low crowned broad brimmed hat with a wisp of crape around it came in. The man's face was clean shaved and under the rim of his hat dark hair curled in ringlets as if just from the curling tongs of the hair dresser.

The man spoke before I recognized that it was Henri Mogeme. He said he had come to bid us Good-by as he was about to sail for his old home. I took him to the back end of the store and father and A. L. Pennock were there. When he took off his hat father remarked that he had grown some ten or more years younger. History was soon told. He had a roll of papers in his hand which he unrolled and showed us colored drawings of Hydraulions in detail. He said this was the work of his nephew. He said that after graduating at the Polytechnic he resolved to make himself a practical workman and the only way of doing so was to go out incognito and that his father, the Duke, thought it a mad scheme and was not willing that he should go alone and he had therefore taken his nephew who was an orphan and for nearly four years they had been together. He said that while in France and England he had made several visits home but had not been home since coming to America and that now he was obliged to return as his father had suddenly and unexpectedly died. He said that under an assumed name and character was the only way he could accomplish the object he had in coming to this country because he knew the Americans' fondness of toadying to titled foreigners and that as a son of a Duke with the prospective title society claims would have taken all his time. There was but one person in America to whom his identity was entrusted and that was Mr. Biddle the head of the broker firm and that was a necessity in case of any trouble, such as his fellow workman had tried to bring on him . . . .[72]

In showing his nephew's drawings it was to show how well he had played his part as they had a large number of drawings of American machinery which he said might be useful to him. He regretted that he had not been able to devote some time to the west, particularly the steamboat navigation of the great rivers. When I asked after the boy he said he was in New York getting their belongings ready for a vessel to sail directly for a German port and that they had already engaged passage. [18]

[72] I have found no further information on the German, except for the deleted portion (2,500 words) of this passage, which tells of the spying on Mogeme by other workmen. A review of published travels has yielded nothing.

8. Isaiah Lukens and Joseph Saxton

Two of the most attractive personalities delineated by Sellers were those of Lukens and Saxton, both small town boys who became outstanding craftsmen and innovators. Lukens, nearly 30 years older than Sellers, is seen as patient preceptor and friend of all boys of mechanical bent who came his way. Sellers and Saxton, who was about 10 years older than Sellers, became fast and life-long friends.

Isaiah Lukens was born in 1779 near Horsham, in Montgomery County, Pennsylvania, less than 20 miles north of Philadelphia.[73] He grew up to the trade of clockmaker and watchmaker, in which his father was engaged. He was about 32 when he went to live in Philadelphia, taking up residence in his shop in back of 173 Market Street, probably near Fourth Street.[74] In the 1813 city directory he was listed as "turner &c." He built many tower clocks, his most noted commission being that in 1828 for the clock to be installed in the restored tower of the old State House, now Independence Hall.[75]

At the first election of officers of the Franklin Institute in 1824, Lukens was made vice-president, an office that he held for many years. Having become interested in the then new surgical operation of crushing stones in the bladder in order to permit flushing out the fragments, he devised an improved lithontriptor, a claw-like instrument that could be manipulated externally. In 1825 he journeyed to England to introduce his instrument there, but apparently it was coolly received.[76] He returned home in 1827 or 1828. He died in 1846.

Lukens was a fine craftsman in the best tradition, and his most proficient pupil was Saxton.

Joseph Saxton was born in Huntingdon, Pennsylvania, on the banks of the Juniata, in 1799. The second of 11 children, he was put to work at the age of 12 in his father's nail factory, and he was apprenticed for a time to the village watchmaker. When he was 18 he made his way to Philadelphia, traveling by boat to Harrisburg and thence overland on foot to his destination.

After having mastered the skills that Lukens could teach him, Saxton visited England in order to enlarge his knowledge.[77] In the several years that he spent in London, principally as an assistant to Jacob Perkins in his Adelaide Gallery, Saxton became acquainted with some of the outstanding engineers and scientists of his day. Among his acquaintances was the celebrated Faraday, lecturer extraordinary of the Royal Institution in Albemarle Street. It was Saxton who in 1833, building upon the discoveries of Faraday and others, devised a successful though

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[73] A sketch of Lukens's life appeared in the *Journal of the Franklin Institute* (December 1846), vol. 42, pp. 423–425. Another is in Charles Coleman Sellers, "Portraits and Miniatures of Charles Willson Peale," *Transactions of the American Philosophical Society*, (June 1952), vol. 42, pt. 1, p. 132.

[74] "Back of 173 High Street" in 1813 and 1820 city directories. Numbering at this time was continuous from the Delaware River westward. Nathan Sellers's store, at 231 High, was next below the northeast corner of Market and Sixth, and across from No. 190, Washington's presidential mansion (Memoirs, book 17). However, George Escol recalled Lukens's "little shop of two stories in what had originally been built for a stable of an Arch St. house. It was on a little alley that ran north from Arch St. near 3rd on the opposite side of the same alley was Tom Says rooms." This was probably between 1820 and 1825, before he went to England. Later, according to Sellers, his shop was at 9th and Market Sts. (letter from George Escol Sellers to Coleman Sellers, May 4, 1895, in Peale–Sellers papers, MSS, American Philosophical Society Library).

[75] Isaiah Lukens contract with Francis Gurney Smith for making a clock for the State House steeple, April 7, 1828 (in collections of Historical Society of Pennsylvania).

[76] British patent 5255, September 15, 1825, and U.S. patent of December 30, 1826. No record of the U.S. patent survives

rudimentary commutator, which led to a practical rotating electrical generator.

Returning to the United States in 1837, Saxton was employed in the U.S. Mint until, in 1843, he moved to the Coast Survey and was given the responsibility for constructing the standard balances, weights, and measures that were distributed to the various state governments. Many examples of this work are still in existence, delighting the eye and exciting admiration for his surpassingly fine craftsmanship.

Joseph Henry paid him a well-deserved compliment in describing him as one who "had the good fortune, denied to many, of neither being behind nor in advance of his age, but of being in perfect harmony with it. He neither pestered the world with premature projects destined to failure because the necessary contemporaneous conditions were not present; nor retarded the advance of improvement by advocating old errors under new forms."

Saxton was a tall man, his forehead was high and broad, and his countenance was, according to Henry, thoughtful and benevolent. Honored and esteemed by his more illustrious contemporaries, Joseph Saxton willed to his successors a heritage of mechanical excellence that one may hope will, in time, be adequately appreciated.

Figure 24.—Isaiah Lukens (1779–1846). Portrait by Charles Willson Peale, 1816. Photo courtesy of The Franklin Institute and Frick Art Reference Library.

I have alluded to the activity in mechanic arts during the few years preceding the organization of the Franklin Institute; I now propose incidentally to speak of some of the leading spirits that conceived of and organized that institution, in what was truly a transition period. [19]

Henry and Stephen Morris; Samuel V. Merrick and his partner, Agnew, then engaged in building fire-engines; Matthias Baldwin, carrying on a general jobbing machine shop, and at the time, if I recollect right, constructing the first hydrostatic presses made in America; the members of the firm of Sellers & Pennock, Rush & Muhlenberg, Professor Robert M. Patterson, Franklin Peale, the inventor and constructor of the first steam-power coining press for the U.S

in the National Archives. Lukens visited Jacob Perkins while he was in England. A letter from Lukens to Thomas P. Jones dated March 8, 1827, is quoted in Bathe and Bathe (cited in note 26 above), pp. 128–129.

[77] A memoir of Joseph Saxton's life was written by his friend Joseph Henry, the first Secretary of the Smithsonian Institution. In his memoir Henry mentioned a diary that Saxton kept "for several years" while he was in England, in which he "recorded daily events intermingled with suggestions which illustrated his habits, his thoughts, and his varying employment" (Joseph Henry, "Memoir of Joseph Saxton 1799–1873," National Academy of Sciences, *Biographical Memoirs*, vol. 1, Washington, 1877, pp. 287–316). This diary has not been located, but the present editor maintains a fervent hope that it yet exists.

Mint, were among the enterprising and progressive men of the day, and the conceivers and originators of the Franklin Institute of Pennsylvania. I must not forget to name Dr. Thomas P. Jones, afterwards Commissioner of Patents, and Dr. John K. Mitchell, who were among the first to lecture before the members of the Institute on applied mechanics and chemistry.[78]

I have referred to the small class that William Mason gave instruction to in the use of instruments in mechanical drawing. The lessons were few, and he crowded so much into them that he soon exhausted himself. In the class I worked with were John C. Trautwine, previous to his going into Strickland's office, and while he was yet a pupil of Espy's; Wm. Milnor Roberts, Solomon W. Roberts, Edward Morris, (all well-known civil engineers); John Dahlgren, (world-wide known as the inventor of the cannon named after him, and as commodore in charge of the United States Navy Yard at Washington), all at that time pupils of Joseph Roberts at the Friends' School, 4 North Fifth Street, Philadelphia. Among this little band, of which I am alone the survivor, a life-long intimacy and friendship existed. [20]

It is hard for the machinist of the present day to realize that, at comparatively so recent a period, bedposts, legs, and rounds for the old-fashioned Windsor chairs, spade handles, rolling-pins, and the like, were turned on spring-pole lathes, operated by a foot treadle, one-half the time being lost in the backward motion of the piece being turned. Although the wheel and crank attachment to the foot treadle had been adopted for a long time, and was used by the better class of workmen, it was not until two or three years previous to 1824—the date at which the Institute was organized—that the wooden grooved treadle wheel, for cat-gut or raw-hide round belts, gave place to the cast-iron wheel and flat belt. This innovation was made by Isaiah Lukens, and was followed by Mason and Tyler. These wooden crank or treadle wheels were constructed of segments of hard wood, beech or mahogany, so arranged as to present the end grain of the wood to the periphery of the wheel, the depth of the felloes being about 5 inches; width of face, say, 4 inches, admitting of three grooves of the required diameters to change the speed of the lathe mandrel without varying the speed of working the foot treadle. To give weight to these wheels to act as fly-wheels, and to counterbalance the crank and treadle, rows of holes around the rim on its sides were bored, and cast full of lead. As late as 1828 the spring-pole lathe had not entirely gone out of use for chair rounds and spade handles, nor had small steam engines, now so extensively used, taken the place of the big wheel turned by manpower, for heavy lathe work, or to drive the grindstones and emery-wheels of the cutlers and surgical instrument makers in the cities.

It was about the year 1822 or 1823 that a Maudslay slide-rest, then a new thing in England, found its way to Philadelphia.[79] It was taken hold of and greatly simplified by Rufus Tyler, who was at that time making small iron shear foot-lathes, he having adopted the steel mandrel, conical on its front bearing, running in hardened steel collars, and also the push-pitman to the treadle, instead of the ordinary hooks (this was original with him). The lathes and slide-rests of Mason and Tyler were certainly the best tools made for sale at that time.

Isaiah Lukens was chiefly engaged in making town clocks, but found time, with never more than the assistance of one or two men, to finish two or three small lathes and an air-gun or two in the course of a year, for which there were always ready purchasers. He also got up a simple slide-rest. To cut the screws for it he converted one of his little iron-shear foot-lathes into a very effective slide lathe, with gearing to cut screws of various pitches.

The bed-plate of his slide-rest was wrought iron forged with a drop stud or spindle that was turned to fit in the ordinary rest-carrier, to take the place of the common rest. The face of this bed-plate was

[78] Merrick, Baldwin, Patterson, Jones, and Mitchell are noticed in *Dictionary of American Biography*. Henry and Stephen P. Morris were makers of iron and brass forgings and umbrella frames (Henry Morris letter book, etc., 1822–1825, 4 vols, in collections of Historical Society of Pennsylvania). John Agnew continued building fire engines when the partnership of Merrick and Agnew was dissolved in 1836; he died in 1872 (advertisement in *A. M'Elroy's Philadelphia Directory for 1840*; *Journal of the Franklin Institute*, 1872, vol. 95, pp. 214, 215).

[79] Henry Maudslay (1771–1831), of London, is generally credited with having introduced the slide-rest—which provides a positive means of guiding a cutting tool with relation to the work—into machine shops by designing and building for sale a practical rest that was immediately and widely accepted. The Maudslay design, although it had the necessary elements, was yet groping toward the solution that now appears so obvious, in which the rigidity of the rest is greatly increased by reducing its height, resorting then to other and simpler means for gaining the necessary height to reach the center of the work. (See fig. 26.)

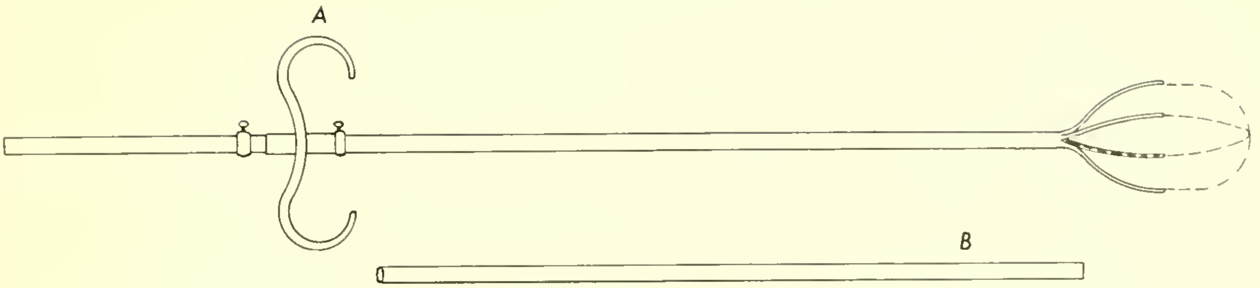

FIGURE 25.—Lukens's lithontriptor, 1825. The instrument with wires (shown dotted) for crushing bladder stones was inserted through tube B and manipulated externally by handle A. After British patent 5255, September 15, 1825. The instrument was patented also in the United States, December 30, 1826.

9 inches long by 3½ inches wide, the cross-head having a travel on it of 5 inches, and the tool-carrying block or head a traverse of 2¼ inches. These measurements are not given from recollection, but from a Lukens slide-rest now by me, that has been in my possession over sixty years, and in use most of that time. It is in good condition now. It is not like the boy's old knife, that first had a new blade and then a new handle: for the bed-plate, with its screw and traveling-head, are as originally made. The tool-carrying cross-moving head was of brass, and wore out by clamping in the turning tools. I renewed this with cast iron, but in every respect like the original.

It affords me great pleasure to give a history of this old slide-rest, as it enables me to pay my tribute to one of the greatest of our pioneer mechanics, who was emphatically the young beginner's best friend, and a sound mechanic to the core. He was a bachelor, of rather eccentric habits. He lived in his shop, sleeping in an adjoining room, taking his meals at an old hostelry on Market Street, largely frequented by the farmers of Chester and Lancaster counties, where he would meet his friends and relations from the country. He was naturally of a social disposition, although an impediment in his speech made him appear shy and diffident in ladies' society. He called his shop his wife, and he really loved it. He also loved his old grey horse that he kept at the stables of the Market Street tavern, and either in the morning before "sun up," or on moonlight evenings he would have him hitched to his yellow two-wheel top gig and take lonely rides, unless he chanced on some boy to whom he had taken a liking, then he would claim him for company. He always took a summer vacation of from six to eight weeks. At these times he would lock up his shop, and with his fishing tackle, mineral hammer, and change of clothes in his gig box, his trusty air-gun by his side, he would drive off on his solitary excursions, never hinting to his most intimate friends what course he would take. I doubt if he knew himself: but he was free to be guided by circumstances. There is scarce a point of interest to the mineralogist in northern New Jersey, eastern and middle Pennsylvania, that he did not visit, even extending his lonely drives as far south as Washington.[80]

Lukens lost an eye from a chip of steel when dressing a grindstone. Up to that time he was certainly the finest workman in Philadelphia, but afterwards he was fearful of trying his remaining eye on very fine work.[81] He took an assistant—I cannot say as to an

[80] In 1822, Lukens brought back from the Catskills a live rattlesnake, which he presented to Charles Willson Peale for his Philadelphia Museum (CHARLES COLEMAN SELLERS, "Portraits and Miniatures by Charles Willson Peale," *Transactions of the American Philosophical Society*, June 1952, vol. 42, pt. 1, p. 132).

[81] Writing to his younger brother Coleman on May 4, 1805, 11 years after this article was written, George Escol gave this slightly altered version: "Lukens was never the fine and accurate workman that Rufus Tyler and Wm. Mason were—but for speed he far outdid them." However, Lukens was engaged in an essentially different class of work from that of Mason and Tyler. In the same letter Sellers wrote of Lukens: " . . . for bushings and flat surfaces, escapements, pallets and such like his favourite tool was a soft metal lap wheel and grinding with

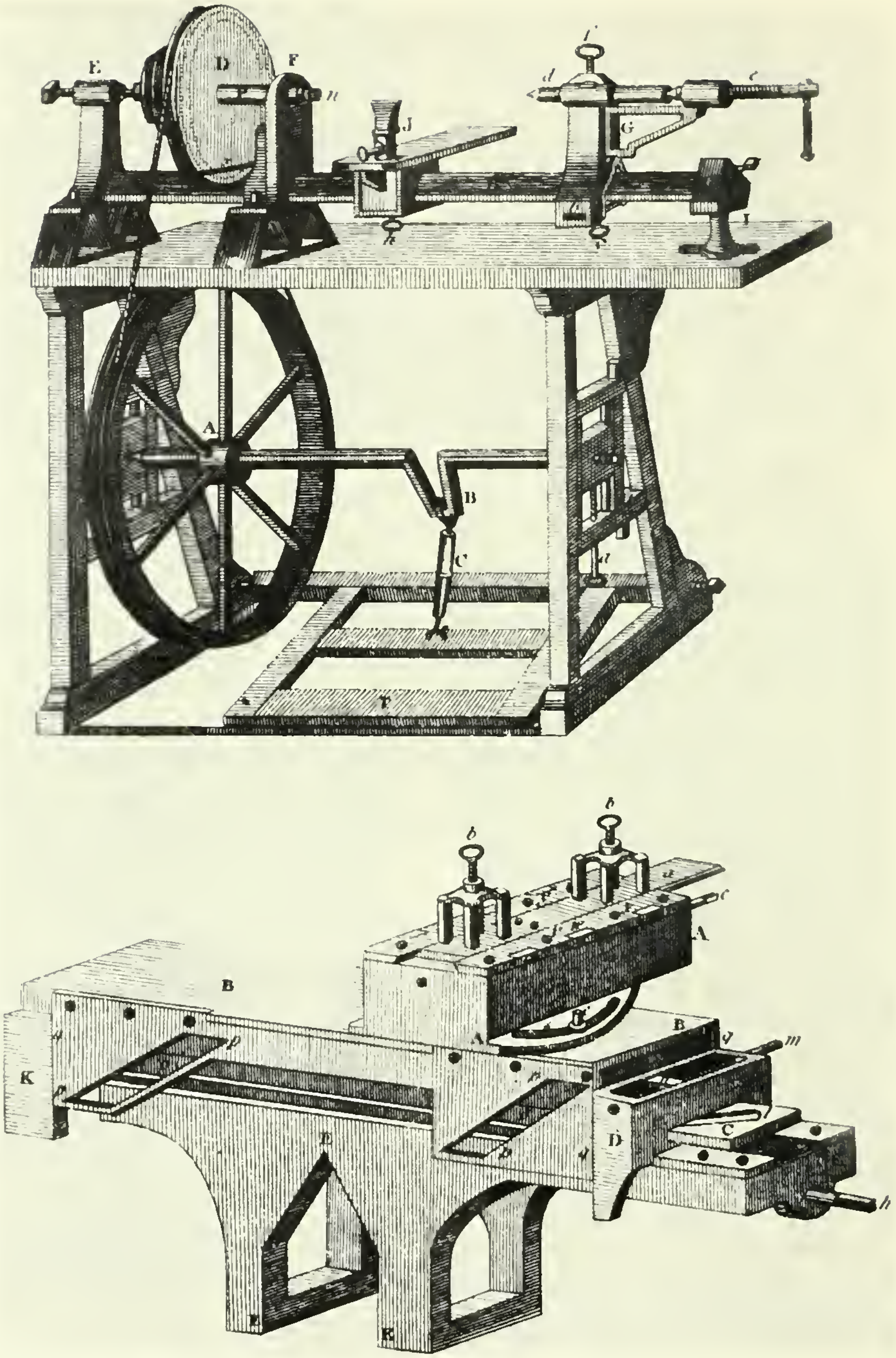

Figure 26.—Maudslay's lathe and slide-tool, about 1807. The slide-tool (lower), was fitted over the inverted-V lathe bed, replacing the conventional tool rest, shown installed, above. The cutting tools were secured under the four-legged yokes by thumbscrews *b*, *b*. From Olinthus Gregory, *A Treatise of Mechanics*, 3d ed., 3 vols. (London, 1815), vol. 3, pl. 36.

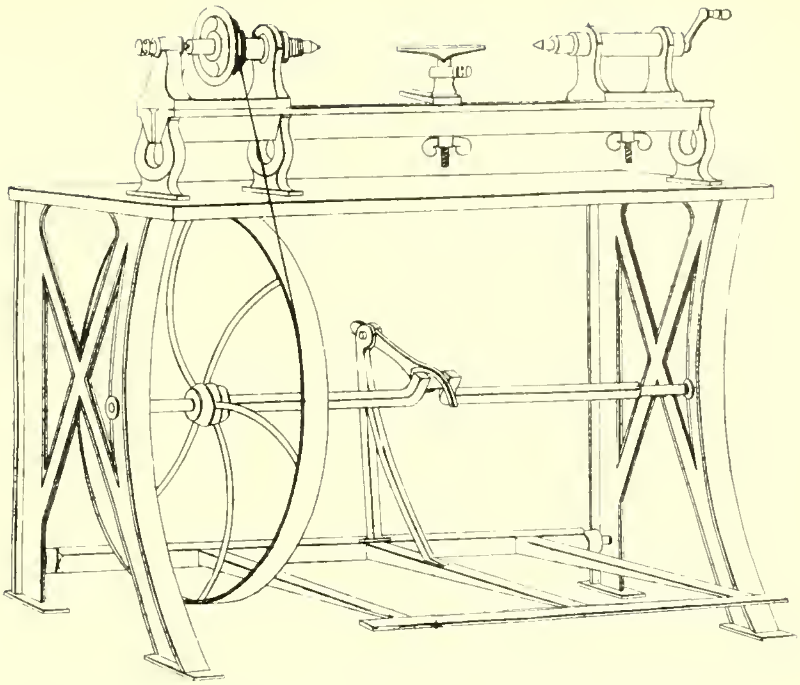

FIGURE 27.—Tyler's lathe, 1828. Built for the trade by Rufus Tyler, of Philadelphia. From *Journal of The Franklin Institute* (January 1828), new ser., vol 1.

apprentice; he called him his pupil, and he did honor to his preceptor. I refer to Joseph Saxton, who has left his mark in his scales for the U.S. Mint, in instruments for the coast survey during his long connection with Prof. Alexander D. Bache, and as head of the Department of Weights and Measures of the United States. From the time of Saxton's coming to Philadelphia we were intimate and warm friends until his death.

The first summer vacation of Lukens' after Saxton commenced to work with him, his shop was not closed as usual, but Saxton was left in charge, to "tinker," as Lukens said, with anything he liked. He planned, and was making for himself a cane gun. My elder brother and myself each concluded to make one; and, although we had every facility of the time to do the work in the shop our father had fitted up for us, there was a small portion of the work could be better done with Lukens' slide-rest.

I was in his shop beside Saxton doing that little job, when Lukens, who had unexpectedly returned from his summer trip, came in. He looked at, and asked what I was doing. On examining the plan he suggested some slight alterations. Saxton showed his gun that was completed. He had worked out the plan himself, and Lukens was greatly pleased with its simplicity.

Lukens had returned in improved health and spirits, and asked why I did not make a slide-rest for myself. He then produced the forging of my rest, and said he had rough-chipped it, had turned the stand stem, and it would fit my father's rest-carrier, and was about the right height for his lathe. He therefore told me to take it, and try my hand on flat-filing. We had no planers or shapers in those days. The hammer and cold-chisel had to do the rough work on forgings, often far from perfect and with plenty of stock left to remove. In this case the rough work had already been done by Lukens. He loaned me his patterns, from which I had the brass castings made. I cut the screws on his lathe, and did most of the work in his shop, occasionally helped by himself or Saxton. The pleasant associations connected with this slide-rest have no doubt, been the cause of my preserving it, and using it as a favorite tool during these long years. I have related the circumstance to illustrate the considerate kindness of Lukens to earnest beginners.

After Saxton closed his term with Lukens, to perfect himself as a machinist and to enlarge his views, he went to England and spent several years there . . . . [21]

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emery and oil. This was driven by a crossed catgut belt from a groove in the rim of a face wheel with a handle for crank . . . he turned the wheel with his left hand while he held his work to be ground in his right hand." (Letter in Peale-Sellers papers, American Philosophical Society.)

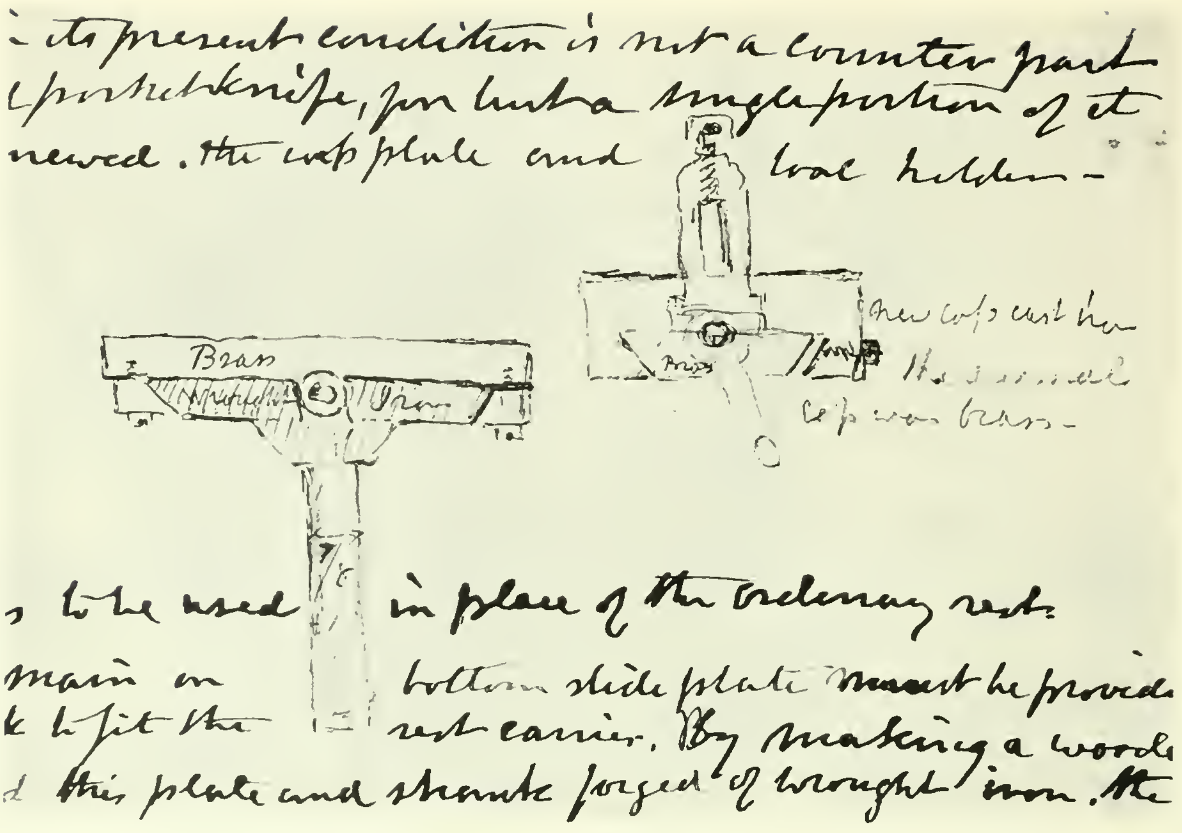

FIGURE 28.—Sketch of slide-rest as built by Sellers about 1820. In letter from George Escol Sellers to Horace Wells Sellers dated Crestview, October 14, 1895. Peale-Sellers papers. Photo courtesy of American Philosophical Society Library.

It is often the most trifling thing that changes the destiny of man. I will now . . . relate as nearly as I can, as [Saxton] did to me, the incident that decided his course and took him from the farm into the workshop.

He had sprung up rapidly, and, as he said, had outgrown his strength. The work on the farm was irksome to him, and every chance he could get he would steal away with an old flint-lock musket, whose barrel he had shortened to convert it into a fowling piece. He said his fondness for hunting and neglect of the farm work greatly distressed his father, who could know nothing of the feeling of lassitude that came over him, and the utter averison he had for his occupation. Often when he was thought to be hunting, he was lying in the shade of some tree thinking, as he expressed it, of improbable possibilities that might occur to change his father's views and take him from the plow, that was nothing but tramp, tramp back and forth in the furrow, exhausting physical powers and leaving the brain to stagnate.[82]

His father, to encourage him to greater exertion in the line he wished him to pursue, on certain conditions, promised him a rifle. He said he was not conscious that he had improved any; that he had

[82] Henry's memoir of Saxton does not mention farm work specifically, but since the community was in rural surroundings and work in the nail factory may have been seasonal, there was plenty of time for farm work and hunting, too, in the long years of youth. However, that Sellers was confused as to Saxton's boyhood is indicated by his mention, in the next paragraph, of Lancaster, which is more than 100 miles from Huntingdon. Carlisle, mentioned later in the text, is 50 miles from Huntingdon.

worked on as if in a dream, when one day his father surprised him by saying, "Joe, you have fairly earned your new rifle. I am going to Lancaster and will buy you the best one I can find. What bore do you want?"

He replied that he did not want less than three balls to the ounce, but he would prefer one-half ounce; that he wanted one that would kill a bear or bring down a deer at long range; but that he did not want any other make than Gibbs.

When his father returned with the rifle and put it in his hands he said, "Joe, I think if you lug this heavy thing a day you will soon get tired of fooling your time away hunting: but if it don't suit you, Mr. Gibbs has agreed to exchange it for a lighter one."

It was not long before he found he had made a mistake. Bears were growing scarce, the deer season short, the bullets were too large for squirrels and small game, and the rifle too heavy for quick shooting. But his pride was touched, and he was not willing to acknowledge his mistake. He found he could save lead by using a smaller ball and thicker buckskin patch; these patches he thoroughly saturated with melted tallow.

One day when starting out on a hunt he primed his rifle, shaking the powder well into the touchhole, closed the pan, and tried to force down a bullet with one of these well-greased patches, but it would not stay down; whenever he loosened his hold of the ramrod, it would rise in the barrel. After several times forcing the bullet down as far as he could by hand grip on the ramrod, and finding it still coming back, he lost patience; he put the end of the wooden ramrod against a tree, grasping the rifle in both hands, and said, "Dang you! you *shall* go down now and stay there." He gave a violent thrust.

When he got up from his back, his hands and arms were lacerated and bleeding, and his gun lay some distance from the tree further than he was. When he gathered himself up he was dazed. His first collected thought was what a fool he had been to prime his gun before putting in the powder and pushing down the ball, and then to be so careless as to have set it at full instead of at half cock, as he supposed he had done. On examining his hands he found them badly torn by splinters of the ramrod.

He picked up his rifle, expecting to find it had burst. No, it was all right. The hammer with its flint stood at half cock. On opening the pan, the priming was unburnt. Here was witchcraft, or something very like it. On examining the touchhole,

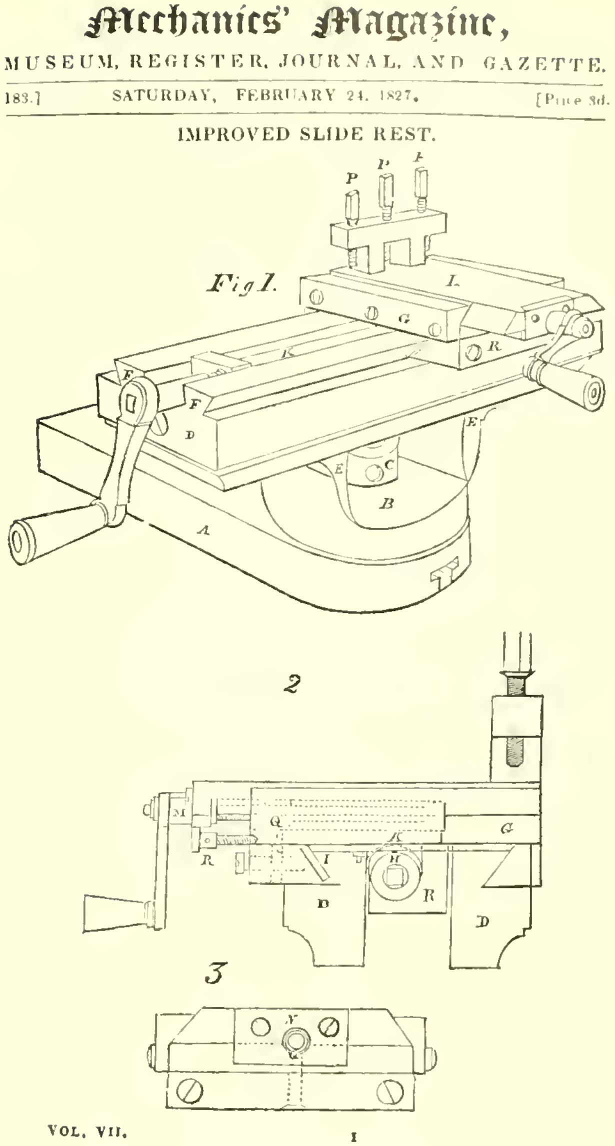

FIGURE 29.—Slide-rest, 1827, as built for the trade by Matthias Baldwin and William Mason.

he found it plugged with lead hard driven in. Little thought his father, when playing, as he thought, a practical joke in spiking the gun with a lead shot, that it would prove the turning point in his son's life career.[83]

[83] Henry's version of this story gives only the bare essentials; however, it apparently was a story that Saxton told and retold, perhaps with such embellishments as an occasion permitted.

Joe was not long in satisfying himself that it was the elasticity of the air being cut off from escape by the touchhole, and the tight piston made by the buckskin patch on the bullet, that caused the bullet to rise; but it did not to his mind account for firing the powder. Thinking it possible there might have been small particles of sand or flint in the powder, he experimented by adding to them; but neither friction nor percussion, as he tried them, would ignite the powder. He asked the schoolmaster, and the doctor, the learned men of the district, but got no solution. He said he could not rest; he lay awake at nights thinking, when it suddenly occurred to him that his gunbarrel was full of air at a certain temperature, and he asked himself the question, "What becomes of the heat in the air if suddenly compressed? would it not be sufficient to ignite the powder?" Acting on this thought he got an old pistol-barrel, polished it well in the bore, plugged the touchhole, fitted a perfectly air-tight piston, on the bottom of which he had a small projecting pin, on which he wound cotton lampwick saturated with powder softened by alcohol, and by sudden concussion ignited it. He was greatly elated, thinking he had made a new discovery.

Soon after this he went with his father to Carlisle, and there he saw a glass air-compressing pump, with a little cup in the piston for holding tinder to be ignited by the percussion of the air; and when no tinder was in it the flash of light could be seen. He also found in the hands of boys at the college little brass percussion pumps for igniting tinder.

This only increased his longing to get out into the world and learn what was doing and what had been done. His father, finding him so set in this, took him to Philadelphia.[54] All he asked was a chance to learn, and he would take care of himself.

Lukens' little shop was just the place. Although Lukens wanted help, he was averse to taking any one for a fixed time under instruction. He said to my father that it was easy enough to get any number, but not so easy to get rid of them if they did not suit him; for no matter how ill they filled the place, he could not turn them adrift. When the circumstance of the discharge of the rifle was related to him he decided to take Saxton, for he said that a boy who could work back from effect to cause was the making of a man. In this case the boy had stretched up to nearly, if not quite, six feet tall. [22]

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[54] According to Henry, Saxton, in company with two other boys, floated down the Juniata and Susquehanna to Harrisburg, where they sold their boat and continued to Philadelphia on foot.

FIGURE 30.—The second U.S. Mint, Philadelphia. Designed by William Strickland, this building was completed in 1833. From *Gleason's Pictorial Drawing Room Companion* (July 17, 1852), vol. 3.

9. The United States Mints

Early coins of the United States have been carefully described in numerous publications. However, when we ask how these coins were wrought we find that little attention has been paid to such questions. Modern textbooks of diesinking, for example, leave a distinct impression that the art was commenced yesterday, or perhaps this morning, and that it came into being in perfect, complete, and final form. Nor has the evolution of the several processes of casting, rolling, annealing, blanking, edging, coining, and so forth yet received much more attention from the technical historian than from the textbook writer.

The building in which the first mint was established in Philadelphia in 1792 was still in existence in the early 1920's. Its owner, Frank H. Stewart, tried to sell the property to the City in order to preserve it, but there was no interest shown by the City and it became another victim of progress. Stewart did, however, inquire into the history of the building, and his work, privately printed, sets forth the record that he could piece together.[85]

The present narrative presents by far the clearest picture known to this editor of what actually went on in that three-story brick building

[85] FRANK H. STEWART, (cited in note 43 above). GEORGE G. EVANS, *Illustrated History of the United States Mint* (Philadelphia, 1890), is a work concerned almost exclusively with the coins produced. PATTERSON DUBOIS, *Our Mint Engravers* (Boston, 1883), is a slight work that was reprinted from *American*

in North Seventh Street, corner of Sugar Alley.

The second mint, completed in 1833 at the northwest corner of Chestnut and Juniper Streets, was in a building designed by William Strickland.[86] In 1835, the Sellers brothers furnished heavy iron castings for new equipment in the melting department, which was overhauled by Franklin Peale after his return from a two-year study of European mints and minting procedures.[87] When the branch mints in North Carolina and Georgia were established in 1836, George Escol designed the steam engines to be used in them. His designs overturned, by the way, a dogged preference for vertical steam engines to drive the coining presses and other machinery.

Naturally, as the capital of the United States at the time, the first mint was located in the city of Philadelphia, and few realize now the humble beginning from which the greater mints of the country have sprung. The old U.S. Mint in Philadelphia was on the east side of Seventh Street, on one of those areas called in Philadelphia a city block, these blocks being bounded on their four sides by the principal streets, and perhaps subdivided into smaller blocks by alleys or courts. The particular block in question was between Sixth and Seventh Streets on the east and west and Market and Arch on the south and north, and in point of fact the building was about midway of the block on the corner of a small street named Sugar Alley, which ran from Sixth to Seventh Streets, bisecting the block.

The building used for the mint had very much the appearance of an ordinary three-story brick dwelling house of that period, the back building and yard extending on the alley. In a rear room, facing on the alley, with a large, low down window opening into it, a fly press stood, that is a screw-coining press mostly used for striking the old copper cents. Through this window the passersby in going up and down the alley could readily see the bare-armed vigorous men swinging the heavy end-weighted balanced lever that drove the screw with sufficient force so that by the momentum of the weighted ends this quick-threaded screw had the power to impress the blank and thus coin each piece. They could see the rebound or recoil of these end weights as they struck a heavy wooden spring beam, driving the lever back to the man that worked it; they could hear the clanking of the chain that checked it at the right point to prevent its striking the man, all framing a picture very likely to leave a lasting impression, and there are no doubt still living many in Philadelphia who can recollect from this brief notice the first mint.

The impression made upon me as a boy was the more enduring as it was one of almost daily occurrence. The block on which the old mint stood, besides being divided by Sugar Alley, had on Sixth Street near Market the entrance to what was known as Mulberry Court. This court extended nearly half way to Seventh Street, and at the head of the court was a dwelling house facing the entrance to the court. This house separated Mulberry Court from another alley or court that entered from Seventh Street, known as St. James Street. The difference between the terms alley and court in this case was that the name alley was given to a narrow street of uniform width, either entirely passing through the block or entering it for a short distance, while the term court was applied more particularly to a narrow entrance from the main street widening into a broader area, around which area the more pretentious houses were frequently erected.

On the north side of Mulberry Court were three dwelling houses, in one of which I first saw the light.

Journal of Numismatics (1883), vol. 18, pp. 12–16. Jacob R. Eckfeldt and William DuBois, *A Manual of Gold and Silver Coins of All Nations Struck within the Last Century* (Philadelphia, 1842), describes the medal ruling machine, which was developed by Franklin Peale from the earlier designs of Christian Gobrecht.

[86] A brief sketch of U.S. mints to 1880 is given in Scharf and Westcott (cited in note 14 above), vol. 3, pp. 1812–1819.

[87] Franklin Peale was in Europe from 1833 to 1835 (Sister St. John Nepomucene, "Franklin Peale's Visit to Europe in the U.S. Mint Service," *Journal of Chemical Education*, March 1955, vol. 32, reprinted in *Numismatist*, December 1958, vol. 71, pp. 1473–1479). The 272-page manuscript report of his visit is amongst the extensive Philadelphia Mint papers in Record Group 104, U.S. National Archives. The report refers to numerous drawings, "intended as working drawings," made to accompany the report, but the drawings have not as yet been located. The report reveals that the large balance, built by Joseph Saxton and now on display in the U.S. Mint in Philadelphia (fig. 40), was constructed at Franklin Peale's order in 1835, while Saxton was still in London. A biographical notice of Franklin Peale appears in *Proceedings of the American Philosophical Society* (1870), vol. 11, no. 85, pp. 597–604.

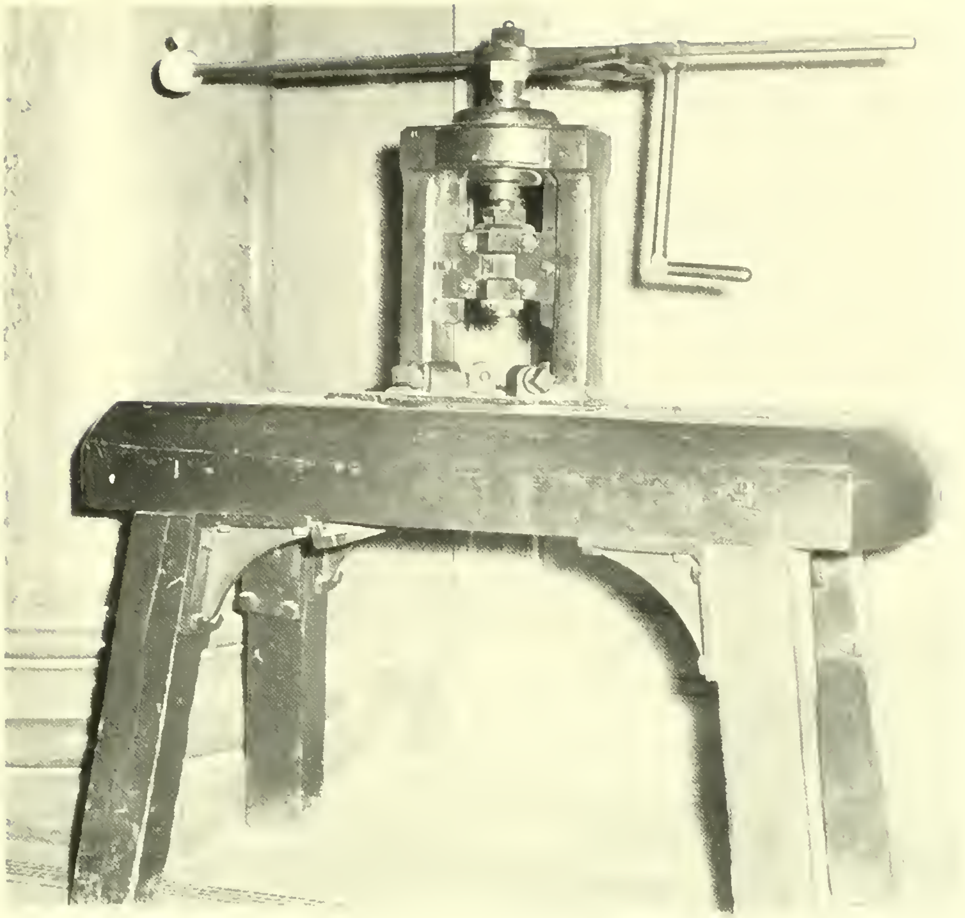


FIGURE 31.—Early coining press used in the U.S. Mint. This machine was restored from disassembled parts, leaving the arrangement of the levers in some doubt. The fly weight is too small to fit the author's description. On display in the U.S. Mint, Philadelphia. Photo courtesy of the U.S. Mint Service, Mrs. Rae V. Biester.

The lot where stood the house in which I was born cornered with one on Sixth Street occupied by Mr. Frederick Graff,[88] who followed Latrobe as engineer of the Philadelphia water-works, and who designed and constructed the Fairmount water-works; a gateway connected our yards. Mr. Graff was one of my father's most intimate acquaintances, who with Dr. Robert Patterson, then in charge of the mint, and Adam Eckfeldt, chief coiner, were together frequent visitors at our house on the court; it was a clannish neighborhood, gates connecting all our yards, even to the yard of the fire-engine shops carried on by Jacob Perkins and my father at the end of St. James. From this yard was an opening into Sugar Alley, which to us as youngsters had other attractions than the coining press, for there stood the little shop of the best molasses candy maker in Philadelphia. The house at the end of the court was eventually removed, the street being then called St. James Street, now Commerce Street, of which street it is a continuation.

One day in charge of my elder brother I stood on tip-toe with my nose resting on the iron bar placed across the open window of the coining room to keep

[88] Graff papers, consisting mainly of drawings, are in Franklin Institute Library, Philadelphia. Some Frederick Graff correspondence (1806–1829) is in the collections of the Historical Society of Pennsylvania.

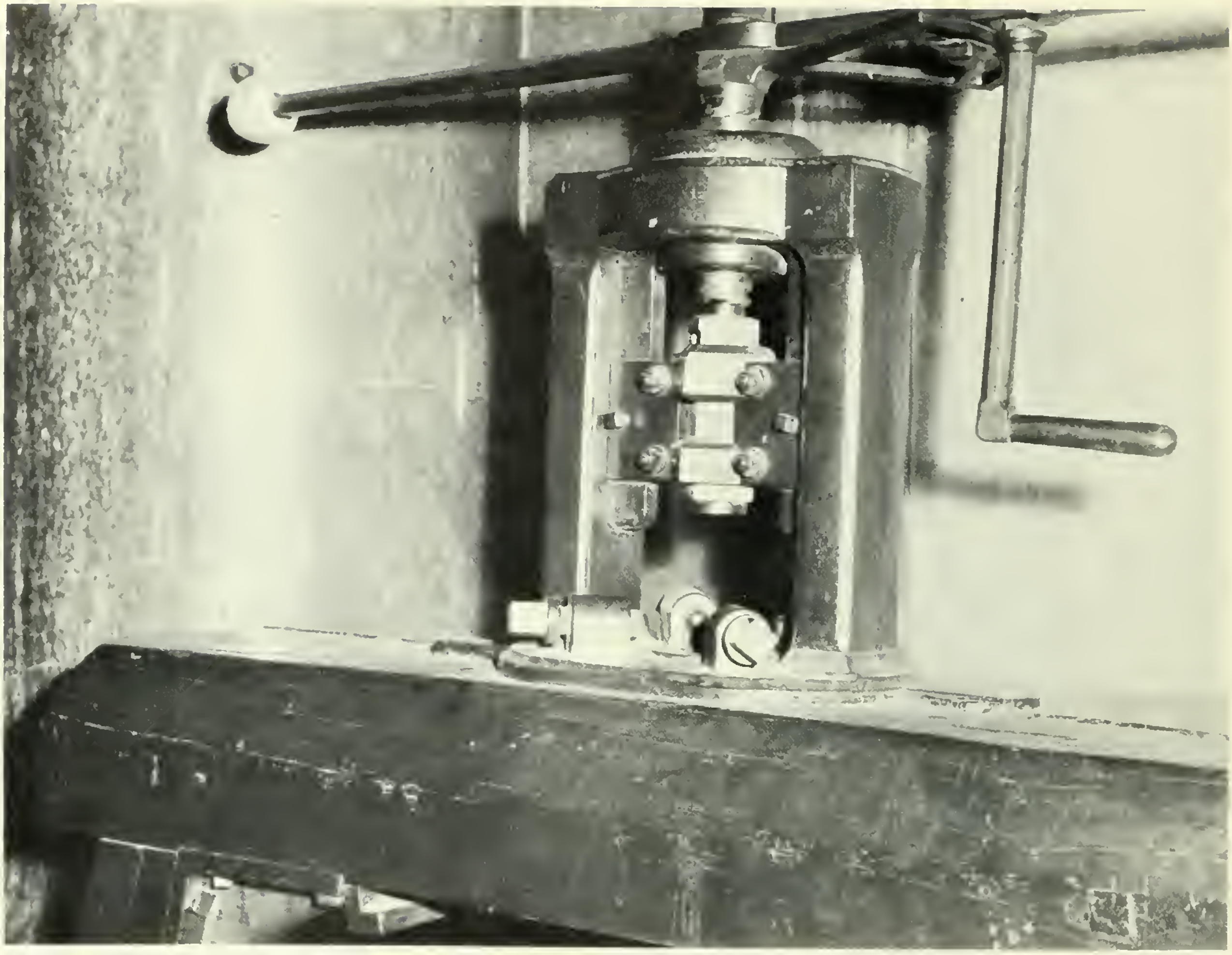


FIGURE 32.—Enlarged view of early coining press showing the relatively short "quick-threaded" (that is, of long lead) screw. Photo courtesy of the U.S. Mint Service, Mrs. Rae V. Biester.

out intruders, watching the men swing the levers of the fly press; it must have been about noon, for Mr. Eckfeldt came into the room, watch in hand, and gave a signal to the men who stopped work. Seeing me peering over the bar, he took me by the arms and lifted me over it. Setting me down by the coining press he asked me if I did not want to make a cent, at the same time stopping the men who had put on their jackets to leave the room. He put a blank planchet into my hand, showed me how to drop it in, and where to place my hand to catch it as it came out; the lever and weights were swung, and I caught the penny as we boys called cents, but I at once dropped it. Mr. Eckfeldt laughed and asked me why I dropped it?

Because it was hot and I feared it would burn me. He picked it up and handed it to me, then certainly not hot enough to burn; he asked if it was not cold when he gave it to me to drop into the press; he told me to look and see there was no fire, and feel the press that it was cold; he then told me I must keep the cent until I learned what made it hot; then I might, if I liked, spend it for candy.

When I showed the bright new cent to my father, whom I found in his workshop, and asked him to tell me what made it hot, he said he would show me; he

FIGURE 33.—Arcade Building, Philadelphia, located on Chestnut Street near Sixth. Designed by John Haviland, this building was completed in 1827. There were three floors, the first two having some 80 shops open to arcades; the museum was located on the third floor. From Traugott Bromme, *Gemälde von Nord-Amerika*, 2 vols. (Stuttgart, 1842).

handed me a common sulphur-tipped match,[89] then took up a small rod of copper, told me to feel that it was cold, held its end on an anvil, and struck it a few quick sharp blows with a hammer, then applied it to the match which I held in my hand, which to my amazement was at once ignited; he said, now you have something to think about and may be able to understand when you are older; it was an object lesson that led to many a train of thought.

When years after in speaking of it to my mother's father, Charles Willson Peale, he took up an old file of letters and sorted out a number from Benjamin Thompson (Count Rumford) and read from them many passages descriptive of his wonderful experiments and researches into the nature of heat, and its generation by friction or percussion, that have since been so beautifully illustrated and enlarged on by Prof. John Tyndall in his work on "Heat as a Mode of Motion," and by Joule on the "Correlation of Forces," after a lapse of over half a century. [90] . . .

The little yard in the rear of the old mint was a very attractive place to us youngsters [with] its great piles of cord wood, which by the barrow load was wheeled into the furnace room and thrust full size in the boiler furnace, which to my young eyes appeared to be the hottest place on earth. There almost daily was to be seen great lattice-sided wagons of charcoal being unloaded, and the fuel stacked under a shed to be used in the melting and the annealing furnaces.

As I grew older and better able to understand, my interest in all the various processes increased, from the fuel yard to the melting room to see the pots or crucibles charged with the metals and their fluxes placed in the furnaces and the fires started, and when melted to see the man with his cage-jawed grasping tongs lift the crucible out of the fiery furnace and pour the melted metal into the ingot molds. Then the rolling these ingots into strips of sheet metal, splitting and turning them into narrow strips by revolving cutting shears. Thinning or pointing the end of the strips by rollers with flatted spaces on them, so that the strips can be inserted between the regulated and fixed dies of the draw-bench to equalize their thickness as they are seized by a pair of nippers or gripping tongs, the hooked handle of which the operator at once engages in a link of the constantly traveling chain by which the strip is drawn through, between the dies, the operator then by hand pushed the grippers back into place to take a grip on another strip. These strips were fed by hand into the planchet cutting-out presses, and it required practice to attain the adroitness to so handle the strips to cut them out to the best advantage so as to leave the least metal to be returned to the melting pots. Silver planchets by the rolling and drawing process become too hard for coining without first annealing.

Then the hand-milling press was a very interesting one to watch, it was raising and notching or lettering the rim of the planchet as a preventive against clipping or robbing. This was done by rolling between grooved and notched parallel rulers or bars, one being fixed, the other movable endways by a pinion working into a rack. The operator after placing two planchets one in advance of the other between the parallel bars, then by a partial turn of a hand-crank the movable bar is thrust ahead sufficiently to entirely rotate the planchets, when they are taken out and two others put in.

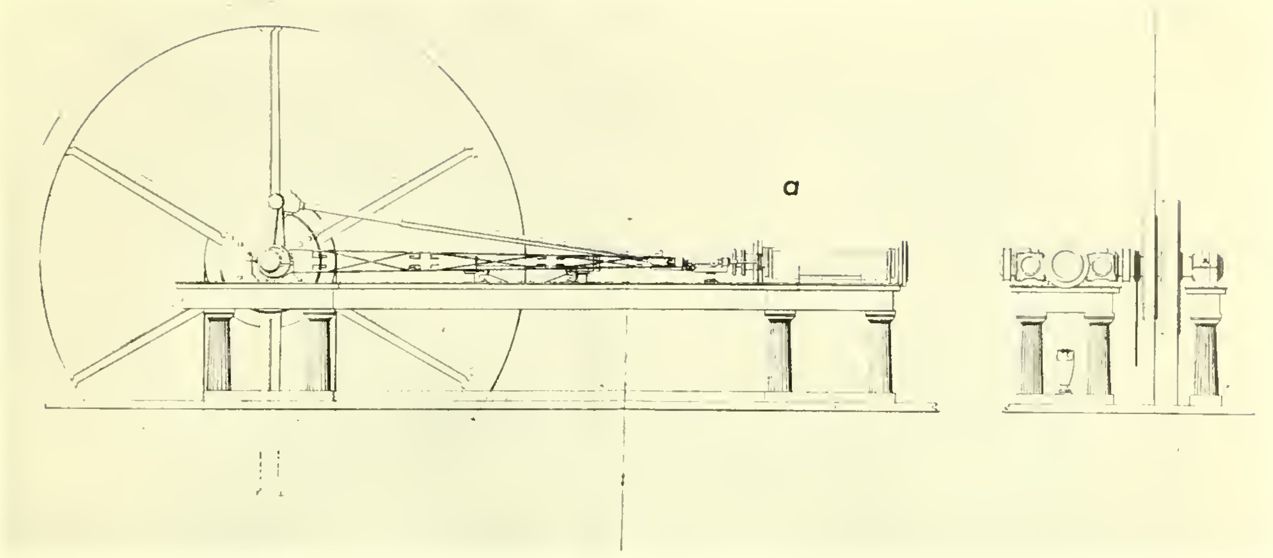
Every gold and silver planchet as cut out was passed through the hands of an adjuster; if overweight reduced by a file, a leather pouch in front of his bench catching the filings; if too light they were returned to the melter.

I have no recollection of ever having seen the copper planchets for cents being made in the mint, but I have a vivid recollection of small iron hooped casks filled with copper planchets for cents and half cents. I have the impression that they were imported as copper in that condition and only stamped or coined in the mint.[91] These casks were similar to the casks in which card wire was imported from England at that period. My object in giving these notes of opera-

[89] This is not an anachronism. "Common matches, which are in daily use for lighting fires, derive their principal utility from being tipped with sulphur" ("Sulphur," in ABRAHAM REES, *The Cyclopaedia*, London, 1819, vol. 36. This volume was published in 1816).

[90] It should be remembered that Charles Willson Peale died in 1827.

[91] The copper planchets were in fact imported for more than 30 years from Matthew Boulton works in Birmingham, England. In 1796, when negotiations for furnishing the planchets were under way, Boulton would have preferred to mint the pennies complete in his works for £140 per ton, of which £21 per ton was for minting. However, he consented to supply the planchets while pointing out that "there is an art in the annealing, without which, were the Copper rolled ever so fine, the surface would be injured, but these are things I am perfectly master of, and have an excellent Rolling Mill and every other convenience, besides which I am concerned in many Copper Mines and a partner in a Copper Smelting Works . . . ."



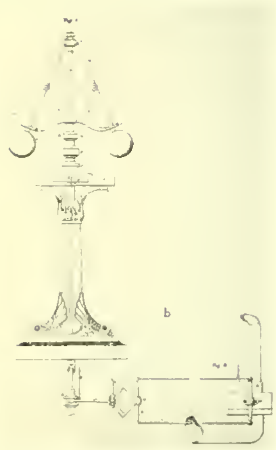


FIGURE 34.—Steam engine designed by Franklin Peale, at the U.S. Mint, Philadelphia. This engine drove the new toggle-joint coining press shown in fig. 35. The governor is shown below engine at left. Plates from Paul R. Hodge, *The Steam Engine* (New York, 1840), in which this observation appears (p. 206): "The close attention that has been paid to the order of architecture selected is very obvious in the entablature, the capitals of the columns, the ornamental tripod stand of the governor, the etruscan vase for the starting handle, and the *fret* work of the eccentric lever . . . ."

tions of the old mint is that to the general reader the advances from the old hand to steam coinage and their importance and value may be understood. [23]

When the present U.S. Mint in Philadelphia [92] was built it was furnished throughout with entirely new machinery that the old mint might be kept in full operation during its construction. The new machinery did not differ in any essential points from the well tried [machinery] of long service in the old, only differing as to amount to meet the requirements in increased coinage. With this new machinery we had nothing to do. I felt great interest in the building as it progressed, inasmuch as it was under the charge of my friend, J. C. Trautwine, then a pupil of William Strickland, its architect. After the new mint went into operation the machinery of the old mint was sold under the auctioneer's hammer, mostly by weight as old metal. We became the purchasers of the rolling mill department with its shafting and connected machinery. The housings, rolls, etc., did not go into the melting furnace, but were refitted as a

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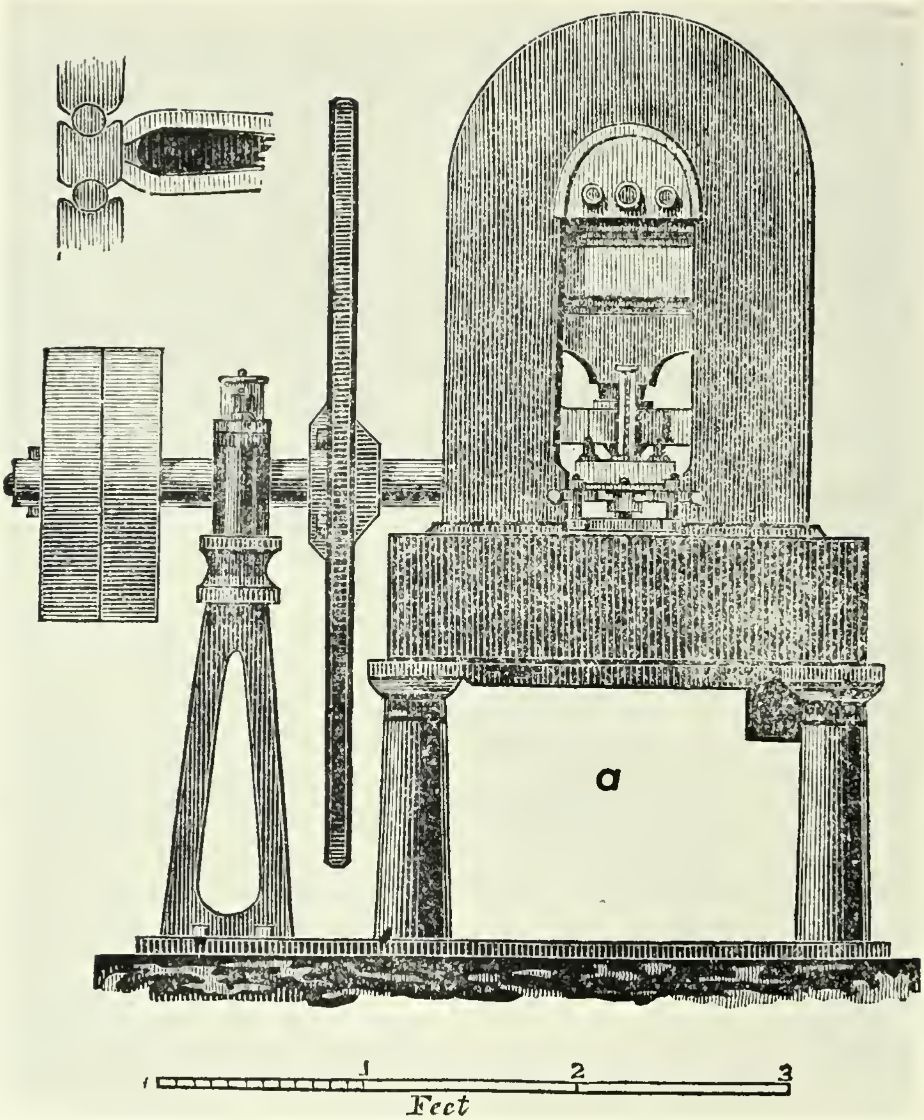
The planchets were shipped in casks, each weighing about 375 pounds. A shipment of 20 tons departed from Liverpool about a month before the start of the War of 1812; another shipment was ordered before word reached Philadelphia of war's end. The balance due Boulton and Watt in 1812, £74: 6: 11, had grown through the war to £87: 8: 10 in 1815. (Boulton to Samuel Bayard, February 25, 1796; Boulton to Boudinot, April 2, 1799, 60 casks, nearly 10 tons; invoice, Liverpool, February 11, 1812; Boulton to Patterson, May 1, 1815; all in Philadelphia Mint papers, U.S. National Archives.)

[92] The Philadelphia Mint, now located on Spring Garden Street at 16th, where stood originally the Rush and Muhlenberg Bush Hill Works, was built in the early years of this century, after Sellers's death. The "present" mint described here was new in 1833, as noted in the introduction to this chapter.



train of rod rolls and went into service in a Pennsylvania rolling mill.

In giving such recollections as may occur to me of the evolution in the various processes up to the final steam coinage, I shall endeavor as far as possible to clear them of the accumulated cobwebs and dust of time. These advances and improvements commenced during the administration of Dr. Samuel Moore as director,[93] who first saw there was room for improvement in the melting and refining department to secure more uniform results and to save waste.

For the purpose of learning what had been done both chemically and mechanically in the European mints and metallurgical establishments, that they might be introduced in the U.S. Mint, he obtained permission to appoint an assistant assayer and an appropriation to send him abroad for a thorough investigation of methods. For this purpose my mother's half brother, Franklin Peale, was selected and appointed and went abroad on the mission in May, 1833, and he was engaged in the investigation about two years, reporting progress from time to time.

[93] Director from 1824 to 1835, preceded by Robert Patterson, the elder, and succeeded by Robert M. Patterson, son of the earlier director.

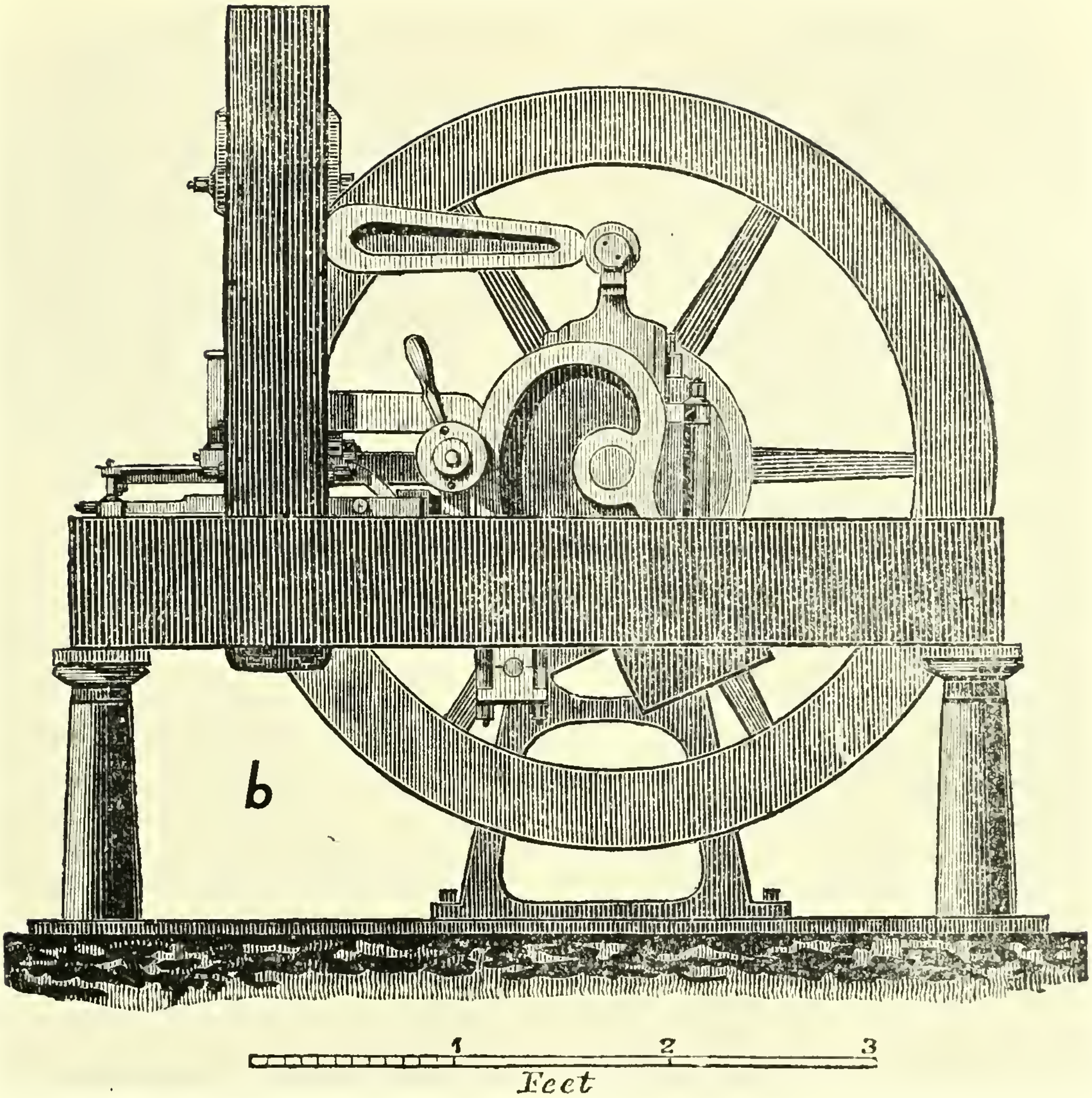


Figure 35.—First steam-driven coining press, U.S. Mint, 1836. Designed by Franklin Peale. Front view (opposite) and side elevation. Detail of the toggle joint is shown at extreme upper left of figure on p. 68. From *Journal of The Franklin Institute* (November 1836), vol. 22.

On his return he took his position in the mint as assistant assayer, and at once inaugurated the most important changes in that department, which eventually led to vital changes in coinage from hand to that of steam power, but of this further along. To show the fitness of Mr. Peale for the position which led to such important results, a résumé of his early training will not be out of place here.

. . . . Franklin of his own volition had gone to the cotton factory of William Young, on the Brandywine, in Delaware, to learn the trade. Mr. Young was a friend of the family and great confidence was placed in his counsel and advice in leading the boy out of what was considered a foolish whim. Connected with Young's cotton factory was a machine shop for making carding and spinning machinery. It was carried on, if I am not mistaken in the names, by the brothers Hodgson; [94] into this Franklin soon drifted. They were for the time considered very fine workmen when hand tools had to be depended on. I have heard one of the brothers say that within a year Franklin with cold chisel and file on hand . . . work far excelled them.

When Franklin became satisfied that he had learned all he could in that establishment he returned to Philadelphia and went to work with my father, who was at that time a member of the old firm of N. & D. Sellers, at making machines for cutting and bending wire into card teeth. While working at that my elder brother worked with them, and I got many good lessons in the handling and use of tools. He was a skilled workman as a turner on the foot lathe with hand tools. I have rarely seen his equal, never his superior. In that shop to show his skill he turned one of those wonderful ivory balls—three skeleton balls one within the other—in imitation of those brought from China. As to filing flat surfaces, to show and explain how a file should be shoved to avoid rocking I have seen him file a piece of metal over two inches broad, so that when a straightedge was laid on it bore on the extreme outer edges, and light could be seen under the center; in others words, filing to the curvature of the file he was using.

At a later period when he was manager of the Philadelphia Museum he delivered such chemical and other lectures as could be made interesting to the general public by brilliant experiments. He also exhibited many ingenious automata of his own invention and construction. About the same time he delivered at the Franklin Institute a course of lectures on machinery, illustrated by models and movable card drawings.[95]

About the time the accounts came from England of the locomotive experiments on the Liverpool and Manchester R. R. that excited great interest in all civilized countries, Mr. Peale, to profit by the excitement and general interest, designed a model locomotive, based mainly on the description of the Ericsson engine in the Rain Hill tests.[96] This working model was built by Matthias W. Baldwin, and for a time was a great attraction, making the circuit of the museum rooms, that at that time were in the Arcade Building, drawing two miniature cars, each seating four persons. At the time this model was built Mr. Baldwin was carrying on the business of making bookbinders' tools and copper cylinders for calico printing. No doubt this little locomotive may safely be considered as the nucleus of the great Baldwin Locomotive Works of the present day.

Prof. Robert M. Patterson succeeded Dr. Samuel Moore as director of the U.S. Mint. He was a warm friend of Mr. Franklin Peale, and had great confidence in his philosophical and mechanical ability, and it was during his administration that most of the great improvements resulting from Mr. Peale's mission to Europe were introduced and carried to perfection in the mint. No one could have been better qualified for the directorship of the mint than R. M. Patterson, who it might almost be said was born in or to it—the son of Dr. Robert Patterson, who in the early history of the mint was for so long a period its head. Adam Eckfeldt as chief coiner had grown old in the service. This was before the time of nefarious political doctrine, that "to the victors belong the spoils," had reached the officers of the mint, to whom of all others practical knowledge and experience is so essential; "it is practice that makes perfect."

Mr. Eckfeldt was a man of staunch integrity, a cautious, careful, orderly and painstaking man; he was not one of the dashing, pushing, inventive mechanics, though under his care many apparently slight improvements were gradually adopted that in the aggregate amounted to a great deal in the economy of working. He was by no means deficient in inventive ability. I have more than once heard that leader in fire engine building in Philadelphia, Patrick Lyon, give Mr. Eckfeldt the entire credit for the long-end levers with folding handles, that superseded the side-levers on the old-fashioned fire engines, and by which the operators applied their force easier and in a more direct manner. Although Pat Lyon was the first to

[94] Sellers was not mistaken in the name. However, the map of the Brandywine Millseat Company Survey, 1822 (MS in Hagley Museum) indicates that the Hodgson brothers' shops were located a mile or more from Young's mills.

[95] He was employed in the Museum from 1822 to 1833; and he lectured at Franklin Institute from 1831 until he departed for Europe in 1833 (CHARLES COLEMAN SELLERS, cited in note 20 above, vol. 2, pp. 345, 382).

[96] It will be remembered that Ericsson's *Novelty* was not the successful contender in the 1829 Rain Hill trials. It would be interesting to know why Peale chose this design rather than that of Stephenson, whose *Rocket* was the winner (see *Journal of The Franklin Institute*, May 1833, vol. 15, p. 301). In a lecture on the model, Franklin Peale explained its "analogy to, and differences from" the *Novelty*.

FIGURE 36.—Medal coined on the steam-driven coining press, March 23, 1836. Diameter 1¼ inches. Photographed by courtesy of the U.S. Mint Service.

introduce them he always spoke of them as the Eckfeldt levers.

Although Mr. Peale's legitimate duties in the mint pertained to the assay and refining department, and in which he was making great changes, including the introduction of the humid assay and some important changes in the details of refining to save labor and prevent wastage, the yellow smoke or fumes from the mint smoke-stack at the time created quite an excitement among the residents of neighboring houses who knew nothing of the work the acids were doing. Mr. Peale's natural bent being mechanics his mind ran from his department to improving the machinery of the coining, and Mr. Eckfeldt availed himself of his suggestions, in a moderate degree. The first instance that I can recall to memory was to import a die sinking lathe. I do not recollect the name of the inventor, but it saved hand labor in duplicating dies. I shall have occasion to refer to this further on.

It was during the transition stage of the assay and melting that we were first called on to do any work for the mint. The first job was making patterns for and the casting for the new melting furnaces; also for a cupel furnace [97] and a crushing and grinding machine, pulverizing the old black-lead crucibles to recover the metal that adhered to or permeated them, but we had nothing to do with the finer machinery until after our first locomotive was put in service on the Pennsylvania State road in 1836, some account of which I have given [in chapters 22ff, below]. Dr. R. M. Patterson and Franklin Peale were of the company on an excursion to exhibit the performance of the engine to Lancaster, Pennsylvania, and return, a few days after which we received a note from Dr. Patterson requesting us to call at the mint.

I answered this call, when Dr. Patterson placed in my hands a copy of a note he had addressed to M. W. Baldwin, S. V. Merrick, and to several other mechanical concerns, inviting proposals for the machinery of the branch mints, then about to be built at Charlotte, North Carolina, and Dahlonega, Georgia, saying that he should have addressed similar notes to us had he known that we were constructing machinery of the quality, as to workmanship, as was required.

He knew that we were engaged in general foundry work, and for iron furnaces, rolling-mills and paper-mill machinery; that to his mind did not come up to the required standard, but on the locomotive excursion the workmanship of the engine had satisfied him of his mistake. He said bids would be received for any portions of the work and referred me to Mr. Eckfeldt, who was present at the interview, for specifications.

[97] A cupel is a relatively small furnace for the refining and preparation of precious metals.

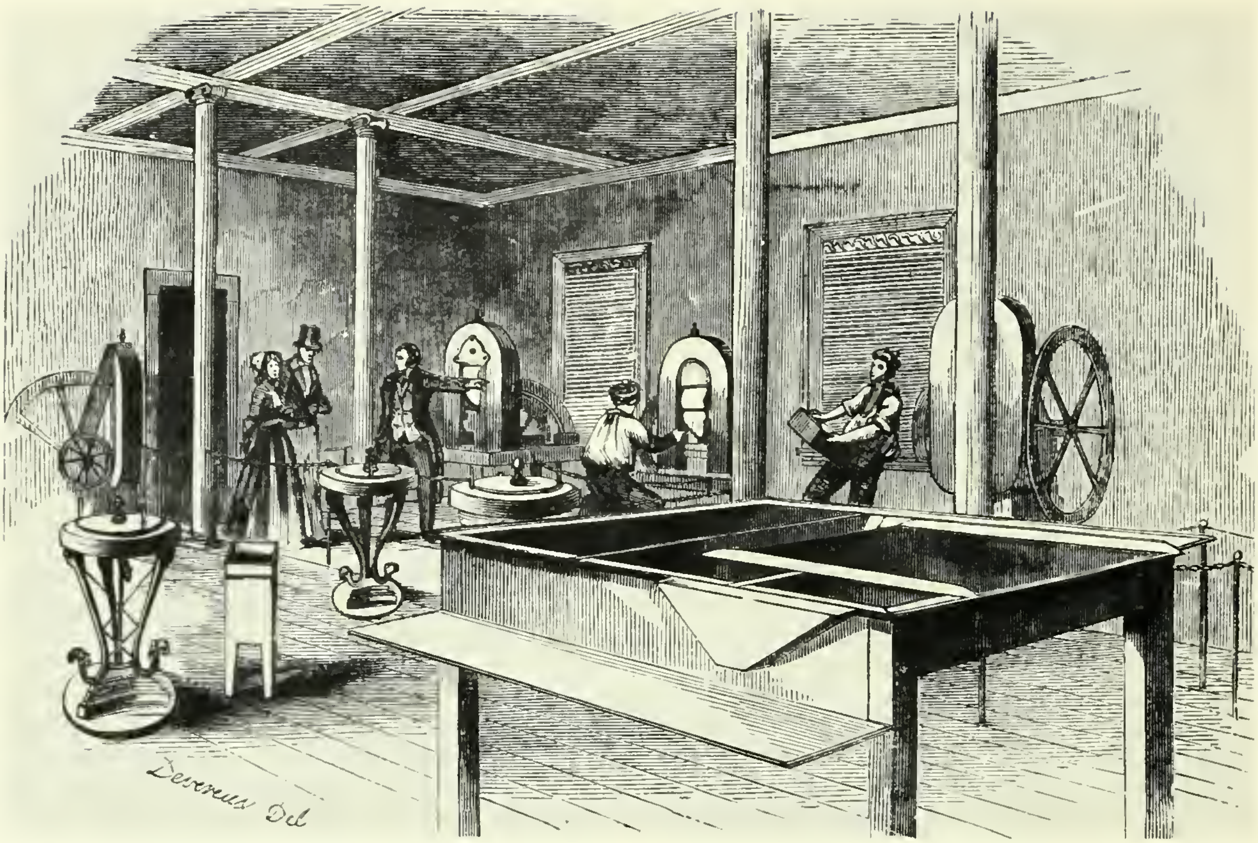


FIGURE 37.—Pressing and milling room of the U.S. Mint, Philadelphia. Three toggle coining presses are shown in background; three coin milling machines are in left foreground. From *Gleason's Pictorial Drawing Room Companion* (July 17, 1852), vol. 3.

He said bids would be considered for iron and brass castings, including patterns, finishing by surface measure; also by day's work, including use of lathes, tools, etc. This interview was on a Saturday afternoon; he regretted that the time was so short and that he had not called on us sooner, for if we desired to bid for any portion of the work we must do so by noon on Monday.

To my surprise, on reference to Mr. Eckfeldt I found that there were no drawings or plans of any kind. The specifications were all in writing, and for the details of machinery reference was made to the machinery then in operation in the mint. That for the steam engine, gave diameter of cylinder, length of stroke, length of connecting rod, size and weight of fly-wheel, cylinder to be vertical, the general plan of engine to conform to that in the mint, which I think was a Rush and Muhlenberg engine, the successors of Oliver Evans.[98] In addition to the shafting [were] pillow blocks, hangers, giving size and lengths, all of cast-iron, with coupling boxes, etc.; as to the rolling mill, draw benches, coining presses, milling machines, we were referred to those then in use.

[98] In the U.S. Treasury Department's "Report on the Steam-Engines in the United States" (H. Ex. Doc. 21, 25th Cong., 3d sess., p. 156), the mint engine is listed as 30 horsepower, built in 1829–1830 by Rush and Muhlenberg. Early mint accounts show payment to Oliver Evans of $6508.52 on June 24, 1817, for a steam engine and sundry iron castings for machinery of the mint (FRANK H. STEWART, cited in note 43 above, p. 186.)

I found Mr. Eckfeldt so opposed to horizontal steam engines that he would not listen to their being adopted; he had not had any experience with metallic ring spring packing, and he believed that with the ordinary hemp packing a horizontal cylinder would soon wear oval and the piston head could not be kept tight.

The interview with Dr. Patterson and Mr. Eckfeldt was a long one, and it was after night when I got home at our works to consult with my brother; taking with me such written specifications as Mr. Eckfeldt had prepared—so meager and no time to refer to the machinery in use that I did not see a possibility of making estimates safe to bid on. The getting up of plans and patterns for the long-stroke vertical engine was out of the question. Having still on hand the old rolling-mill machinery on which very trifling changes had been made for the new mint, a scale beam estimate would give a tolerable safe basis to bid on for that portion. We might secure the castings for the melting departments, for we had all the patterns for the improved furnaces that Mr. Peale was constructing in Philadelphia and expected to introduce into the New Orleans Mint, beyond which I did not think it possible we could secure any of the proposed work. [24]

But on that Saturday evening while my brother was getting the weights of the old housings, rolls and their connections, I started on sketches to show Mr. Eckfeldt the extreme simplicity of a horizontal steam cylinder, mounted on a cast iron box bed or shears, instead of on wooden sills, as was the custom at that time. These sketches resolved themselves into two rude colored drawings—an elevation and ground plan. The elevation I have recently found among a lot of odds and ends that have knocked about with me for more than half a century; the finding of this has recalled to memory much of what I am now writing. I worked on these drawings most of the night and probably a good way into Sunday.

I kept my appointment at the mint about noon on Monday, taking with me these hastily made drawings; also drawings of the ring metallic packing for piston head as used in our first locomotive, and also a movable model of an arrangement that at that time we were making to regulate by governor the point of cut off. It was a very simple device gotten up by a Mr. Childes, at that time our foreman in [the] finishing shop. It was a simple D slide-valve, but instead of opening and closing the steam ports by

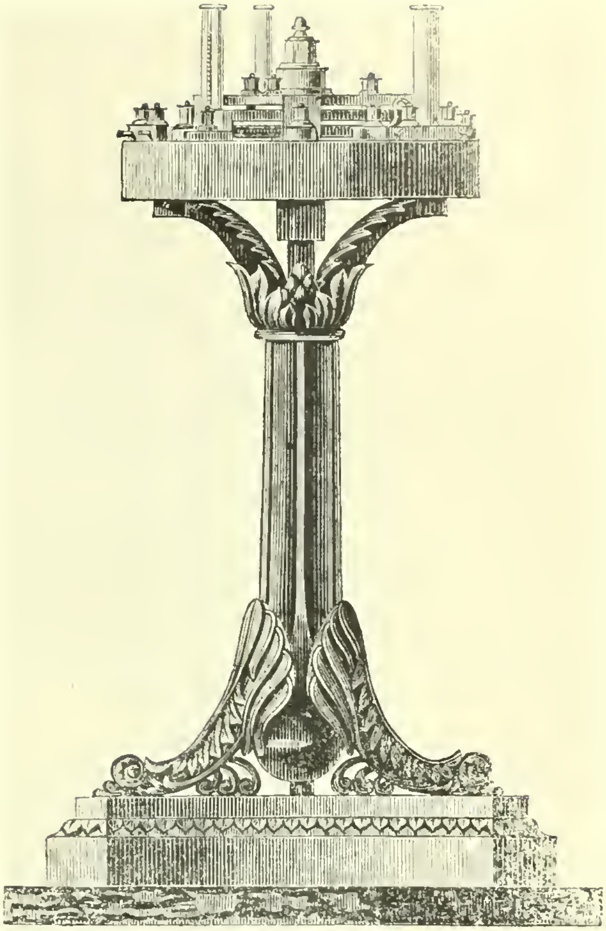


Figure 38.—Coin milling machine, designed by Franklin Peale, for raising and serrating the rim of a coin. From *Journal of The Franklin Institute* (November 1836), vol. 22.

its ends it had ports through it, the top of the valve being faced, on which lay a loose plate or valve with two upright stops between which a conical wedge turned so as to regulate the play of this plate and allow the valve proper to slide under it. To insure the top valve traveling with the main valve until stopped, a constant steam pressure on it was secured by a small opening into the escape section of the D valve.[99]

[99] When a study is made of governor controlled cut-off valve gear schemes leading up to that of George Corliss, in 1849, this gear can take its place amongst the large group of designs perhaps more ingenious than useful.

This simple little device, the simplicity of the feed pumps as we were then placing them under the steam cylinder operated by an arm from the cross-head, and the solidity of the proposed cast-iron bed so pleased Dr. Patterson that he used many arguments to induce Mr. Eckfeldt to give up his vertical hobby; the argument that had the greatest weight was the necessity of the greatest simplicity to avoid being obliged to keep skilled workmen for repairs at such out-of-the-way places as Charlotte and Dahlonega were supposed to be. Should the change be made to horizontal steam engines some change in the designs of the buildings might be necessary. The matter required consideration and probably some correspondence with the architect at Washington.

The only conclusion reached at that interview was that we should have the castings and work appertaining to the assay and melting department of the mints, and an appointment made for Dr. Patterson, Messrs. Peale and Eckfeldt to visit our shops at Cardington, the objective point being to see the operation of our planer, which at that time was the only one in Pennsylvania, there being, if I am not greatly mistaken, only two others in the United States, one in Kemble's West Point Works, and the other in Dr. Nott's—both imported machines.[100] Ours was a very rude affair as compared with the perfect machines of the present time, but by allowing it plenty of time it did good work. Its only automatic action was in the screwdriven bed plate to give a quicker return; both cross-feed and up and down feed being by hand, requiring constant and careful attention of the operator. The size the machine would take in and plane was 8 feet in length by 4 feet wide and 3 feet high. Its capacity had much to do with shaping and sizing the designs for furnace plates and other mint machinery. The introduction of the kind of ingot molds that had been made by Maudslay for the royal mint finished on his planer [made possible] the increase in silver melts from fifty pounds to over two hundred much sooner than it would have been done if the finishing by cold chisel, file, and scraper had to be depended on.

A few days after this visit we received notice from Dr. Patterson that the works for the branch mints had been divided. The portion given to us was, in addition to the melting department on which we were then engaged, for the branch mints—the steam engines (horizontal), shafting, rolling mills and milling machines, including the erection and starting of all the machinery. The coining presses and draw benches were given to the Merrick works, then carried on by Merrick, Agnew and Tyler.[101]

This work brought us into almost daily communication not only with Dr. Patterson but with both Peale and Eckfeldt, and I became pretty thoroughly acquainted with every step that was taken during the transition period, as every advance step was very thoroughly discussed, and now as I write so crowd on my memory that I find it hard to cull what may be of interest to the general reader. [25]

[In 1836] there was imported, I think from France, a die sinking lathe.[102] To use this lathe to do its portion of the die sinking a template die [was made] for the dollar about 6 inches in diameter. For this Uncle Titian [Peale] modeled the flying eagle and Mr. Thomas Sully, the female figure of Liberty. From these, plaster casts were made and from them plaster [molds] from which to cast bronze templates. I think the bronzes were cast at Merrick's but were not satisfactory; then a lamp maker's foundry was tried with no better results. I told Dr. Patterson and Uncle Franklin of what I had seen Henri Mogeme do to mould the fine Berlin iron and his crucible castings and what he had told me of the importance of moulding by pressure and not tamping, [which] he called kneading or dry facing. Uncle Franklin suggested that we should try to make an iron casting from the

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[100] It is my impression that a planing machine had been built in Providence, but I have not found positive documentation. It is certain, however, that the cold chisel and file were still the most important tools for producing plane surfaces. For example, the 16-ton bed-plate castings for engines of the U.S.S. *Mississippi,* cast in 1839 at Southwark Foundry of Merrick & Towne were finished by chipping and filing (*Transactions of the American Society of Mechanical Engineers,* 1894–1895, vol. 16, pp. 757–758). JOHN FRITZ, in his *Autobiography* (New York, 1912), p. 60, refers to use of a two-handed chisel and sledge in 1849. For general information on the West Point works, see KEMBLE (cited in note 71 above), pp. 190–203. Dr. Nott's was the Novelty Works, on New York's North River. An illustrated article on this works is in *Harper's New Monthly Magazine* (1851), vol. 2, pp. 721–734.

[101] In another account of the mint work, an excerpt from which is inserted two paragraphs below, Sellers named Merrick and Towne, who operated the Southwark Foundry. However, there were many interlocking partnerships, and this one was not impossible.

[102] This machine, known only as a "Contamin lathe," is mentioned in connection with the exhibit of the original flying-eagle medallions at the U.S. National Museum.

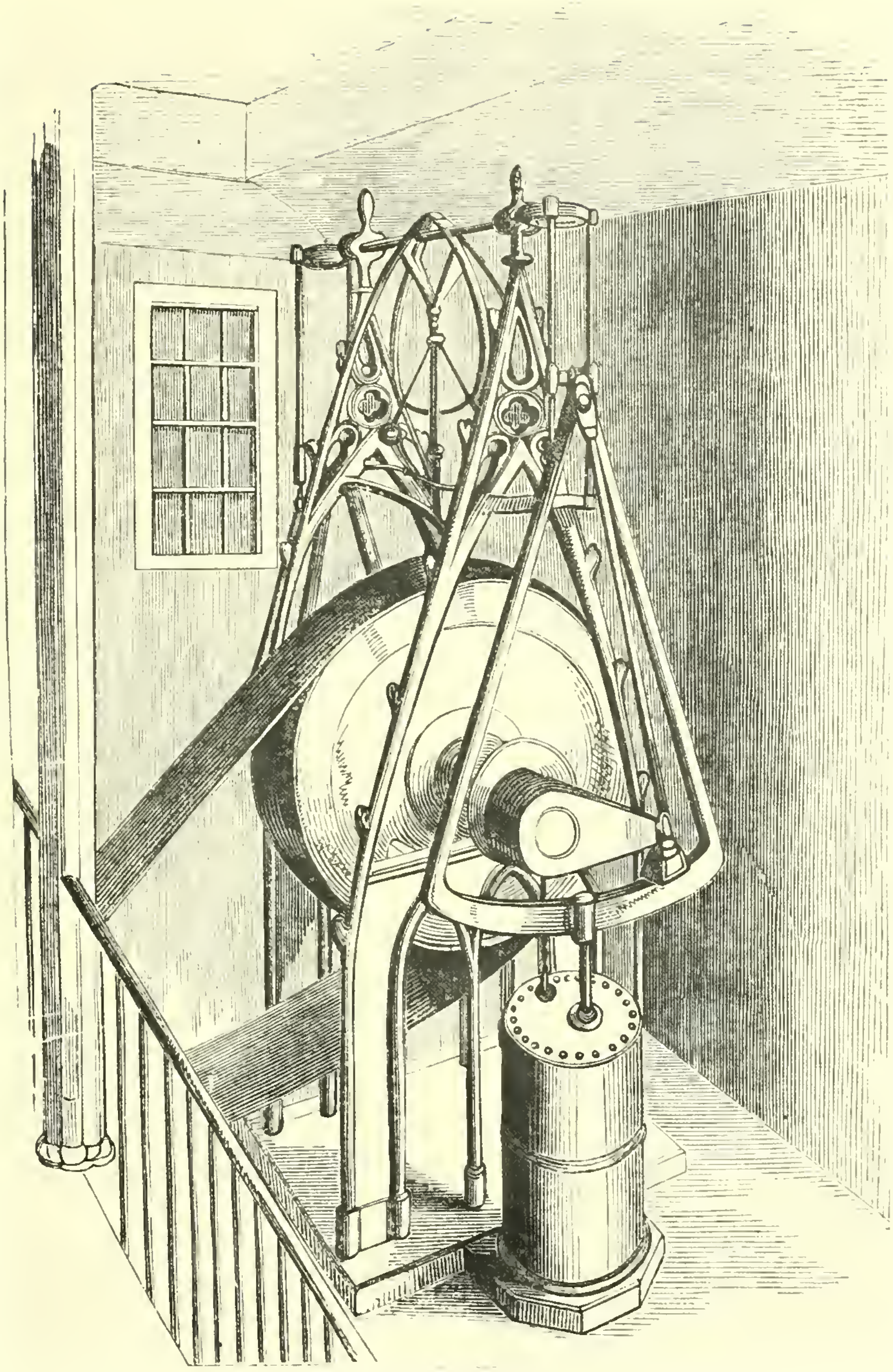

FIGURE 39.—Main steam engine at the U.S. Mint, Philadelphia. Probably built in 1829–1830 by Rush and Muhlenberg. The text accompanying the illustration stated: "There is a most beautiful steam engine . . . called a steeple engine." The engine had two cylinders. From *Gleason's Pictorial Drawing Room Companion* (July 17, 1852), vol. 3.

medallion patterns and for that purpose he went out to Cardington with me. As the medallions were flat on the back and the edge turned with ample draft, the moulding was only done in half flasks, the pattern being fastened on a board. For facing we used the foundry dust swept from the overhead collar beams. A thin coating of this perfectly dry through a bolting cloth sieve was sifted onto the pattern, then the moist sand through a wire sieve and as layer after layer was added without any jarring, the sand with a flat block was carefully pressed. When the flask was filled it was turned over and the pattern carefully drawn, then the gates were cut for the metal and the air vent and the other half flask adjusted. The intention was to have used a crucible taking the metal from the cupola and reheating to purify, but Uncle Franklin proposed that the first trial should be made chiefly from the cupola and it turned out so well that the crucible was not resorted to, and only the two castings were made and as perfect as possible from the pattern. Though the die sinking lathe was a great help, if I recollect right the Government was opposed to its use. [26]

About this time Mr. Peale was advanced from assistant assayer to that of assayer, melter and refiner (this was in 1836, and to chief coiner in 1839). Although engaged in the radical changes in that department his active mind could not be concentrated on its details alone, fortunately for the public service. He saw room for improvement in handling the metal ingots after leaving his department, and he suggested and planned improvements that have proved to be of great value.

Although Mr. Eckfeldt was pleased with what had been accomplished he did not at first look favorably on the improvements Mr. Peale suggested in his special department of chief coiner. He once said to me, "If Mr. Peale had full swing he would turn everything upside down; why he even talks of throwing away our costly coining presses that have done and are doing such good service, dispensing with man-power, and yet he won't hear of applying steam power to our old screw presses, which has been successfully done in the Royal Mint, London. He wants something better and no doubt he would have it if we were starting anew."

The giving up of almost life-long pets that had been Mr. Eckfeldt's constant care would naturally go hard, and still harder coming from another department, but as improvements gradually crept in and proved their efficiency Mr. Eckfeldt gave full credit where it belonged, and I remember him becoming quite enthusiastic over the labor saving in duplicating working dies.

In the fall of 1832 I visited the Royal Mint, but I was hurried through as sightseers generally are. At that time there was in the coining room a row of screw coining presses similar to those in our home mint, save that they were driven by steam power, though the driving power was not visible in the room. The top of the screw still carried its heavily weighted balanced lever, from the momentum of which the coin impression was made; the weighted lever end striking a wooden spring block was thrown back by the recoil opening the dies for thrusting out the piece coined and inserting a fresh planchet. The power was given by a shaft through the ceiling from the power-room above, which by a clutch box, took hold of the top of the screw; this clutch was automatically engaged and disengaged. As Mr. Peale's mission to England was nearly a year later than my visit he must have been acquainted with the entire operation, though I do not recollect among the numerous drawings he made of the machinery of the Royal Mint, any detail drawings of the mode of applying and disengaging the power; and from what I recollect of the conversations with him on the subject the impression is left that it was anything but satisfactory to him. He dwelt much on the value of progressive . . . pressure to be had by the toggle for coining instead of the blow or impact given by the screw with its flying weights. Through daily intercourse and frequent discussions I feel that I have a pretty clear recollection of the progress of his invention of the steam coining press that was so nearly perfect at the first essay.

The original press was exhibited at the Centennial in Philadelphia, in 1876, at work striking medals—it was represented as Peale's first press, and as having been made by Merrick, Agnew & Tyler, under Mr. Peale's supervision. This does not fully agree with my recollection.[103] That firm built the first coining press for coining dollars and half dollars that went into operation in the fall of 1836, at which time Mr. Eckfeldt was chief coiner; Mr. Peale did not take that position until Mr. Eckfeldt's retirement in 1839.

The mint repair shop was not fitted with tools for doing heavy work, which was done out at other shops.

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103 The press in question, now on exhibit in the Franklin Institute Museum, delivers upon demand souvenir medals.

For the first Peale press the patterns and castings were made at our works, the forgings made and finished from drawings, and were delivered at the mint, and they were mostly put together by Mr. Peale doing much of the work himself. In confirmation of these recollections, I still have the original drawings from which the work was done. I was present when the press was adjusted and the trials made on the copper planchet with the one-cent dies of that period. [27]

This test was only in the presence of Dr. R. M. Patterson, the then director of the U.S. Mint, Adam Eckfeldt, the old and first coiner of the U.S., Mr. Gobrecht, the die sinker, Joseph Saxton and myself. [28]

When properly adjusted it [the press] was exhibited coining a one-cent size copper medal, having on its face, around the rim, UNITED STATES MINT, 1836, and in the center and on the reverse a liberty cap surrounded with rays. [29]

Of those present at the select exhibition on the 23d [of March, 1836], I recollect Matthias W. Baldwin, Rufus Tyler, William Mason, S. V. Merrick, and S. Morris,[104] as among the most prominent mechanics of the time. [30]

The press was then regularly put to work on the copper cents of that period in the fall of the same year, when the dollar press was put to work. A total change was made on the face of the coins. The female figure, with liberty shield, staff and cap, was designed by Thomas Sully. I do not recollect who made the model in relief from his design, but that of the flying eagle on the reverse, surrounded by United States of America—one dollar, with twenty-six stars on the plain surface, was designed and modeled by Titian R. Peale. From these relief models, which were about 6 inches in diameter, castings were made to be used as templates or tool guiders in the die-sinking lathe. To get these castings satisfactory many experiments were tried in our foundry, finally settling on a kind of speculum alloy not too hard for hand finishing.[105]

Although the die-sinking lathe was a labor-saving tool in the rougher portions of die sinking, it did not dispense with the final delicate hand finish, yet Mr. Charles Gobrecht, who was then die sinker, was much opposed to its use. When the first few dollar coins were struck, it was found that Gobrecht had taken the inexcusable liberty of placing his name on the die, which became conspicuous on the coin, and the coinage had to be stopped until it could be obliterated.

Mr. Peale's improvement in the draw-bench for equalizing the thickness of the metallic strips, making the return of the grippers to take hold of the strip to be equalized automatic instead of being shoved back by hand, was an important advance in the coining department; it was followed by the rotary milling machine for raising the edge of the planchet, which did its work rapidly, only requiring attention in keeping the feed tube supplied with planchets. This was a beautiful machine from an artistic point of view, as was all the machinery devised by Mr. Peale, who brought to his work the refined eye of an artist. Through a hollow column from a tripod base the driving shaft unseen rotated the milling wheel or die by a cam arrangement within the circular table; the planchets were fed from the screwing tube, all the work being automatic, dispensing with the labor of a skilled hand, and doing the work with not less than ten times the rapidity. Those beautiful scales for weighing gold and silver, so plain and simple in appearance, and of such nice accuracy, were of his design, and their final adjustment the work of his own hands.

The small steam engine, so architectural in design, that for many years drove the steam coining presses until their increase called for greater power, was, from its high finish and silent movement, a most attractive object to all visitors to the mint, was of his design, and was constructed under his personal supervision. In planning this little engine, the capacity of the planer I have referred to was a consideration. The table or bed plate was an oblong, hollow cast-iron box, supported on four fluted doric columns, the entire table being finished and polished, as was also the rim of the fly-wheel. These architectural designs for machinery were before the plain, simple, round-cornered and direct forms dictated by utility of the present time, but in their chaste simplicity were a step in the right direction.

During the construction of the engines and machinery of the branch mints, both Dr. Patterson and Mr. Peale were frequent visitors to our works, and on

[104] Stephen P. Morris, founder of Pascal Iron Works, which later became Morris, Tasker and Company (SCHARF AND WESTCOTT, cited in note 14 above, vol. 3, p. 2252.)

[105] The repetition is caused by insertion of a passage particularly describing the molding process. The discrepancies I have been unable to resolve.

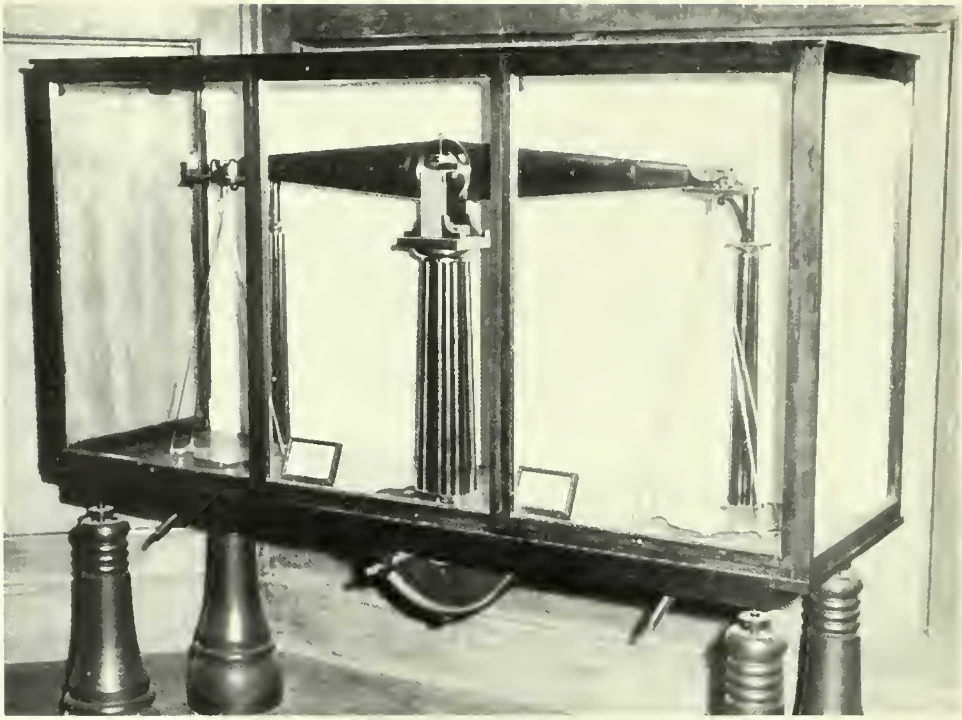

FIGURE 40.—Mint balance built about 1835 by Joseph Saxton in London at the order of Franklin Peale (see note 87). On display in U.S. Mint, Philadelphia. Photo courtesy of the U.S. Mint Service, Mrs. Rae V. Biester.

consultation great changes were made from the original plans, in all of which Mr. Peale took active part, taking an immense amount of labor to secure the best practical results.

When we consider that all the improvements in coining were made by Mr. Peale while acting in capacity of assayer, melter and refiner, and were entirely extraneous to the duties due the country in that capacity, and for which the salary—whatever that might be—was considered the equivalent, we can form some idea of how much the country at large is indebted to his inventive genius and zeal. The bulk of the inventions were put into practical operation while Mr. Eckfeldt was chief coiner, and it was not until his retirement in 1839 that Mr. Peale got his reward by being advanced to that position, giving him the management and control of the products of his own brain work. As to what the pecuniary advance was I know nothing. He served in the capacity of chief coiner until the fall of 1854, during which period no essential changes were made in his original steam coining press, milling or other machinery. Improvements were made in minor points, but the general principles remain the same to the present time . . . . [31]

10. Redheffer's Perpetual Motion Machine

The name of Charles Redheffer keeps popping up in footnotes today, just as his remarkable perpetual motion machine kept appearing and reappearing in Philadelphia and New York, in Liverpool, England, and no doubt in other cities and towns, when he was alive.

In Philadelphia, the showman Redheffer made his appearance in the fall of 1812 with an advertisement in the daily newspaper, *Aurora*, announcing an exhibition of his "self-operating, self-moving machine" in Chestnut Hill, a suburb of Philadelphia. The admission price for gentlemen was five dollars; "female visitors gratis." The editor of the *Aurora* was impressed. In an editorial comment comparing Redheffer to Godfrey and Fitch, inventors of quadrant and steamboat, respectively, he exulted in Pennsylvania's leadership in mechanical philosophy.[106]

In 1813, Isaiah Lukens built for Charles Willson Peale's Philadelphia museum a model of the Redheffer machine, and some 12,000 handbills were printed to tell the inhabitants that it could be seen in operation in the museum.[107]

Redheffer returned to public notice again in the summer of 1816 when he invited a 25-member committee—including Nathan Sellers, Robert Patterson, Adam Eckfeldt, and men of similar stamp—to consider the merits of his machine. He did this after the state governor refused to appoint such a committee. After an initial meeting in late July at the City Hotel, on Chestnut street at Seventh, the group assembled on two successive Saturdays in a room in the west wing of the State House to see the machine operate.

They fidgeted for several hours on the first Saturday while Redheffer tried vainly to start his machine. On the next Saturday they listened to the extraordinary proposition that two or three of their members (Redheffer suggested Nathan Sellers and George Clymer) be apprized of the secret by Redheffer, and that they in turn reveal it to the committee in the absence of the inventor. The committee's response was a flat demand that the machine be shown in operation immediately. Redheffer said he "could not, with safety—but refused to give reasons or explanations."

The committee thereupon, on August 27, published in *Poulson's American Daily Advertiser*, but not in the *Aurora*, an account "To the Publick" of the whole bizarre proceedings, appending their names to a round and sound denunciation of Redheffer and his behavior.[108] However, it is not clear that anyone was convinced that there was any overt fraud involved. Thomas P. Jones, editor of the *Journal of The Franklin Institute*, referred to the machine in an article published in 1828, 12 years later.

"On which side," Jones asked, "were the scientific of Philadelphia ranged when Redheffer's machine was exhibited at Chestnut Hill? Those who recollect the period will find no difficulty in answering the question. We believe that nineteen-twentieths of those who were so esteemed

[106] Quoted in SCHARF and WESTCOTT (cited in note 14, above), vol. 1, pp. 561–562.

[107] CHARLES COLEMAN SELLERS (cited in note 20, above), vol. 2, p. 280.

[108] According to Cadwallader D. Colden, Robert Fulton had exposed the fraud when Redheffer exhibited his machine in New York, in 1813 (COLEMAN [younger brother of George Escol] SELLERS, "The Redheffer Perpetual Motion Machine," *Cassier's Magazine*, September 1895, vol. 8, pp. 523–527; this article refers to COLDEN's *The Life of Robert Fulton*, New York, 1817).

were avowed believers, or, as the politicians would say, *upon the fence*." [109]

Jones in 1828 accurately assessed the approach of the great majority of men to the question of "perpetual motion," as it has been generally understood from the 13th to the 20th century. Over the years, an increasing number of people have paid lip service to the conclusion that the operation of such a device would require violation of natural laws. Jones pointed out, however, that "there are but few persons who admit this truth as they admit an axiom; there appears in general some mental reservation; some apprehension, that if they declare the thing impossible, it may, nevertheless, happen that some lucky wight may 'hit upon it,' and ruin their reputation as accurate philosophers." [110]

The quest for perpetual motion continues. I doubt whether there lives a mechanically inclined person who has not gone through the phase of being attracted by the question, usually going so far as to commit a rude sketch to paper and to confront a friend or colleague with the question, "Why won't this work?"

Generally that is the end of it; but I have answered my share of letters from those who have "hit upon it" (on paper), and who want either to receive the standing reward that they have been told exists, or to share their exciting discovery with the public, asking only the public acclaim that will come with their great revelation.

[An incident of] my boyhood was strongly impressed on my mind, and as I do not know any one now living who can describe it from their own knowledge, I shall try to do so, believing it will be of interest. . . . I refer to Redheffer's perpetual motion, which in its time created as great a furor in the world as any movement motor has. With our knowledge of the present time we look with amazement at the credulity of men of means, supposed to possess more than ordinary intelligence, investing their money in secret for interests in theoretical motors claimed by their projectors to be regenerators of the economic laws of the world. This was exactly what was claimed by Redheffer, and interests in his wonderful discovery were eagerly purchased.

I have no way of fixing the date of this excitement, nearer than that my first recollection of it was hearing the matter discussed during one of my summer vacations at the residence of my grandfather, Charles Willson Peale, who at that time was living at his country-seat near Germantown, one of Philadelphia's suburbs; this would place the date somewhere near the end of the teens of the present century.[111]

I recollect that at one of these discussions my grandfather expressed himself as believing that Redheffer, though at that time he was practicing a fraud in exhibiting his motor in operation on the original conception of the theory on which he based its operation, had been honest in the belief that the machine would be a perpetual self-mover; and that it was not until he had discovered his error after having wasted his time and impoverished himself, that he resorted to the ingenious device that enabled him to exhibit his machine in operation, to recuperate by the exhibition fees and gull the creditors into purchase of interest in his perpetual motor. My father, who was present at this discussion, was not disposed to be so lenient; he freely expressed himself as believing the thing to have been a fraud or trick from its earliest conception.

The machine then on exhibition being within easy walking distance, it was proposed that the party go to see the wonderful machine in motion; I, as a boy, accompanied them. We found quite a crowd there; lines of carriages in waiting; many pedestrians from the city. The machine was running, and many of the visitors were holding their pocket-knives on the grindstone that was apparently being driven by the perpetual motor. Mr. Redheffer was explaining in his characteristic manner the principle on which the machine was built and operated. "You see," said he, "the machine running, and the power with which it turns the grindstone; now this power is entirely due to the manner the little carriages are loaded on the revolving platform"; he then said he would answer any questions, and fully illustrate the principle. "You see here I have a little four-wheel carriage; its platform is double, and so arranged that I can set it at any angle. I have this plain plank for it to run on; now the platform is level and parallel

[109] *Journal of The Franklin Institute* (November 1828), vol. 6, pp. 318–327.

[110] Ibid.

[111] In 1816, when Sellers was not quite 8 years old.

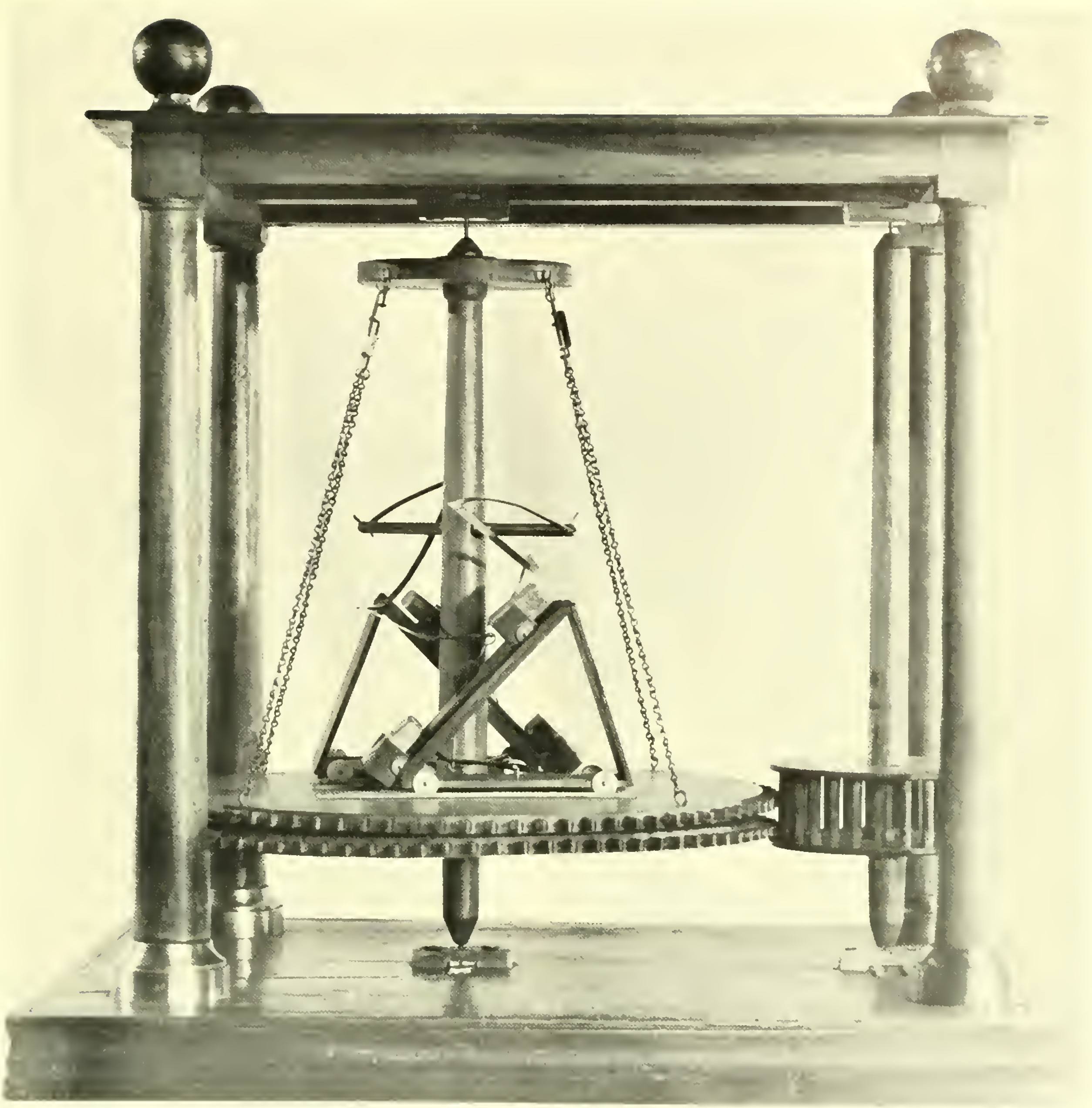

FIGURE 41.—Model of Redheffer's perpetual motion machine. This model was built by Isaiah Lukens for the Peale Museum in 1813. Photo courtesy of The Franklin Institute.

with the plank. I place on it this weight" (which was a leaden brick, rectangular, about 3 x 4 inches, and about one inch thick); the carriage stood still, gravity being directly down, the weight equally distributed on all the wheels; the bed was then raised and fixed at an angle of about 45°, and the weight carefully placed on it; the carriage started and ran some 10 feet or 12 feet, then stopped.

A very plain-looking man standing by said: "Friend Redheffer, I think thee gave it a little starting push."

"Not the least," was the reply. "Watch me, I will show it again." This time with one hand he held the carriage in check, while with the other he placed the weight on the incline; when he loosed his hold on the weight, simultaneously removing the hand that held the carriage in check; it was evident to all close watchers that the weight slid down the incline a short distance to its stop.

"I see," said the plain inquisitive man, "that thee did not give it a push, but thee let the weight slide enough to start the carriage; but, see, it did not run as far as the first time. Now, Friend Redheffer, when I load my wheelbarrow with rock it takes all my strength to start it, but when started I can trundle it along with ease. This starting the scholars call overcoming the inertia; but I am no scholar, I only know what I see or feel; but it does seem to me that if thy weight loaded on the slant exerts a power sufficient to start the carriage to overcome the inertia, and that power is, as thee asserts, constant, the carriage, instead of stopping, should increase in speed, and go on running forever."

"And it would," said Redheffer, "if it were not for the friction and the resistance of the air; these, you see by my machine running, I have overcome," pointing to the machine, which most certainly was running, and apparently exerting some force.

The plain inquisitive fellow seemed to have ruffled Redheffer so much that most of his attention was given to him, either to convince or to get rid of him. He said to him: "I think I have here what will convince you that a fixed weight in the position I place them on my carriages will exert a constant pressure in that direction that will and does force the carriage ahead, and if friction and all other obstructions are eliminated its onward course would be perpetual, as you see it does in my working machine. Here I have this cast-iron cannon suspended by its muzzle by this short free link chain" (the cannon was one of those stubby cannon used on merchant ships as signal guns). "Now," said Redheffer, "put your feet against this cleat on the floor, take hold of the butt ball of the cannon, and pull it to about the angle I have my weights on the carriages, and tell me if it does not maintain a constant pull, and does not grow lighter."

Very soon the man said: "No, I really think it grows heavier, and pulls harder; but Mr. Redheffer, thee ought to have a great steelyard and suspend the cannon on that, then thee could show if any of the direct down pull or gravity was lost or changed by pulling the cannon out of the perpendicular."

"That is a capital thought," said Redheffer, "for if there is any loss it would show what I gain by the angle I load the weight on my carriages."

There was much more of this kind of badinage between the plain, simple-minded engineer and Redheffer. I have told this as a continuous story, only intended to convey the general substance; part is from recollection, but probably more from conversations with my father in later years.

A conversation between him and my grandfather, after we left Redheffer's exhibition, made a lasting impression. Grandfather asked father if he did not think it a bold thing, and a capital piece of acting in Owen, to play the ignorant inquisitor. My father asked what Owen? The reply was: the fine Welsh machinist and clockmaker that worked with David Rittenhouse until his death, and has pursued clockmaking ever since. My grandfather then said before going into the show he had recognized him by his voice, and that was totally changed after entering the building; he had watched him closely without discovering the least halt or change in his assumed character; since coming out he found Owen hugely enjoying his successful joke, which, he says, he did not undertake with an intention of exposing Redheffer, but only for a little quiet fun. He showed a couple of English silver shillings so bent and shaped that one was so placed in his mouth as to depress the corner, and prevent the play of the muscles about the corner that are so expressive of character; the other was used to modulate his voice and enable him to keep up his assumed character; the only other disguise was the Sunday suit borrowed from Mr. Peale's Scotch gardener—the knit cap, broad collar, square cut, short-waisted coat, and loose trousers covering his ordinary breeches, and silk stockings, and a pair of dirty brogans completed his disguise.

After this long digression I will now try to describe the Redheffer machine, as exhibited. The foundation of the structure was a trap rock boulder, hollowed out on top sufficiently to form a step-box for an upright shaft. As near as I can recollect, this shaft was some 10 or 12 feet long or high; it was made of wood, say about 12 inches diameter, and octagonal; its step and journals ordinary cast-iron wing gudgeons, the lower one resting in the rock step-box, the upper journal by strap-box to a cross-beam. This shaft was free to revolve, and so arranged with the stone step-box, and open strap-box on the upper end, that no power could be possibly applied to either of these journals without being discovered. Near the lower end of this vertical shaft was a strong wooden wheel of about the diameter of the length of the shaft. This was a spur-wheel, with wooden cogs, beautifully constructed, and a fine specimen of the millwright's art. The outer ends of the arms of this wheel were planked over, forming a concentric platform of about two feet wide. For stiffness and stability, light iron suspension rods ran from the arms close to the concentric platform to a spider ring, or wheel, at the upper end of the vertical shaft. On this concentric platform was a narrow-gauge tramway, encircling it. On this tramway were placed several four-wheeled carriages. The platforms of these carriages, on which the propelling weights were placed, were at an angle of about 45° to the tramway. The teeth of this spur-wheel worked into a lantern pinion or trundle-wheel, in early times known by millwrights as a wallower. This was on an upright shaft, on the upper end of which was a crown-wheel, bevel, or miter, driving a horizontal shaft, on which was a V pulley, with a corresponding one on [the] shaft of a grindstone. A round belt of either catgut or rawhide, [was] drawn very tight between the V pulleys. When the weights, which were of lead, and probably as much as forty or fifty pounds each, were placed on the carriages, the big wheel would at first slowly commence to revolve, but would soon acquire what was claimed to be the normal speed due to the weights. Then the credulous crowd were invited to sharpen their knives on the grindstone driven by the untiring perpetual motor that neither consumed fuel or food, and whose lifetime alone depended on the durability of the materials of which it was constructed. Soon a crowd would be pressing to take their turns with their Barlow blades, to be shown as having been ground by the power of Redheffer's great invention, the perpetual motion.

I have but a dim recollection of the discussions, or the opinions expressed by those present at this exhibition of the machine; but many times subsequently I have heard my father state that he had been very positive in advancing his belief in the entire thing being a fraud; that instead of the perpetual motion driving the grindstone it was being driven by the grindstone, or in other words, that the shaft of the grindstone was being driven by crank and manpower on the other side of the partition.

The grindstone being placed near the partition, its journals, to prevent cutting by the grit from the stone, were covered by roughly made wooden boxes in a manner to convey the idea that it was an afterthought; when the box cover next the partition was removed it was plain to be seen that the grindstone shaft did not reach the partition, but no opportunity was given to caliper this end of the shaft, and if slightly out of round when the box cover was replaced, an undetected connection could be made with the operating crank, and the power be carried to the machine by the tight round belt through the bevel wheels and the lantern pinion.

My father said that the wooden cogs of the platform wheel were so nicely made, fitting so closely into the rounds of the lantern pinion, that in the shadow from its top platform it was impossible to see whether the pinion was driving or being driven, that the same might be said of the bevels on upright and horizontal shaft. My father, to satisfy himself, had gone with some slips of soft, damp paper, which, when unobserved, he had inserted between the cogs and the round and had got ocular demonstration that the lantern pinion was driving, and not driven, and he had become satisfied, and had freely so expressed himself, as to the modus operandi of the fraud being practiced.

This got to Redheffer's ears, and so excited him that when the legislature appointed a committee, at his own solicitation, to examine and report on his wonderful discovery and invention, he refused to allow the examination until some one was substituted for my grandfather Nathan Sellers, who was named on the committee, on the ground that both he and his son Coleman had so strongly represented the whole thing a fraud and deception that a fair, unbiased report could not be expected with either of them on the committee.[112] I do not know how the matter got before the legislature, or its object. On my inquiries as to the nature of their report, the reply was noncommittal. They had seen the machine in motion, had heard the charges of fraud, but, if one, they had failed to discover it.

Though nothing of value had come from the motor, the interest in it had not abated, and it was still a successful exhibition, crowds daily visiting it. One day on hearing loud talking in my father's office, and what sounded to me as insolence to him, I went forward in time to hear Redheffer say to him, "Your charging me with fraud has done me great injury, and I insist on your coming and bringing with you

[112] This paragraph appears to be almost entirely in error. See introduction to this chapter.

whoever you choose, and I will convince you and them that my perpetual motor drives the grindstone; you may cast the belt, or do whatever you like."

My father, who seemed hurt by the language that had been used, believing it was due to Redheffer to give him the chance, reluctantly agreed, and a time was fixed. My father took with him my uncle, Rubens Peale, Isaiah Lukens, and I think, either William Mason or Rufus Tyler—most probably the latter, as he was the most frequent visitor at our house, and the open-front carriage my father drove only carried four persons. Lukens was the town clock-maker and general machinist; no man of that period better known, or held in higher estimation. Both Mason and Tyler were accomplished machinists, makers of the highest order of philosophical instruments, fine-class foot lathes, slide rests and models. I have often heard Lukens relate the incidents of this visit in a most humorous way, made more so by his impediment in speech, when telling anything exciting.

They found the grindstone removed from its position near the partition, the belt cast, the stone standing, and the motor running; the only change my father observed was in the position of the bevel wheels—the crown wheel that had been under that of the horizontal shaft was now on top. This change Redheffer explained as having been made to admit of being thrown out of gear, on raising the shaft out of its step-box, that the length of the rounds of the lantern pinion admitted of his doing so; he thought that would convince Coleman Sellers that the power that ran his motor did not come by the way of the grindstone, but was due entirely to the weights on the carriages. The machine was stopped, and propped to prevent starting; the shaft was raised sufficiently out of its step-box, as Lukens used to describe it, to admit of passing a knife blade under; that was all the rounds of the lantern pinion would allow, but, as Lukens said, not sufficient to let him put his finger under, to feel if the bottom of the shaft was not like the pipe of a watch key, that, on being lowered, would connect with the power, that, on signal, might start in the adjoining room.

Then he, without giving any reason for so doing, was about asking of Redheffer the privilege of taking the upright shaft down with its lantern pinion, and allowing the machine to run without that appendage, when he was interrupted by my father saying to Redheffer, "Your machine is beautifully finished in all its parts; why was it not carried out in this?" putting his cane on a plank or timber rather roughly hewed, showing the marks of the broadaxe.

To this Redheffer's reply was, "I was in a hurry making the changes, and as it is entirely outside, and not connected with or essential to the machine, I let it go."

"Yes, yes, I see it is not, but it does not seem to be securely fastened, and could be easily removed without the least injury to the machine; if you will sell it to me, and let me take it up now, I will give you one hundred dollars for it, and you can replace it for less than one dollar."

It was here, in telling the story, that Lukens, in his inimitable way, mimicked Redheffer's rage, when indignantly rejecting an offer that he took as an insult. The telling was so amusing that we never tired of hearing it repeated. Father had rightly surmised that the plank in question covered the entire secret.

Rubens Peale was at that time manager of the Philadelphia Museum, belonging to his father; he conceived the idea that the furor raised by Redheffer might be turned to advantage, if a working model of the perpetual motion could be so constructed that the power moving it could not be discovered, it would prove attractive. This Isaiah Lukens undertook to do, and made rather a rude working model. This, I think, is still in existence in the collection of the Franklin Institute of Philadelphia.[113] This did not carry out the perfect deception required, and in its exhibition needed the constant attention of someone to manipulate it, to stop on the removal of the weights, and to start on their being replaced. The lower journal or step of the upright rested on a plate glass that could be removed, and the upright with its platform wheel raised or lowered, but would hold this shaft perpendicular. Above this glass step there was a light bridge, but heavy enough to have the power from clock work in the base by light, delicate gearing, to carry the power to the upright through it; this was a step in the right direction, but it did not meet the case. But to make a working model that would start on placing the weights on the inclined beds of the railway carriages, and stop

[113] I saw the model, in 1960, in storage at the Franklin Institute. Another model was made by Lukens in 1822 for the Peale Museum in Baltimore (letter from Rubens to Franklin Peale dated June 11, 1822, in American Philosophical Society Library, pointed out by Wilbur H. Hunter, Jr., "Tribulations of a Museum Director in the 1820's," *Maryland Historical Magazine*, September 1954, vol. 49, pp. 214–222).

on removing them—this was the problem that Lukens undertook to, and did solve, in so ingenious a way that the deception was perfect, and to my knowledge never discovered, though repeatedly examined by the most thorough and ingenious men of that period.

The beautiful machine he made for the Philadelphia Museum was mostly of mahogany; it had a massive rectangular base, within which the clock spring and gearing was concealed; at each corner of the base rose a mahogany column, each column above its entablature finished by a mahogany ball; from one of these balls a steel rod passed down through the center of the column to the gearing in the base, making it by the ball a "stem winder." Diagonally from the column were the beams to carry the glass box for the upper journal of the main upright shaft, which was of wood, octagonal, in imitation of Redheffer's, with wing gudgeons for both lower step and upper journal. The lower step journal was of much greater diameter than the upper, in model, as near as I recollect, about ½ or ⅝ inch in diameter. Both upper and lower, being of transparent glass, could be seen through, to show that there was no possible connection with the shaft. The lower or step-box was, as seen, a large square plate of glass firmly fixed in the base of the machine, with a hole in its center to fit and receive the lower gudgeon; this step-box was two separate plates of glass, the upper square one secured to the base had the hole for the gudgeon bored entirely through it; the lower plate was solid, circular, and in close contact with the upper; it was mounted in a revolving ring carried by arms from a vertical shaft with regular boxes and step, and driven by a train of spur wheels from the clock-work, which kept it constantly revolving. The lower wing gudgeon of the perpetual motion was made of hardened steel, and highly polished, the upper journal long enough to allow the shaft to be sufficiently raised as to lift the lower one entirely out of the step-box, and be examined. The end of the lower gudgeon was ground off to so slight a bevel that it could not be perceived, but the weight of the upright with its platform and cars, in reality, only rested on the outer edge of one side of it, and their weight was not sufficient to cause adhesion sufficient for the revolving glass to transmit its motion to them, but when the leaden weights were placed on the inclined beds of the carriages it would slowly start, and soon get up to its normal speed; this slow starting, taken in connection with the large space, giving the chance at all times to see through the glass boxes made the deception complete, and as I have before stated, was never discovered.

The machine was enclosed in a glass case and when the museum was in the old State House, or Independence Hall, it was in the care of old Moses, the profile or silhouette cutter of the museum, whose duty was to see that the clock work never ran down during the hours of exhibition. He would open the case, and allow inquiring visitors to remove and replace the weights; he told of Redheffer asking this privilege, then sitting for hours watching the machine running, and all the time talking to himself, the gist of which, as far as Moses understood, was, Lukens has hit it, and proved my theory right.

Lukens told of Redheffer having called on him, and began by abusing him for having stolen his invention, and robbing him of the income he made by its exhibition; that people instead of going out to Germantown, now all went to the museum. Lukens reminded him that stealing and robbing were ugly words that he would not allow, that then Redheffer changed his tactics, and proposed a union of interests, saying that he, Lukens, by skill and superior workmanship, had accomplished what he was aiming to do, and that by a union large sums of money could be made. Lukens said he told him that he would have nothing to do with money made in that way. He had made the machine for Mr. Peale, and had been paid for its cost and the time he spent on it, and that was all he should ever make. They had never claimed it to be a perpetual motion, but simply a model of a machine that he, Redheffer, was exhibiting as such.

Redheffer persisted in expressing his belief that Lukens had solved the question, and that there could be no trick in the museum machine. Lukens had said, "If you believe so, go back to the museum, have Moses open the case, take off the weights, and it will then stop; then reverse the carriages, replace the weights, you will find it will start and continue to run in the same direction it was running, directly the opposite to what it should, if your incline loaded static weights were the propelling power. If that don't satisfy that the angle or inclination of the weights has nothing to do with the running of the machine, just load them onto the platform wheel in any position you choose, and the thing will run just the same; they make it run, and it won't run without them."

I have never seen any published account of the device Lukens adopted to carry on for so long a period so perfect a deception. At one of the early meetings of the Franklin Institute, he fully explained and illustrated it. I do not know what became of the museum model, but I have the impression that it became the property of Barnum, and was burned with his Philadelphia collection in the William Swain Building at the S. E. corner of Chestnut and 7th streets. [32]

Part II

On Papermaking In the United States and England

This part of the book is chiefly concerned with papermaking devices, both hand and machine, and their builders, but Sellers's observations are of much wider significance to an understanding of the development of machines for manufacturing operations of all kinds.

His visit to England in 1832, where he was entertained and treated with unusual openness by some of the outstanding mechanicians of the day, enabled him to observe several prominent shops and mills and to compare English with American practice. Although he was only 24 years old, the relative ease with which he gained the confidence of and obtained information from such cautious men as John Dickinson and Bryan Donkin suggests that Sellers was an intelligent—even expert—listener to detailed technical descriptions, and that the information that he had brought with him from America was of great interest, even if its influence upon English practice was hardly measurable.

The transition from hand to machine papermaking occurred during 20 years or so after 1815. Dickinson and Donkin, both of whom figure prominently in these pages, were the leading designers and builders of papermaking machinery. To Donkin goes particular credit for developing and perfecting the Fourdrinier type of machine, while Dickinson carried on a parallel development of the evacuated-cylinder type.

In America, before he was 10 years old, Sellers was gaining experience with machine papermaking on the Brandywine Creek near Wilmington, Delaware, in the mill of Coleman Sellers's good friend Thomas Gilpin, who had copied the Dickinson cylinder machine.

George Escol's boyhood had been fairly surrounded by the tools and talk of papermaking. His grandfather Nathan Sellers, his father Coleman, and his brother Charles all were engaged in the making of wire paper molds and the fashioning of watermarks for handmade paper while carrying on their numerous other mechanical enterprises. Although the principal innovations by the Sellerses in papermaking equipment were the annealing of small sizes of wire in the absence of a destructively oxidizing atmosphere and the improvement of wire mold making, it is likely that few mechanically advanced ideas escaped the alert and well-connected family.

Most of the technically inclined American visitors to England in the early 1830's were there to learn how to build canals and railroads, and often to buy rails and rolling stock. But George Escol Sellers journeyed there to learn all he could about advanced machines and methods that might be adapted to papermaking in the United States. His mission was accomplished successfully although he spent less than three months in England. He found time also to inspect, under the guidance of the elder Brunel, the unfinished Thames Tunnel; to visit the celebrated machine works of Maudslay Sons and Field; and to spend many interesting and enjoyable hours in the company of his good friend Joseph Saxton, who introduced him to numerous people and places in London, and particularly to the marvels and curiosities of Jacob Perkins's Adelaide Gallery.

The last chapter of this section (chapter 18) is a strange and exciting tale of counterfeiting that not only conveys the suspense and hazard of the chase and the hopelessness of a prisoner in the era of universal solitary confinement but provides also a unique account of the ingenuity and consummate skill expended in imitating paper and engraving that were specifically designed to discourage duplication.

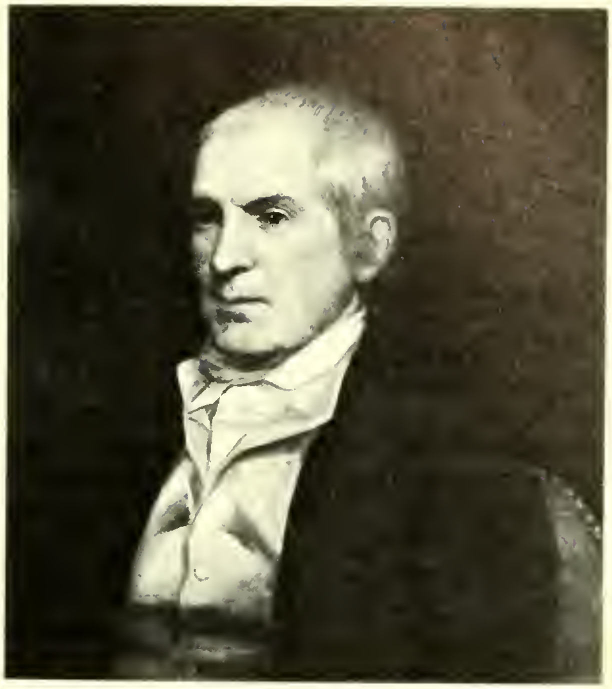

FIGURE 42.—Nathan Sellers (1751–1830). Portrait by Charles Willson Peale, 1808. Photo courtesy of James Townsend Sellers and Frick Art Reference Library.

11. Nathan Sellers and Wire Working

Nathan, first son of John and Ann Sellers, was born in 1751 on the ancestral Sellers estate in Upper Darby, just west of the county of Philadelphia. On the Sellers property, cut east and west by the West Chester Road and north and south by Cobbs Creek, was Nathan's home until he moved during the Revolutionary War to the "Market Street Store" at 231 High Street. To the Upper Darby estate he returned at the age of 66, building at that time a new home, called "Millbank," to serve him during his retirement.

He was a Pennsylvania militiaman when, in the summer of 1776, he marched off to war in New Jersey with Col. John Paschall's Flying Camp. Within a few weeks, however, he was returned to his home by a resolution of Congress because of the urgent need for his skill in wire work and the construction of paper molds, and from that time forward his life was devoted to the exacting art of making molds and watermarks.

He formed a partnership with his brother David, six years his junior, and the business, which encompassed numerous other enterprises such as the making of woven wire sieves, textile cards, and eventually riveted leather fire hose, was carried on in the Market Street house and store that George Escol came to know so well.

The firm of N. & D. Sellers survived the death of David, in 1813,[114] and Nathan was actively at work until 1817, when, plagued by strokes of vertigo, a "terrible nervous condition"—attributed to his wire work[115]—and other infirmities, he retired to Millbank "to seek rest and quiet to my Brain, in the country, and there to guard by every means in my power, such as frequent bleeding, temperance and avoiding ardent thinking, against the recurrence of such strokes." [116]

In spite of his ill health, Nathan lived until 1830, and during the last year of his life he maintained a detached but lively interest in the establishment of his son's and grandsons' Cardington Shops, close by Millbank.

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[114] "My recollection of Uncle David," wrote George Escol, "was very indistinct for I was only five years old when he died. I recollect liking to sit on his lap before the open fire in the back end of the store, but the most lasting impression was seeing him in his coffin in the little parlour in the 6th St. house and how cold his forehead felt when I was told to kiss it." (Memoirs, book 1, p. 20.)

[115] Ibid., p. 27.

[116] Letter from Nathan Sellers to Nicholas Biddle dated October 24, 1824, quoted in DARD HUNTER, *Papermaking in Pioneer America* (Philadelphia: University of Pennsylvania Press, 1952), pp. 138–139. An appreciation of Nathan Sellers is in Hunter's book, pp. 130–139. See also JOHN W. MAXSON, JR., "Nathan Sellers, America's First Large Scale Maker of Paper Moulds," *The Paper Maker* (1960), vol. 29, no. 1, pp. 1–16. Mr. Maxson is writing a biographical work on the Sellers family.

From my earliest recollection everything pertaining to papermaking was familiar to me. I might almost claim to having been born to the business, my grandfather, Nathan Sellers, having been the first person to establish the business of wire-drawing and wire-working, and certainly the first man who made a pair of paper moulds on this continent . . . .

I have often listened with great interest to my grandfather's account of the straits the people were reduced to for want of paper during the revolutionary embargo. Fly-leaves were torn from printed works and blank leaves from account books for letter-writing. The stock of paper for printing Continental money had run out, the English-made paper moulds had worn out, and there was no wire in the country to reface them.[117] This was the state of affairs when his honorable discharge from the army was granted by special Act of Congress. From the many conversations I had with him on the subject, I got the impression that the object was to employ him in making moulds for the Government use; that it had been represented that he was competent to do so, and not that he had been pursuing the business; and that on his return he had immediately gone to Yorktown, Pa., and there made the moulds for the Government, but his diaries . . . throw a different light on it.[118]

On the 3d [of September, 1776] we find him at work on paper moulds, continuing in the old routine, diversified by signing Continental money on September 24 and 25; brassing (this means new facing) and water-marking moulds for Willcox, of Ivy Mills, Chester County, Pa., now Delaware County, at that time making paper for Congress and for Continental money under military protection. I will here remark that up to the present time the Willcoxes continue extensively engaged in making the finest qualities of bank-note paper . . . .

The entry of May 17, 1776, of "Straightening wire for paper moulds" refers to what was known as laid moulds, in contradiction to woven or vellum-faced, each successive wire being laid by hand on the frames they were to cover and form the faces of; being secured at each bar, one to the other, by hand-twisting the crosswires that were of such a thickness as to regulate the spaces between each parallel wire. It must be self-evident to any one that the hard brass wire from the reel or coil, and simply cut into lengths with its set or curvature, could never be laid one wire parallel with the other, preserving equal distances apart, without first having the curvatures taken out and being made perfectly straight. My grandfather had preserved all of his original tools, including the straightening board used at the time of the above entry; also a wire-drawing block, made of lignum-vitae, wire plates, rippers, that is, link pincers that closed, gripping the wire in the act of drawing it—all of which were in my possession until my removal to the West in 1841.

Looking at these old relics it was always a marvel to me how a young man, fresh from the farm, could have taken up and successfully pursued a business without any knowledge of what had been previously done. It must have been a series of inventions and experiments.

As to this first straightening board, it was on the same principle as was in use in England and France, but in construction greatly improved, so much so as to have been re-invented and patented in France as late as 1800 or thereabouts. The principle of taking the curvature out of the wire is by drawing it between stiff wire pins fixed in a board, which act to bend the wire first in one direction, then in the reverse, in a waving line, the waves decreasing or growing shorter until the last bend leaves the wire perfectly straight. The placing of the pins required considerable skill on the part of the operator, and often considerable adjustment by bending in or out by strokes of a hammer. In my grandfather's original straightener, two or three first bends were made by pins permanently driven into the board; the after bends by a series of small flat steel bolts, rounded at the working ends, and slightly grooved for the wire to run smoothly in. These bolts were secured to the board by a couple of staples to each bolt. They were set in position and adjusted to give the required bends by set screws against their ends. Immediately in front of the last bolt was set a permanent shear or cutting blade, jointed to it an upper blade with a wooden handle that the operator held in his left hand, while with a pair of pliers in the right hand he took hold of the wire, drawing straight by running his thumb on the edge of a straight-edge secured to the board to the mark indicating the length of wire required when, by

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[117] This paper shortage is further documented in Lyman H. Weeks, *A History of Paper-Manufacturing in the United States, 1690–1916* (New York: Lockwood Trade Journal Co., 1916), pp. 41–56.

[118] The diaries, more properly journals, are in the American Philosophical Society Library. Their contents are sampled in Hunter's and Maxon's accounts of Nathan Sellers. See note 116, above.

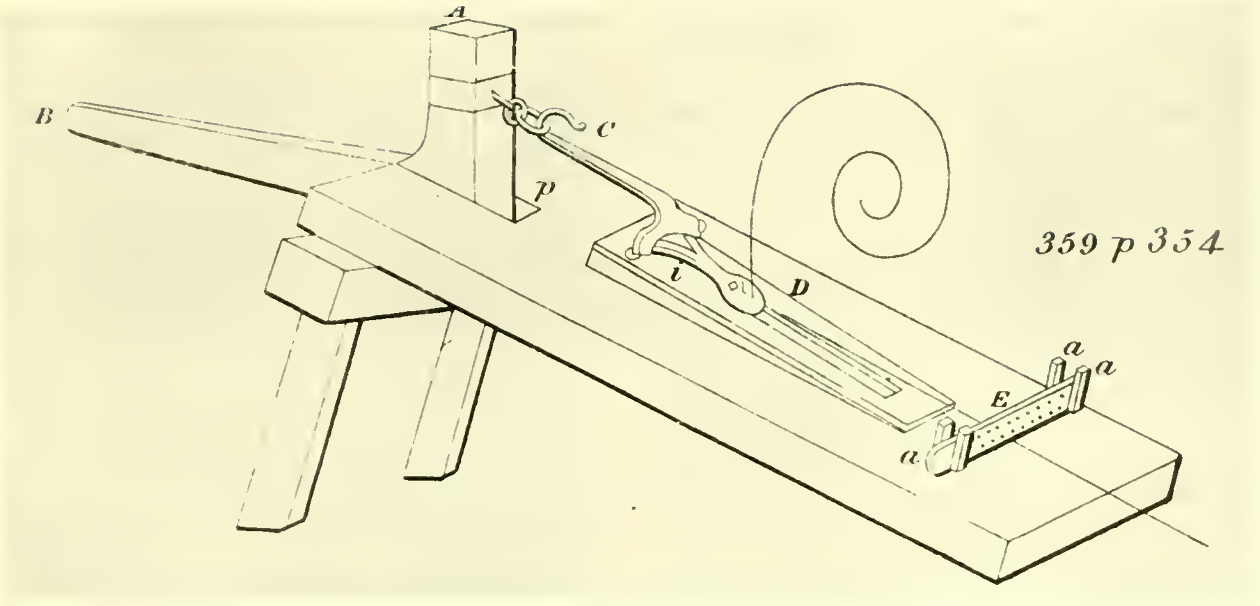

FIGURE 43.—Sloping wire draw-bench similar to the one described by Sellers. The tail of the lever (B) was actuated by studs or cams on a water wheel shaft. From John Nicholson, *The Operative Mechanic, and British Machinist*, 2d American ed. from 3d London ed., 2 vols. (Philadelphia, 1831), vol. 1, opposite p. 354.

depressing the handle in the left hand, it was clipped off.

As late as the year 1832, I found the pin straighteners still in use in England. One extensive wire worker was using the adjustable arrangement I have described. He called it the Sellers straightener, which he explained by saying that his predecessor had been a correspondent of Nathan Sellers, from whom he had received the plan, and at the same time the plan of his annular annealing pots, which they had not succeeded in using for the finest numbers of brass wire, which I found them still annealing over open charcoal fires, requiring great skill on the part of the workman, and even then the work was very imperfectly done.

On examining their furnace, the cause of failure was evident; a uniform heat could not be had in it, nor could the degree of heat be regulated with any certainty. I made them drawings of grandfather's furnace that had been without any change in plan successfully used for over fifty years, had one erected, charged a pot, worked off a heat, to the amazement of the proprietor, who was not slow in seeing certainty where there was uncertainty and a saving of not less than ten per cent in labor in that particular branch of his business. [33]

From all I can learn the early memorandums of drawing brass wire relate to a sizing of the wire, and not making it from the crucible or ingot. All imported wire of that period, when in long lengths, showed a perceptible difference in size, one end frequently being a full number larger than the other. This was supposed to be owing to the wear of the holes in the draw-plates, and not as it proved to be an accumulation of minute scales or hard matter in plates closing the holes and constantly reducing the size of the wire as it was being drawn.

For laid moulds, wire of absolute uniformity was required to give a perfectly smooth level surface, hence the necessity of a careful redrawing of all imported wire for that purpose, in fact all the finer numbers for weaving the vellum faces were subjected to the same redrawing or sizing; frequently they were reduced from so much larger sizes as to require several annealings.

But it was not this perfecting of brass wire that led directly to the annealing in closed vessels, important factor as it afterwards proved to be in the successful prosecution of that branch of the business. It was the difficulty experienced in drawing the finer qualities of iron wire suitable for card teeth, and for weaving into fine numbers of iron wire. The entire process at that time was of the crudest character. The wire rods, instead of being rolled as at present, were made from slabs forged at some one or other of the Pennsylvania charcoal furnaces, taken to a mill on Chester creek, rolled into flats, passed through slitting rolls made for slitting nail rods, leaving them about ½″ square and not over 6 feet in length.

Grandfather induced the proprietor of this slitting mill to erect a furnace for reheating these rods and to have some grooves turned in his plate rolls, thinking that by passing two or three times through these grooves would give a good round wire rod; but it was not a success, the slit rods were rough and irregular on their corners; on passing through the rolls corner pins were driven into the rods not perfectly welded, so that the wire drawn from them was full of flaws. For a long time the process pursued was to take short heats on these slit rods on an open hearth, and draw into round rods in half round swedges under a light quick-stroke trip hammer. The long and frequent exposure to the air caused a very hard scale to form on the surface, that had to be removed before passing through the wire plates. This was done by quick light strokes of a hand hammer, and by scraping; a tedious process requiring great care, for if the scales were not all removed, in the first drawing through the wire plate, they would either be indented into the rod or thrown off, and so fixed in the hole of the plate as to cause deep and unsightly scores in the wire that all after drawings could not entirely remove.

The drawing of rods into wire of about $\frac{3}{32}$-inch diameter before using wire blocks or drums was all done by short pulls by nippers or linked pincers, operated by cams or studs on a water-wheel shaft against a wooden lever to which the chain to the nippers was attached; this lever was kept in contact with the shaft by a chain connecting it to a strong spring pole. Each stroke gave a pulling motion to the nipper of about 12 inches. The draw-bench was set at such an inclination that the nippers would return for a fresh grip by their own weight, opening their jaws sufficiently to allow them to slide under the wire down the incline, being kept in position by a stud on their under side that slid in a well-lubricated groove in the draw-bench, the wire remaining between the jaws, that were so shaped as to allow it to pass over the arms of the nippers, allowing time for them to close and take hold of the wire. The 12-inch stroke gave about 11-inches pull through the wire plate.

Although this alternate pulling process had gone out of use long before my time, the old machinery had not been removed, and my grandfather fully explained the manner of its use. The plan was simple enough, but very defective, not only losing the time of the return of the nippers, but they would frequently fail to take hold of the wire, and always at every bite they would leave the marks of their teeth on the wire. This plan of drawing wire must have continued in use in England for the coarser kinds long after it had been supplanted in America by powerfully driven iron drums or blocks, for I well remember the tooth marks on imported wire, and so close together as to show their pulls were not over 3 or 4 inches long. It is hard for us of the present time to imagine the long continuance of this crude, jerking process before the adoption of the simple expedient of constantly revolving drums, especially when we consider that the revolving wire block had long been in use for drawing the fine numbers of wire, and its adoption for the coarser wires was only a question of power and strength of the machinery.

If I am not greatly mistaken, the credit of this advance is due to Josiah White, to whom we are also indebted for the introduction of anthracite coal, the opening of the mines on the Lehigh, and its improvements to admit of running small coal barges.[119] He created a wire mill at the falls of Schuylkill with a train of small rolls to run billets into round wire rods, and cast iron drums or blocks on which the wire was drawn, after having given a few pulls with the nippers to give length to clamp to the blocks. This was not invention but simply adopting by increased strength and power, what was successfully working on fine wire to the drawing of the largest. But had it not been for this advance, simple as it was, what would

[119] Josiah White (1781–1850), merchant, wire worker, builder in 1816 of a wire suspension foot-bridge 410 feet long and 2 or 3 feet wide at the Falls of the Schuylkill, and developer of anthracite coal and of waterways to deliver the coal to a market. There are two slight biographies: Richard Richardson, *Memoir of Josiah White* (Philadelphia, 1873), and Elizabeth G. Stern, *Josiah White* (New York: Stephen Daye Press, 1946). The former is useful for an engraved portrait and a short physical description of White. Both are based upon the same autobiographical manuscript: *Josiah White's History Given by Himself* (Philadelphia, 1909), privately printed from the privately held manuscript.

we do in this day of telegraphs, telephones and barbed-wire fences?

To return to the early wire drawing of my grandfather, he explained that as the wire was elongated as drawn by the nippers, he seized and coiled it by hand into rings of a suitable size for annealing. He was not long in discovering the great waste by oxidation from the frequent annealing in open furnace, that on the coarser wires the scale was removed without seriously injuring the wire by steeping or boiling in vats of very dilute sulphuric acid, which at that time was a costly process, but some saving was made by evaporating the spent liquid in the shape of the residual copperas or green vitriol, but as the wire was reduced in size, the effect of the acid was very injurious, causing much waste by breakage in drawing fine numbers, and sometimes rendering it so brittle as to unfit it for card teeth, not only breaking in bending the teeth, but in after use the cards breaking off close to the leather. Some mode of annealing must be devised to prevent contact with the air and oxidation.

The first experiment he tried was to reel the wire into coils of about 1 foot diameter, with a body of 2 inches, which he firmly bound with wire, making it as compact as possible. This he encased in well-ground and worked clay, such as is used for brick-making. He was careful in selecting his clay to have such as would not harden and self-glaze at a temperature so high as to effectually anneal the wire encased in it. After slowly cooling, this outer casing was broken off and the wire cleaned by heating, when it was found almost as bright as before annealing.

The next move was to turn on a lathe soapstone rings, half hollowed out to receive the coil of wire, encasing it. When two of these rings were closed together, the union being made tolerably air-tight with finely ground soapstone, making a dry luting, they were placed in a dome furnace, the lower one resting on iron bars. Five or six of these rings placed one above the other, separated by small soapstone blocks, filled the furnace. When heated to a proper temperature, the fire was drawn, the dampers closed, and they were allowed to cool in the furnace, for it was found, if taken out, to recharge the furnace with a fresh set, and they were allowed to cool in the air, the soapstone rings rapidly disintegrated. The wire annealed in these rings was not as bright as when encased in clay; the confined air was just sufficient to blue the wire, without forming any injurious scale to injure the draw-plates.

As to quality of wire, all that was desired was obtained, but the maintenance of the soapstone rings and loss of time in cooling in the furnace was too expensive. To obviate this, a Mr. Miller, who was at that time carrying on a pottery for the finer qualities of earthenware and fire tiles, made a number of fire clay rings that was an improvement on the soapstone, as they did not injure by quick cooling, and could be taken out of the furnace and a fresh charge put in without cooling down. This success led to experimenting with cast-iron annular annealing pots; they were from 12 to 14 inches deep, with annular space of from 2½ to 3 inches. The wire was reeled to a size to fill this space, and so loosely bound that when driven down with a wooden rammer and hand mallet they filled the entire space to the exclusion of the air, as much so as when encased in clay. The top of this annular space, when filled within about 1 inch of the top, were closed with sectional iron plates, well luted.

When I took my first lessons in this process, charcoal was used as the fuel, but it soon gave place to anthracite coal, except for the finest numbers of brass wire. The furnace was of the simplest possible construction, circular, with dome-top annealing chamber, while the pots were placed on a couple of iron bars extending across the furnace sufficiently above the bottom of the charging door to admit of an iron forked lever carrying the pot to pass in and seat it, and again to be used in removing it—the fire immediately under on a grate, as in the common cannon stove. Over and close to the fuel was a flue opening into the main flue; this was closed by a damper when the fire was well ignited, and the entire heat thrown into the annealing chamber, passing through the center and around the outside of the annealing pot—the draft through the chamber being regulated by a circular flue in the apex of the dome that opened into a close chamber. Connected with the main flue, over this circular flue, was suspended a long truncated cone, made of soapstone, so arranged that it could be raised or lowered from the outside of the furnace, leaving an annular opening around it, which could be increased or diminished with great accuracy, and thus perfectly regulating the heat within the annealing chamber.

In the first experiments, the management of this conical damper seems to have been one of great nicety until perfectly understood. To test the furnace for uniformity of heat in the annealing chamber, a very ingeniously constructed double gridiron pryometer was used, having one set near the sustaining bars in the lower portion of the chamber, the other near the apex of its dome. The fire and the damper were so worked as to have the index hands of this double instrument coincide; this was only used in acquiring a perfect knowledge of the manner of working the furnace. In the first annealing of fine brass wire in the annular pots, two cupels were placed side by side, with a button of fusible alloy on each, one that would melt at a temperature sufficient to thoroughly anneal the wire without danger of melting it, the other to melt at the danger point, which the operator had to be careful not to reach. Careful practice soon taught how to operate with safety, trusting to eye sight right through the peep-hole in the door, and judging by the color of the annealing pot, which, when it arrived at the proper heat, the dampers were closed and time given for the heat to penetrate the entire mass of encased wire; the average time required to anneal a pot was about one hour. One man with a long, forked, iron lever, suspended by a chain to a crane, would with ease withdraw the hot pot and replace it with a cold one.

I have been thus particular in describing the early practice of my grandfather in annealing both iron and brass wire, believing, as I do, that the credit of the experiments that led to the use of close iron annealing pots is due to him, and that England is indebted to America for an advance that not only improved the quality of their card tooth wire, but made considerable saving from the waste of oxidation and its removal by the acid pickling process. The principal proprietor of the English works I alluded to in my last paper [120] told me that he had served his apprenticeship at them. He would not give the exact date of their commencing the use of the close annular annealing pots, but he was confident that it was prior to 1780, or about that period, for they then commenced furnishing the firm of N. & D. Sellers with card wire, they having given up the iron wiredrawing branch of their business. That, on the receipt of the first order for card wire, and fine numbers of iron wire for weaving, Mr. Nathan Sellers made it an indispensable condition that no acid should be used after the wire had been reduced to No. 14, that all after annealings required should be done in close pots, or annealing kettles, as he called them, to exclude the air, and to enable them to do this he sent them sketches of his furnace and pots, and gave an account of the experiments he had tried that led to their adoption.

At the time of my visit this firm had been the agents of and regular correspondents of N. & D. Sellers and their successors for over 60 years. They had carefully preserved the old sketches, which were shown to me, and which I at once identified as the work of my grandfather. They unfortunately were not dated, though reference to some of the early correspondence fixed the date about as above stated. The advantages of annealing the finer qualities of iron wire excluded from the air, was considered of such importance to the concern that for a quarter of a century that portion of their work was done secretly by a member of the firm and one or two confidential workmen. From the most reliable information I could obtain it was not until the beginning of the present century that other wire works adopted the pot or retort system of annealing, and then it was introduced into England by French workmen from the manufactory of Messrs. Mouchel, of the department of L'Orne, France.

What struck me as most extraordinary was that a concern who for so long a period had successfully annealed their iron wire for card cloth and fine steel wires for musical instruments, had so utterly failed in every attempt to anneal fine brass wire. They said the lower coils in the pots were certain to melt and run together, when the upper ones would not be sufficiently annealed to draw well.

After having their furnace remodeled, I admit to having found considerable difficulty in getting up and maintaining a perfectly uniform heat with coke as the fuel, it requiring a different management of both the lower draft and the conical soapstone damper; but after a little practice I made the venture successfully with a pot charged with brass wire of a number fine enough to weave into vellum wire of 80 meshes to the inch.

As late as 1832 some of the English wire mills were still annealing their coarse wires in the flames of a reverberatory furnace, and wasting stock and injuring quality by severe vitriol cleaning, and others that were using retorts or pots did not charge them to exclude the air as effectively as it should have been done for saving in the vitriol process. Two extensive card-wire mills that I visited were exercising the greatest possible care in charging their pots and luting them, bringing the wire out in condition for the wire plates without the use of acids to an injurious extent. [34]

120 Probably Mathews of London. The "last paper" forms the first part of this chapter.

As near as I can recollect, it was about the year 1820 or 1821, that my grandfather and father jointly invented and constructed with their own hands a most important labor-saving machine, for laying or weaving the faces for laid paper moulds. Previous to that time it had been done entirely by hand, each wire being laid separately as it was to remain, forming the outer face of the mould; the fastenings or twists of each seam were made by hand one after the other. Hence as a labor-saving machine, twisting all the seams at the same time, it was as one to the number of seams in a face. For instance, a mould for making commercial post paper, has about 22 seams, each bar of the mould frame representing a seam. Double cap moulds have from 28 to 30 bars; besides this saving, a uniformity never before approached, was obtained. The faces, being formed or woven independent of the mould frames, were laid on and secured to the under face or foundation by sewing with wire. This, about the year 1824, was the earliest work of the kind I turned my hand to.

My elder brother Charles had, about two years previous to this, partially relieved our grandfather from forming the devices for water marks, and sewing them on the moulds, which up to that time, embracing a period of at least 55 years, had been exclusively his work. The manner letters or other devices for water marks were formed of plated copper wire was on blocks of hard wood, faced on the end of the grain, similar to the blocks used for wood engravings. On these were drawn the letters or other devices. Needle points were driven into the block and left projecting slightly above its face at every point where the water mark wire was to be bent. When the blocks were thus prepared the silver-plated wire was held in close contact with them, and wound or bent around these points until the device was formed. It was then carefully raised from the block, laid on the brass plate, the bends adjusted or squared with small hand pliers, previous to sewing on the mould face. This after adjustment was necessary, as no acute angle or square turn could be made around the steel pins. It was not long before my brother improved on this method of forming the devices. He made his designs on metal plates, and used a tool like the watchmaker's small round handled screw driver, notched on its end to straddle the wire to be bent, holding the handle between thumb and fore finger, the wire on the metal plate, by a simple rolling motion of the tool, he could turn a perfectly square turn, follow the device with all the accuracy of the old method, without requiring any after adjustment. At that time all the makers of fine writing papers were very critical as to the uniformity and accuracy of their water marks, such as arrows, dove and olive branch, Robinson's lamb, Kelter's carrier pigeon, and others more elaborate. [35]

12. A Visit to the Mills of the Brandywine

In 1817 or 1818, George Escol Sellers, not yet ten years old, journeyed with his father to see Thomas Gilpin's new cylinder paper machine on the banks of Brandywine Creek, just north of Wilmington, Delaware. The area was a center of industry that included mills for the manufacture of paper, flour, gunpowder, cotton goods, and textile machinery.

The paper mill of Thomas Gilpin had been established 20 years earlier by his elder brother Joshua Gilpin and Miers Fisher.[121] Flour mills had been in operation since before 1750, and by the 1780's several were employing Oliver Evans's bucket- and screw-conveyors.[122] The powder mills were those of E. I. du Pont de Nemours, who had opened them in 1802. William Young's cotton factory and the machine shops of the Hodgson brothers have been mentioned in chapter 9. It was in the Hodgson machine shops on the Brandywine that George Escol's uncle, Franklin Peale, had learned the machinist's trade.

Thomas Gilpin's paper machine, patented in 1816,[123] was based upon the similar machine of John Dickinson, of London, patented in 1809.[124] Details of Dickinson's machine had been obtained through the extensive European travels of Joshua Gilpin [125] and from Lawrence Greatrake, who had returned to England on personal business at the time the Gilpins were considering the practicability of producing machine-made paper in America.[126]

Other cylinder paper machines followed Gilpin's, as related by Sellers. Of John Ames's patent for a cylinder machine, the editor of the *Journal of the Franklin Institute* commented in 1833 that he could detect nothing novel in the Ames specification, since Ames was merely adapting a design that had originated in France and that had since been improved in England and in the United States.[127]

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[121] The Gilpin mill is featured in the Hagley Museum, located on the Brandywine at the site of early Du Pont powder mills, a few miles above Wilmington, Delaware. See Harold B. Hancock and Norman B. Wilkinson, "Thomas and Joshua Gilpin, Papermakers," *The Paper Maker* (1958), vol. 27, no. 2, pp. 1–10; and, by the same authors, "The Gilpins and Their Endless Papermaking Machine," *Pennsylvania Magazine of History and Biography* (October 1957), vol. 81, pp. 391–405.

[122] Peter C. Welsh, "Brandywine: An Early Flour-Milling Center," *Annual Report of the Board of Regents of the Smithsonian Institution . . . 1959*, pp. 677–686. Illustrated, and with notes that are bibliographic in scope.

[123] U.S. patent, December 24, 1816. No restored drawing exists, but a reconstruction of the machine from existing drawings located by Hancock and Wilkinson (see note 121) is on the cover of *The Paper Maker* (1958), vol. 27, no. 2.

[124] British patent 3191, January 19, 1809.

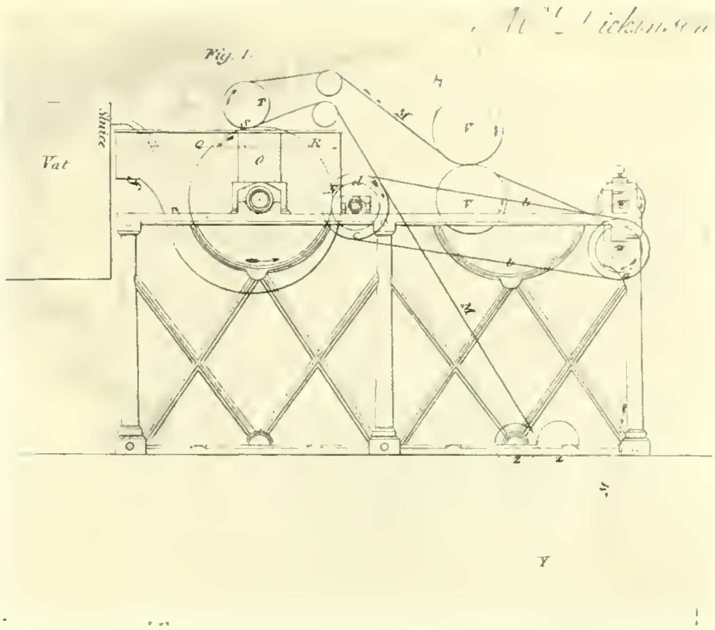

FIGURE 44.—Dickinson cylinder paper machine. The cylinder was immersed in dilute pulp to the level Q–R. The sheet formed on the cylinder's surface was transferred at s to the continuous felted belt (M). From *Repertory of Arts, Manufactures, and Agriculture* (December 1817), ser. 2, vol. 32.

THE MACHINE I REFERRED TO,[128] believing it to have been the first machine on this Continent to make continuous paper, and that I had a perfect recollection of, was in the paper mill of Mr. Thomas Gilpin on the Brandywine Creek a few miles from Wilmington, Del., but I cannot with certainty fix the date that I first saw it in operation; but from other circumstances connected with the visit to the mill with my father I do not think it was earlier than 1817 or later than 1818, and then the machine had been in operation for a considerable time.

I have no distinct recollection of the special object of my father's visit to the mill at that time. But I do remember that he and Mr. Gilpin and his manager, Mr. Greatrake, spent much time in the machine room watching the operation, sketching and discussing points in connection with the forming cylinder and the exhaust pumps. The millwright had been

[125] HAROLD B. HANCOCK and NORMAN B. WILKINSON, "Joshua Gilpin: An American Manufacturer in England and Wales, 1795–1801—Part I," *Transactions of the Newcomen Society* (1959–1960), vol. 32, pp. 15–28; "Part II," (1960–1961), vol. 33, pp. 57–66. This paper summarizes the Gilpin journals, some 62 small volumes, in Pennsylvania State Archives, Harrisburg. These journals show Gilpin's method of working, but are for his earlier sojourn. He was in Europe again from 1811 to 1814.

[126] Lawrence Greatrake is known to me only through these pages and a series of his letters in the Gilpin papers in Historical Society of Pennsylvania (kindly pointed out to me by Norman B. Wilkinson). Bound in a volume entitled "Paper Making Machinery—1816—Property of Richard Gilpin" there are several of Greatrake's letters to Thomas Gilpin between September 1815 and April 1816. The date of Greatrake's first coming to the United States is uncertain. He mentioned, however, that "had I staid another year in England, I had been a partner in the immense concern at Apsley . . ." Dickinson purchased the Apsley mill in 1809 (Anon., *The Firm of John Dickinson and Company Limited*, London, 1896, p. 7), about the time his paper machine patent was issued. Thus Greatrake may well have been Dickinson's right-hand man, as related by Sellers; but his letters do not suggest an earlier familiarity with the development of the Dickinson machine. Greatrake said only that Dickinson "was an apprentice with Richardson and Harrison when I used to do business at their house . . ." and did not mention his having been employed by Dickinson. Greatrake had some financial interest in the Gilpin mills when he returned to England in 1815 to wind up the affairs of his deceased father, and he spent much time and energy in obtaining information on both Fourdrinier and Dickinson machines. Greatrake's letters indicate that he could not obtain a cylinder to take to the Gilpins, as he had hoped to do. (In 1815 Franklin Peale married Eliza Greatrake, daughter of Lawrence. The marriage was a tragic one, for within a year or two Eliza became hopelessly insane.)

[127] *Journal of the Franklin Institute* (April 1833), vol. 15, pp. 225–226. The patent was dated May 14, 1822, and was reissued on October 25, 1832.

[128] Reference is to the Gilpin machine, in a summary article in *American Machinist* (December 4, 1886), vol. 9, pp. 4–5, omitted by the present editor.

called in, and while some changes were being discussed I left them; having [a] considerable portion of the afternoon to myself I took advantage of it to call on Mr. Irenée du Pont, the founder of the Du Pont Powder Mills, whom I had frequently met in my father's office; he took me through the mills explaining everything; this made a lasting impression, for it was the first time I had seen the process of gunpowder making.

I also visited the cotton factory of my father's old friend, Mr. William Young, who had, in connection with his factory, a good machine shop for that period. It was in this shop that my uncle, Franklin Peale, served his apprenticeship . . . .

We spent the evening with Mr. Gilpin in his bachelor quarters, Messrs. Du Pont and Greatrake being of the party. The making of paper by machinery in all its aspects was discussed, also the feasibility of drying the paper by steam heated cylinders. To the best of my recollection Mr. Gilpin expressed great doubts, fearing injurious effects on the paper. He had a scheme of drying by passing the paper from the machine through chamber currents of heated air, the paper being carried on rack belts, partially drying, then passing between heated calender rolls, thence through another long chamber of air heated to a higher degree, and finishing by a second set of calender rolls. I have no knowledge of his ever having essayed to put this plan in practice, though he seemed to have tested the degree of heat, length of chambers, speed of paper, and velocity of the current of heated air necessary to produce the results aimed at.

The Gilpin machine was that of John Dickinson. The original cylinder was made in England and brought out by Mr. Greatrake who had been foreman of Dickinson's "Nash Mill."[129] My impression is that the rest of the machine was constructed at a machine shop erected for that purpose at the mill. For many years the machine was worked with as much secrecy as Dickinson had worked his in England.

The cylinder was not over 3 feet [long] and about 2 feet in diameter, a solid brass casting bored perfectly smooth interior, and the outside was turned in shallow grooves leaving between them ridges with sharp edges corresponding to the bars of paper moulds. In the grooves between the ridges holes were drilled into the interior of the cylinder so close together as to form a perfect net work, through which the water from the pulp passed into the interior of the cylinder; the sharp edges of the ridges that separated the grooves were notched lengthways of the cylinder about ¼-inch apart to receive rods of about No. 16 hard brass wire, that was soldered into the notches, forming an underface like the underface of a paper mould. Over this was a backing of wove wire of about 14 meshes to the inch, on which the fine wire cloth face was placed. The ends of the cylinder were closed with solid brass plate heads having journals cast to them on which the cylinder turned. One of these journals was hollow, through which a tube passed into the bottom of a V-shaped trough with closed ends, the edges of the trough coming into close contact with the inside of the cylinder, which it was held firmly against by having a journal opposite to the tube end and centering in the solid journal of that end of the cylinder.

The dilute pulp being delivered to the cylinder by pumping out the water and partly exhausting the air from that portion of the cylinder covered by the space between the edges of the V-shaped trough, the exterior atmospheric pressure sufficiently consolidated the film of pulp to prevent it squashing and disfiguring the paper as it passed under and on to the felt of the couching roll, and thence between the various press rolls. This V-shaped trough, in which the amount of exhaust could be regulated, was the great feature of the Dickinson cylinder machine, and was deemed essential.

The manner of reeling the wet paper was ingenious. To prevent any undue strain that would tear the wet paper asunder, the reels were driven by the friction of a wooden V-edge wheel in a corresponding V lined with leather wheel on the reel shaft, the amount of traction being regulated by a P weight sliding on a lever arm that pressed the wheels together.

The reels were formed of six wooden slats on spider arms. One of the slats had a groove from end to end in which a knife was run cutting outwards. Thus when the required quantity of paper was wound on the reel, [the knife was drawn through it],[130] separating it and allowing it to fall on to a sliding table from which the porter separated the sheets, carrying and hanging them in the drying loft. To prevent loss of

[129] The Nash mill was purchased by John Dickinson in 1811. (*The Firm of John Dickinson and Company Limited*, cited in note 126 above, p. 7).

[130] Line omitted from printed version has been supplied by this editor. Manuscript has not been found.

time in changing the reels and cutting the paper loose from them, two reels were hung at opposite ends of center-pivoted arms. Mr. Gilpin had attached to each reel a counter with dial showing the number of revolutions or sheets wound.

When a reel had on it the number of sheets required, the attendant would swing it over without stopping the paper being formed, and as soon as the empty reel had taken the place of the full one he would, with a stick, break down the wet paper pressing the end between the slats of the empty reel, and the winding would continue on it.

Mr. Gilpin complained of the necessity of having so many different sizes of reels, or being obliged to change slats to suit the different sizes of paper ordered.

I asked why not make the reels to expand and contract to adjust for the different sizes?

He turned to me and in his quick, impulsive manner, said: "Boy, that is easier said than done. I have often thought of it but I cannot see any way of accomplishing it."

His sudden explosion almost took my breath from me; I felt as a boy, I had been too hasty in putting in my oar. I stammered: "If you will come to our shops, and see grandfather's old sieve hoop rounders or stretchers, they may give you an idea."

These old stretchers were nothing more than a plate scroll screw, that, on turning, thrust out a number of arms against the inside of a sieve hoop holding it to a perfect circle, while the wire cloth was being tacked on—the same in principle as the present universal lathe chuck. It was not long until Mr. Gilpin came to see the stretchers, and was so well pleased that he undertook to have a couple of six-arm expansive reels made.

At that time there was no face lathe in Philadelphia with arrangement for cutting the scroll screw. He had recourse to Isaiah Lukens, who wound a wrought-iron scroll thread, riveted and brazed it on to a wrought plate in the same manner grandfather had made his original stretchers. Mr. Gilpin was very proud of these reels, so much so that he had a graduated scale with vernier attached, that enabled him to at once adjust for any length of paper; this, with his counters and their registers, he considered a great advance, but they were to be superseded by steam dryers, calenders, slitters, and cutters to deliver the finished sheets direct from the machine.

Sometime previous to the visit of Mr. Gilpin's mill a very simply constructed cylinder was brought to be covered with wire cloth. I cannot recall the name of the Frenchman who brought it nor the location of his mill except that it was in New Jersey, and that it was a hand mill making wrapping and sugar loaf paper. It was a small affair, not over 2 feet 6 inches long and about 2 feet in diameter. It was constructed on the principle of a squirrel cage wheel. Six slender-arm brass wheels on an iron shaft that was covered with a copper tube formed the framework of the cylinder. The end wheels had rims about 1½ inches deep by ½-inch thick, and at their smallest diameter a projecting rim or collar about 1 inch, not over ¼-inch thick at its outer edge. The four center supporting wheels equally spaced on the shaft had round rims of about ⅝-inch diameter. Holes were drilled close to the outer edge of the end wheels about 1 inch apart of a size to take in a No. 6 brass wire through these holes. Brass wire rods of that size were run from end to end of the cylinder, resting on and being supported by the round rims of the intermediate wheels. This was the condition of the cylinder when it was brought to the shop of N. & D. Sellers to be finished and faced with wire cloth by its inventor and maker, and I recollect it as a very creditable piece of work. The rims and collars of the end wheels were accurately turned, the arms and hubs finished, as were also those of the supporting wheels whose round rims were turned as much as they could be beyond the arms, the portions between the arms file and scraper finish. The man had worked out in his own mind exactly what he wanted done. In the first place the longitudinal rods must be secured to the round rims of the supporting wheels so as to keep them straight and equal distance apart; this he proposed doing by tieing to the rim with soft copper wire. It was done by the kind of loop sewing as wire screens were then made. This being done the cylinder was wrapped from end to end with No. 18 hard brass wire laid so as to leave a space of ¼ inch between each round. This was secured to the longitudinal rods in the same manner of loop sewing as they were secured to the rims of the supporting wheels, then covered as the Gilpin cylinder was by a wove brass wire backing of 14 meshes to the inch, over which the fine wire face was placed.

The explanation given of the object of the projection rims or collars on the ends of the cylinder, was that the cylinder was to be sunk, to say, ⅔ or ¾ of its diameter in a vat of dilute pulp, these collar projections coming into close contact with the sides of the vat. By tacking a strip of sheep skin with the wool on it to the vat, so that the wool would rest on the collars, and by their intercepting the pulp would form a pulp tight joint, and allow the cylinder to revolve with very little retarding friction. Holes through the vat near the bottom inside of the cylinder led into an outside vat into which the water from inside the cylinder could freely pass; in this outside vat he had a Persian wheel, that by revolving would raise the water to its hollow center axis, through which it poured back into the pulp vat, only allowing so much to escape through an adjustable gate as would correspond to the amount of water coming in with the constant supply of pulp. By regulating the speed of the Persian wheel, the difference in the height of dilute pulp outside and the water inside the cylinder would be kept uniform with sufficient difference to consolidate a film of pulp to pass onto the felt of the coucher without squashing.

I have no knowledge of what experiments had been tried, but from the confidence the man spoke on that head, it gave the impression that he spoke from actual trial results. There must have been difficulties he met with in getting his machine into successful operation, for it was a considerable time before he sent specimens of a very fair quality of printing paper made on the cylinder.

I have been thus particular in describing this cylinder, for I believe it to have been the first simple squirrel wheel cylinder ever made; and also on account of its close resemblance to the cylinder invented and patented by John Ames, of Springfield, Mass., at a later date, and from which patent grew long and expensive litigation.

I recollect that when my father sketched and explained this simple cylinder to Mr. Gilpin that he seemed perfectly incredulous as to the possibility of consolidating a film of pulp sufficiently to couch without the V-trough and exhaust pumps, but at the same time he showed considerable uneasiness; for, said he, could such a simple cylinder and machine be made to work at all it would be a dangerous competitor to his expensive cylinder machine. [36]

If I am not greatly mistaken at the period of our visit to Mr. Gilpin's mill, he was the sole manufacturer of endless or machine made paper in America, and it was from perfecting the simple cylinder that I have described as the work of a Frenchman in New Jersey, and its appliances, that the rapid introduction of machine made paper in America takes its date.

I am strongly impressed with the belief that when John Ames, of Springfield, Mass., got up his squirrel-wheel cylinder and machine, and patented it, that he had no knowledge of what had preceded him in New Jersey, although they were substantially the same.

My father greatly improved this simple cylinder, by substituting for the longitudinal round rods, drawn rods, of an oval or rather egg-shape, somewhat like the wooden bars of the paper mould, only being made of brass, much smaller. These, besides being secured in drilled holes in the rims of the end wheels or the cylinder, were sunk half their depth into sharp-edged rims of the supporting wheels, to which they were firmly secured, instead of simply resting on round rims secured in position by looped wire sewing, as in the case of the New Jersey cylinder. To secure the wrapping wire of No. 18 hard-drawn brass, forming the foundation or under face (without sewing) notches of one-half the diameter of the No. 18 wire, were cut spirally around the cylinder in the outer edges of the oval longitudinal bars, leaving a space of ¼-inch between each turn. This was done by a traversing buzz cutter [131] that spirally notched the bars as the cylinder revolved. The No. 18 wire, being wound in these notches, was held firmly in place by a wove wire backing of about fourteen meshes to the inch, on which the outer face of the cylinder was placed, the only sewing being that to secure the ends of the faces where they met together.

This simple cylinder produced the effect apprehended by Mr. Gilpin; its comparatively small cost, compared with his elaborately constructed cylinder, put it within the reach of all paper makers, no matter how small their mills. Many single vat mill owners were among the first to adopt it.

The putting up and starting paper machines became a leading business for a number of millwrights. The proprietor of the mill would procure a cylinder complete, with the shafting, gearing and spindles for the wooden press rolls, all of which we furnished in sets. Beyond this, all was the work of the millwright. Old apple orchards furnished the material for the press rolls; even the housings they ran in were at that time made of wood. I do not recollect finished cast-iron housings, with boxes complete, being called for earlier

[131] Essentially a milling cutter. Henry Maudslay had devised such a cutter for cutting gear teeth on a lathe. The cutter (according to John Nicholson, *The Operative Mechanic and British Machinist*, 2d American ed. from 3d London ed., Philadelphia, 1831, vol. 1, p. 332) turned at 7,300 revolutions per minute.

than 1829, about which time we began to keep them on hand to fill orders.

The cost to the paper maker of a complete cylinder, 2 feet diameter by 3 feet long, was $160, with a charge of $3 for every additional inch in length. A few cylinders, as much as 30 inches diameter, were made, mostly for making inferior grades of wrapping paper out of stock lacking in felting property requiring more difference between the dilute pulp outside and the water inside of the cylinder, such as straw digested with quick-lime, discovered and introduced about that time by George Shryock, of York, Pa.[132] The cost of putting and starting a simple squirrel-cage cylinder machine with wooden press-rolls, was from $500 to $600.

From about the year 1830 we had a number of millwrights constantly out and employed on this kind of work, it being about that period that the rapid change from hand made to machine made paper had fairly set in. I give the above figures entirely from recollection. When my brother and myself left Philadelphia in 1840, the old account and order books were stored there; but since the death of the person they were left with I have lost all trace of them, which I regret, as from them reliable and actual dates of all the advances made in paper making machinery, from Gilpin's machine and the New Jersey cylinder of the Frenchman, up to the close of 1839, could have been obtained.

From the best of my recollection, Messrs. Phelps & Spafford [133] were the first builders in the United States of the long-web Fourdrinier machine, with steam driers complete, their machine being a close copy of Bryan Donkin's. About the same period cylinder machines with driers were being built at Brattleboro, Vt., and other places, our works at that time being confined exclusively to cylinder machines without driers, which we did not commence building until 1833.

The rapid change from hand to machine made paper, when the start had fairly been made, created so great a demand that many establishments went into the manufacturing of both cylinder and Fourdrinier machines, the names of many of which I cannot recall. Nelson Gavatt, who had been employed in setting up and starting machines for Phelps & Spafford, established works in Philadelphia. At a later period Barton, Rice & Co. and I. L. Severs, of Worcester, Mass.; Smith & Winchester, of South Windham; Merrill & Co., Beloit, are among the names that at present occur to me who built paper machinery.

About the years 1831 and 1832 there was much discussion as to the merits of copper or cast iron for drying-cylinders. The thin copper transmitting the heat rapidly, it was urged that the same regularity could not be kept as when the thicker and less rapid conductor, cast-iron, was used. It was reported that John Dickinson, for his fine qualities of copper plate veneered paper, used cast-iron drying cylinders, and that Bryan Donkin was covering cast-iron drying cylinders with sheet copper that was so perfectly and beautifully done as to excite the admiration of everyone. They bore the appearance of having been finished by turning with great accuracy, a very difficult job with copper as thin as used when not soldered or cemented to the cast iron. Letters from England spoke in such high terms of these improved dryers that several prominent paper makers were contemplating importing machines from Donkin. [37]

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[132] Paper of straw was made by George A. Shryock, of Chambersburg (not York,) in 1829. He purchased the rights to the process from William Magaw, of Meadville, Pennsylvania. (Weeks, cited in note 117 above, pp. 161–162, 221–223.)

[133] Of Windham, Connecticut, in 1830 (*Manufactures of the United States in 1860 . . . Eighth Census*, U.S. Census Office, Washington, 1865, p. cxxvii). The first Fourdrinier machine in the United States was built by Bryan Donkin and erected in Saugerties, New York, in 1827 (R. H. Clapperton, "Invention and Development of the Endless Wire, or Fourdrinier, Paper Machine," *The Paper Maker*, February 1954, vol. 23, no. 1, pp. 1–17). On these points, see also Weeks, (cited in note 117 above), pp. 179–181. A satisfactory history of papermaking machinery in the United States remains to be written.

13. Papermaking by Hand and by Machine

The art of making paper by hand, although it is still practiced commercially in England,[134] had reached essentially its final form during Sellers's boyhood years. It was during these years also that papermaking machinery was being developed. While this chapter anticipates the author's visit to England, its emphasis upon the state of the art in the United States prepares the way for the more detailed descriptions of English practice that follow in subsequent chapters.

John Dickinson (1782–1869)[135] was, when Sellers visited him in 1832, one of England's foremost papermakers, owning at least four machine paper mills to supply his vast paper warehouse in London. The eldest son of a captain of the Royal Navy, Dickinson had been led to the paper trade through his father's intimate acquaintance with the official stationers to the East India Company. Coming into the trade when the Fourdrinier machine was in the early stages of development, Dickinson had conceived of an essentially different approach to the problem of forming paper on a machine. While carrying on a conventional paper business, he developed the cylinder machine that he patented in 1809, two months before his 27th birthday.

It was Dickinson who, in 1829, produced the first smooth-surfaced "safety paper" for bank-notes, incorporating between laminations bits of brightly colored silk thread.

His prominence as a man of affairs was attested to by his election, in 1845, as a fellow of the Royal Society. He was active in business until 1857, when at the age of 75 he retired.

To realize the great value of the continuous sheet of paper making, we have only to glance at the long and tedious hand making process—the number of times that every single sheet of paper had to be handled. Hand labor from the beginning of the process. Before bleaching with chlorine . . . which was not earlier than 1817, the year Grandfather gave up active business, every single rag had to be inspected for on its color depended that of the paper. Even the whitest rags after washing, dusting and cleaning had to go through rotting process before, in the days of the stamps, they could be pounded into pulp. I refer to this to show the first important step was the rag beating engine. After the pulp was made the vat man with his hand mold had to dip sufficient to form the sheets, then to so handle the mold as to drain off sufficient water to leave the pulp of a consistency so that it could, by the coucher, be couched (transferred) to a sheet of woolen felt and covered by another sheet and so on until the pile or post was complete. It would then go into the hands of the lay man whose first duty was its wet pressing (screw press) to remove all surplus water and leave the sheet in a condition so that it could be separated from the felt. He carried it to the drying loft, hung in nests of four or

[134] An informative series of illustrations of hand papermaking as practiced now in an English mill and samples of handmade paper are in Quentin Fiore, "Paper," *Industrial Design* (November 1958), vol. 5, pp. 32–59.

[135] An obituary is in *The Times* (London), January 20, 1869. See also *The Firm of John Dickinson and Company Limited* (cited in note 126 above), 63 pp., and Joan Evans, *The Endless Web; John Dickinson & Co., Ltd., 1804–1954* (London: Cape, 1955), about 300 pp.

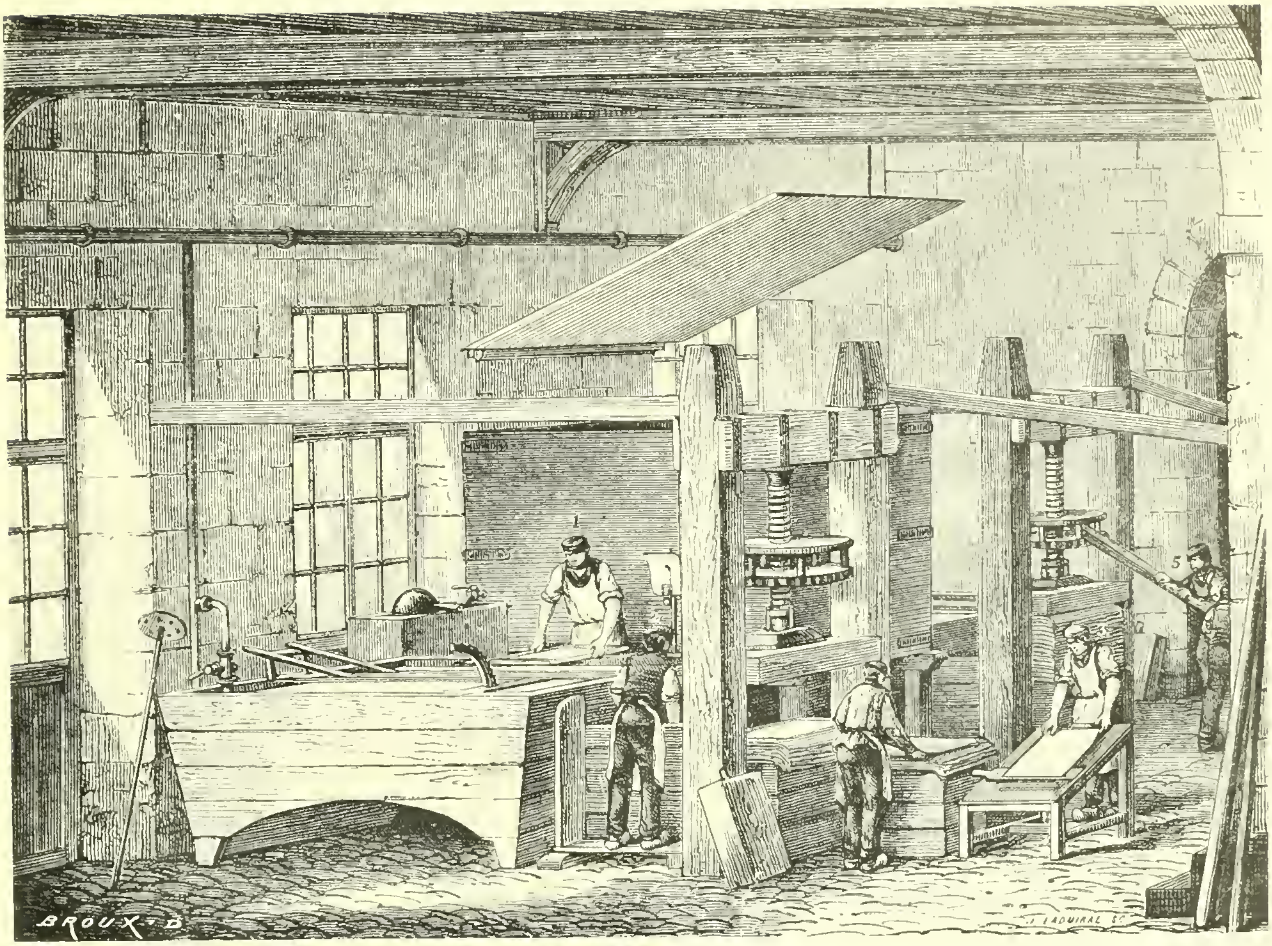

FIGURE 45.—Handmade-paper mill. The vatman (center background) dips the mold into the vat of dilute pulp, forming the sheet of paper. The screw press in the foreground is being loaded with alternate sheets of newly formed paper and felt. Excess water is being squeezed from the stack of paper and felts in the press in background. From Louis Figuier, *Les Merveilles de l'Industrie* (Paris, 1873?), vol. 2.

five sheets well separated on ropes or poles to dry, and after drying, such paper as had to be used as writing paper had to be sized by dipping into a vat of warm liquid animal size or gelatine, and again dried and finished by pressing between boards, sheets of copper or zinc or polished pasteboards known as fullers boards. The highest grades were dried by hot pressing, by heated plates of iron at certain distances apart in every post being pressed. After all of this the sheets, sheet by sheet, had in the finishing room to go through the hands of inspectors, mostly women, who with an erasure would remove specks and knots, rejecting what was called retrieve and that generally amounted to about a quire to every ream put up, which was divided and placed on each side of the ream. Now, we have no retrieve, every parcel of paper put up is perfect according to its grade and instead of an average time in favorable weather of say eight days from the vat for writing papers, now from the same point, prepared pulp, an order may be taken for any desired thickness, size and finish, and within an hour from starting the paper machine,

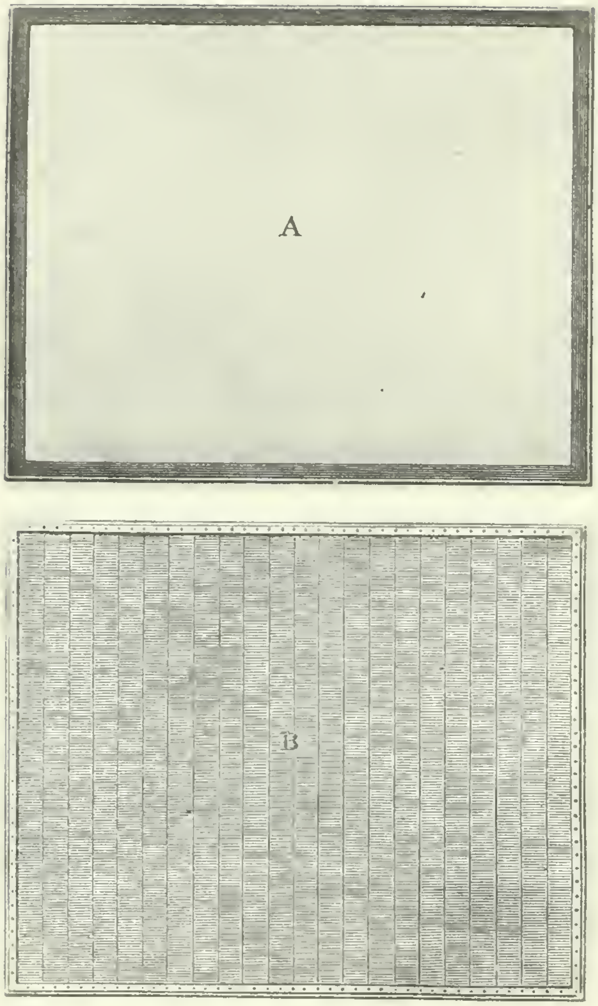

FIGURE 46.—Paper mold and deckel. The deckel (frame), A, provides a lip around the laid wire mold, B, while the sheet is being dipped from the dilute pulp in the vat. The deckel is then removed from the mold in order to couch (transfer) the formed sheet to a felt. From Louis Figuier, *Les Merveilles de l'Industrie* (Paris, 1873?), vol. 2.

whether it be the long web or the cylinder machine, packers may begin putting up the order.

And to whom does the credit belong for this vast advance? The question is easily answered: mainly to Bryan Donkin and John Dickinson in their different lines. The first who took up the long web idea of Robert, a French workman, in principle correct but in detail so imperfect that the machine of Robert & Didot, the mill owner, was an absolute failure; but Donkin's brains and skillful hands made it a perfect success. Not at once, but by long years of perseverance, improvements and additions [he] produced the splendid perfect machine that is known now as the Fourdrinier Long Web Machine, a misnomer, it should have been a Donkin. Fourdrinier's part was like that of Boulton to Watt, capital and confidence.[136]

John Dickinson was a blacksmith making the fly knives and bed plates for the pulp beaters. He conceived the idea of a wire covered cylinder inserted to, say two-thirds its diameter in a pulp vat, which by a properly arranged inside suction the pulp could be couched on an endless belt and be carried to press rolls. This idea was the foundation of the cylinder machine. His cylinder was an elaborate affair and one of very difficult construction. At the time of my visit to London he was carrying on five or six separate extensive paper mills, had the most extensive paper warehouses and was said to be the most extensive paper dealer in London.

My first interview with Mr. Dickinson was not at all pleasant, for on learning that I was an American and interested in paper machinery he launched out in most bitter denunciation of our friend Thomas Gilpin, whom he accused of having wormed himself into his confidence, became acquainted with what he was doing with his first paper machine, bribed Greatrake his right hand man and took him to America, forestalling him there. The nature of my introduction was such that I hoped to get some information I wanted and Mr. Donkin had told me that Mr. Dickinson was the only person who could give me this, but he had added that everything would depend on my getting on his right side. I made my visit short and was leaving greatly discouraged when Mr. Dickinson asked my address in London, and when I gave Mathews, Crooked Lane, he said "he is a most

[136] Nicholas Louis Robert, while employed in the mill of Léger Didot, of Essone, France, in 1798 patented the continuous web machine. Didot took his patents and a model to London, where Henry and Sealy Fourdrinier, stationers and mill owners, took a half interest in the British patent (taken in the name of John Gamble: 2847, April 20, 1801). Bryan Donkin, who was called in to help perfect the model, built the first full-scale machine in 1803. (CLAPPERTON, cited in note 133 above.) See also D. C. COLEMAN, *The British Paper Industry, 1495–1860* (Oxford: Clarendon Press, 1958), pp. 179–199. Donkin's part in the success of the machine is developed more fully in chapters 14-16, below.

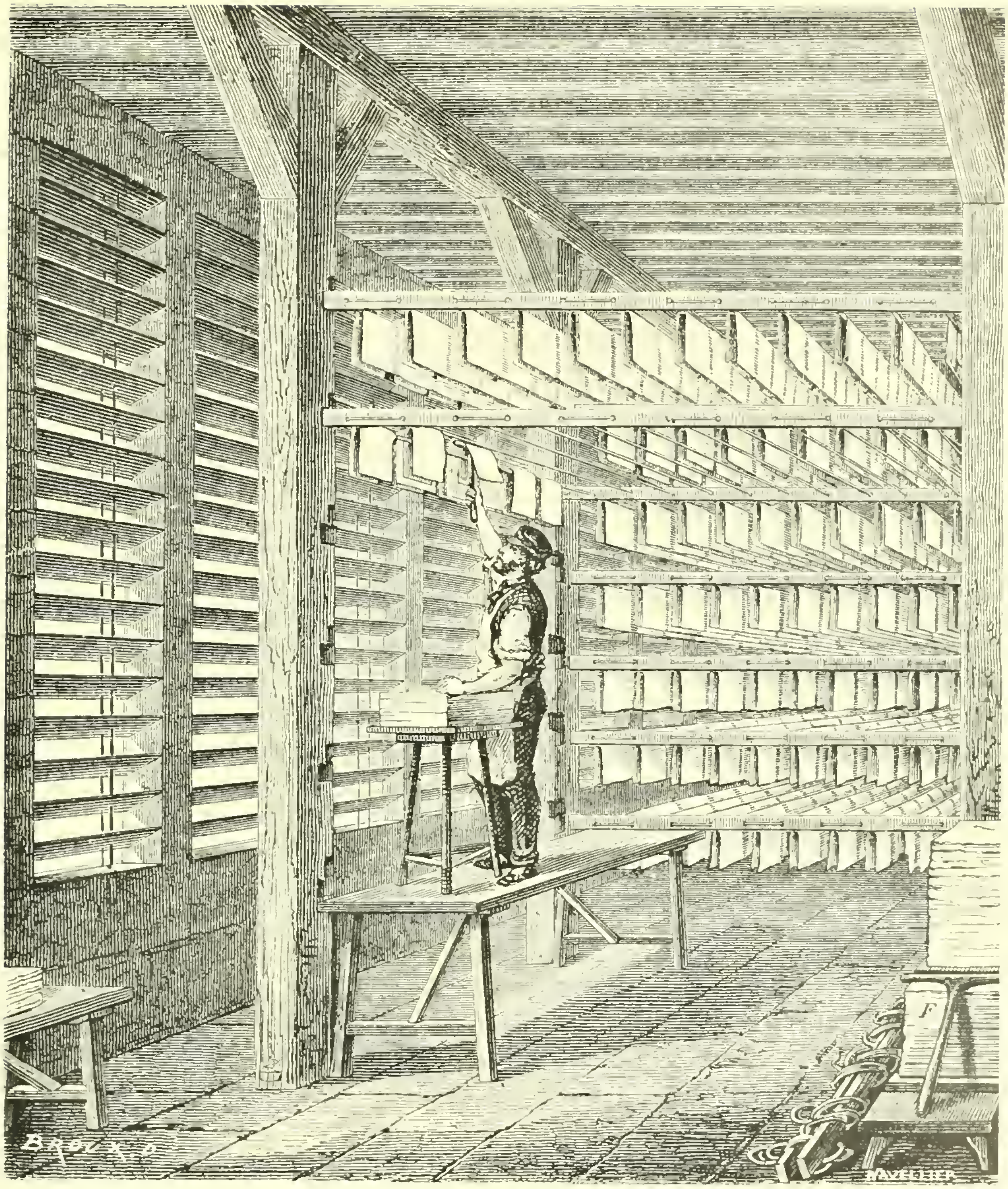

FIGURE 47.—Drying loft. After pressing, the paper is hung to dry on racks in the ventilated drying loft. From Louis Figuier, *Les Merveilles de l'Industrie* (Paris, 1873?), vol. 2.

worthy gentleman." (Greatrake was the father of Eliza our Uncle Franklin's first wife.)

When I made my report to Mr. Mathews, who knew the information I wanted to get from Mr. Dickinson, he seemed a good deal put out. The next evening he told me that Mr. Dickinson had called on him and he thought it probable that I would hear from him, which I did in the shape of an invitation to dine with him, pot luck, as his family were at their house at Brighton. I felt like declining but Mathews insisted on my going. He [Dickinson] had his wife up from Brighton for the night and gave me a pressing invitation to accompany her to Brighton, which I declined. After breaking bread with him he was an entirely different man from what I found in his office and during the remainder of my stay in London I had much more attention from him than I supposed so busy a man could give. I received all the information I wanted as to his cast iron drying cylinders, including drawings he had made for me of what was then his monopoly, machines and dryers for what he called enamelled plate paper.

At the time I was in England there were not more than a dozen of the complete machines in use. I only visited three of the mills. Though invited, I did not get the opportunity of visiting the Dickinson mills. I was indebted to Mr. Dickinson for much information and kindly advice, and it was a great satisfaction to have met on so friendly terms these two great inventors. [38]

I cannot with certainty fix the time of my first visit to York, Pa. when I was shown the room that Grandfather worked in when facing and making molds for the Continental Government, and the Old King paper mill on the Codorus Creek at York, an ante-Revolutionary Mill at the time of my visit being carried on by George King, who I think was a son of the original proprietor.[137] They were old customers of N. & D. Sellers.

The object of my visit was to plan the changes and to give the direction to change the mill from a hand vat into a machine mill. On my return Grandfather was greatly interested in my description of the surroundings and showed that he had a very clear recollection of them and also of a mill I visited on the Conewago, also an old Revolutionary mill, and I have the impression that he said at the time he was there these mills were mostly making cartridge paper from the copperas striped linen rags of the country, or white paper as much as they could get rags to make. It was at York [138] that Shryock first made straw boards and paper by the lime process. We made his cylinders I think at a later period than the alteration of the King Mill was made.

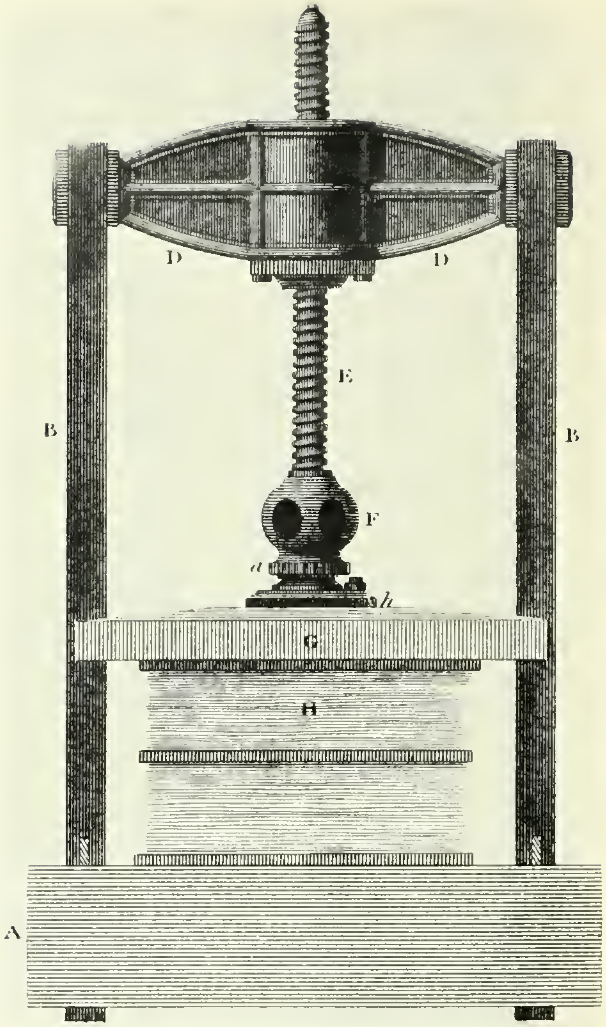

Figure 48.—Screw press, for paper, showing lantern-head (F) on the iron screw. From Abraham Rees, ed., *The Cyclopaedia* (London, 1819), plates vol. 4, "Paper Mill."

[137] Philip Jacob King, in 1798 (Hunter, cited in note 116 above, p. 156).

[138] Chambersburg, according to Weeks. See note 132 above.

The time of this visit must have been as near as I can fix it in 1827 or 1828 for it was before Charles' marriage which was in the fall of 1829, and at the time John Brandt was living in the first mill house put up at Cardington. Charles and I were both staying with the Brandts. Charles was working with him on the card machinery and I in a little shop, a leanto of the old Marshall saw mill.

I had Robert Beatie and another journeyman working with me making the Squirrel Cage paper cylinders that there was quite a demand for, it being the time of the transition from hand made to machine made paper. We had for our power a small overshot water wheel. In the shop we had our high-headed hand wood-turning lathe and a small wooden-shear chain feed engine lathe. It [the shop] was a small affair and was originally built as a shop for David Jones to make paper mould frames in and was used for that purpose as long as he lived and was able to work, and when he became too feeble in which he taught Samuel Meredith, who continued as frame maker until disqualified by age and loss of sight, when George Rawlings took his place and continued as long as we carried on mould making.

Making early paper machinery with the facilities we had was a very troublesome business. The shafts for the cylinders and for the apple wood press rolls that were used before it was found that the paper could successfully be worked from metallic rolls, were turned in the engine lathe I have referred to. The press rolls were also finished in it after having been roughed down by hand in the wood lathe, which besides this roughing was used to bore and turn the brass spider wheels for the paper cylinders, the most common size being 2 feet diameter and a few as much as 30 inches. The turning was done by a Maudslay slide rest, but I do not remember how this came in our possession; I rather think it was imported through Mathews.

While this kind of work was going on Grandfather frequently walked down from Millbank and would sit for hours at a time in the doorway of the little shop watching the work as it went on and he always seemed to take more interest in it than in the work of the card mill. He had taken a liking to my Newfoundland dog with whom he would play and talk to as if he were human. He placed so much confidence in the dog's sagacity and trustfulness that I have frequently seen him throw a silver half dollar into the mill race for the dog to find and bring out, and I don't think he ever lost one.

One day when Grandfather was sitting on a stool at his usual place in the doorway he startled me by a scream. On looking I saw Robert Beatie with his head close to the shaft he was turning with his arm and hand frantically trying to reach the belt shifting lever. I jumped quickly to the lever, shifted the belt, backed the lathe by hand and when I got his long ended black silk cravat which had caught in the carrying dog unwound he fell to the floor limp and insensible and it was some time before we brought him to. I had frequently cautioned him against wearing the long ended cravat. This so frightened and unnerved Grandfather that it was a long time before he again came to the shop. He said he could not get rid of the horrid sight of Robert's swollen tongue.

I have referred to the troublesome business of early paper making machinery, the different parts were so scattered about. The housings were cast at Park's foundry, Kensington; most of the gearing at Wiltberger's foundry, S. E. Corner of Market and 16th Sts. The housings were chipped and filed at Boyle's shop where most of the smith work was done; there were no iron planers at that time. The gear wheels were bored and fitted at our little shop at Cardington and either Jesse Hayes, William Lungren or Caulkins were the millwrights who made the vats and put up and started the machinery. [39]

14. A Visit to England. I: Maudslay and Brunel

George Escol Sellers departed from New York on the first day of September 1832 in the packet ship *Hibernia*, of the popular Black Ball line. He arrived in Liverpool nearly four weeks later, on September 27. After three busy months in England, he returned home in January 1833, after having spent New Year's Day on the ocean.[139]

While Sellers was in England, his sister Elizabeth married Alfred Harrold, who had come to the United States from Birmingham, England. George Escol was accompanied during at least a part of his journey down to London from Liverpool through the Midlands by Alfred Harrold's brother, who apparently was able to open some doors that otherwise would have been closed to an American visitor.

Sellers had gone to England primarily to see papermaking machinery, but he passed up few opportunities to view anything in the mechanical line that was accessible. In the present chapter, his visit to the shops of Maudslay Sons and Field occurred more than a year after the death of the firm's founder, Henry Maudslay (1771–1831), but Maudslay's stamp was so clearly upon the shops and, indeed, upon the mechanical practice of England, that more than cursory mention of him is called for.[140]

Maudslay's genius as a gifted craftsman and original thinker in the machine-building art was evident before he was 20 years old, while he was employed by Joseph Bramah (1748–1814), locksmith and builder of a practical hydraulic press. It was here, in the development of machine tools for producing lock parts, and a few years later, in his own shop but in concert with Samuel Bentham and Marc Isambard Brunel, in developing machines for making pulley-blocks for the Royal Navy that his capacity as an innovator became evident. But it was with the slide-tool, or slide-rest, for an engine lathe that his name has become inseparably associated.

Although Maudslay was not the first to devise a lathe-tool carrier, in which the cutting tool was held securely and could be positively advanced and traversed under control of sturdy screws, his slide-rests were the first generally available in England, and their advantages were within a generation recognized by mechanics everywhere. His screw-cutting lathe, while again not the first in existence, was certainly the first to be widely used.

Perhaps more important than his works, however, was Henry Maudslay's influence upon several younger men who later became prominent machine tool builders. James Nasmyth, Richard Roberts, Joseph Clement, and Joseph Whitworth, all of them leading mechanicians of the generation following Maudslay's, were sincere in their praise of their old mentor. "The masterly manner in which he would deal with his materials, and cause them to assume the desired forms," wrote Nasmyth, "was a treat beyond all expression. Every stroke of the hammer, chisel, or file, told as an effective step towards the intended result. It was a never-to-be-forgotten practical lesson in

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139 George Escol Sellers letterbook, in Peale-Sellers papers (American Philosophical Society Library), contains copies of outgoing letters. The vessel, illustrated but not named in this journal (p. 5), is identified in Memoirs, book 10, p. 7. Date of return is in Memoirs, book 17, p. 3.

140 Maudslay is noticed in *Dictionary of National Biography*; a chapter is devoted to him in JOSEPH ROE, *English and American Tool Builders* (New Haven: Yale University Press, 1916); and a brief summary of his work is in K. R. GILBERT's chapter on "Machine-Tools" in *A History of Technology*, CHARLES SINGER et al., edit., 5 vols. (Oxford: Clarendon Press, 1954–1958), vol. 4.

workmanship, in the most exalted sense of the term." [141]

The spirit of Maudslay, one of England's greatest craftsmen, was yet fresh in the shops that he had lately vacated and where work was being carried on by his sons and by Joshua Field (1787?–1863), who had worked with Maudslay for some 27 years.

Marc Isambard Brunel (1769–1849), the remarkable father of the equally remarkable Isambard Kingdom Brunel, was in 1832 engaged—almost singlehandedly—in pushing his pioneering tunnel under the Thames. Commenced in 1825, the work had been stopped in 1828 because of lack of funds, and it was not until 1835, nearly three years after Sellers's visit, that the task was renewed, to be completed in 1843. Brunel's tunnel, now well into its second century of use, carries London Transport electric trains under the river.[142]

When discussing the advisability of going to England to investigate the entire subject and learn if possible the advantages, if any, over the American machines, Philadelphia was stricken for the first time by the Asiatic cholera. Having no fear of the disease, I became active in cholera hospital arrangements, and in attending at them. The result was an acute attack, and I was so utterly prostrated by it that for recuperation a sea voyage was decided on, and the trip to England was hastened. It being before the

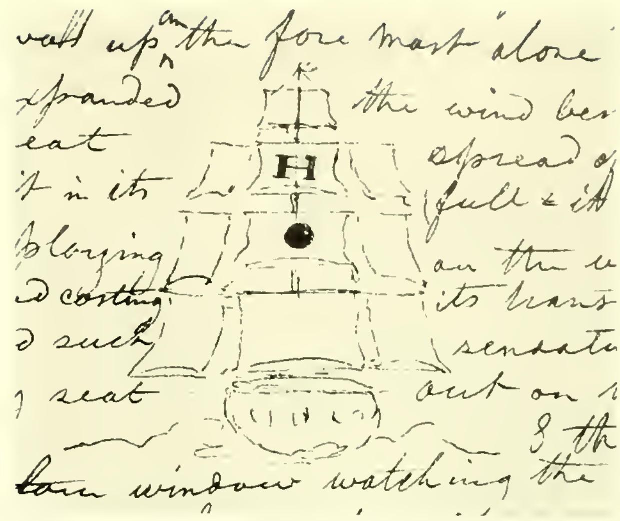

Figure 49.—Sellers's sketch of the packet ship *Hibernia*, of the Black Ball Line, in which he sailed to England. All studding sails (stuns'ls) were set for a pleasant breeze from dead astern. In brilliant moonlight, Sellers climbed out onto the jib boom to get a better view of the veritable cloud of canvas. From Peale-Sellers papers, George E. Sellers letter book containing copies of outgoing letters, 1832. Photo courtesy of the American Philosophical Society Library.

day of ocean steamers, three or four weeks on a sailing packet was deemed sufficient.

I arranged to spend at least four months in England giving ample time to see and learn all that was accessible in the way of civil and mechanical engineering. We had learned through Jacob Perkins and my friend Joseph Saxton, both then in London, that access to many mechanical works was difficult, and, in some cases, impossible for Americans; that Bryan Donkin's works that above all others I desired to see, was absolutely closed against all foreigners. Both Mr. Perkins and Saxton had frequently met Mr. Donkin in a social way, but had never been invited to visit his works. In fact, Mr. Saxton had made application without success. My prospect in that direction looked dull.

My uncle, Rembrandt Peale, the artist, on his return from Italy had spent some time in England, and by invitation visited Sir Walter Scott, at Abbotsford. He said that while there Sir Walter referred to Bryan Donkin in the warmest terms of friendship, and offered

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[141] *James Nasmyth Engineer, an Autobiography*, Samuel Smiles, edit. (London, 1883), p. 147.

[142] See Richard Beamish, *Memoirs of Sir Marc Isambard Brunel* (London, 1862). There is a bibliography in L. T. C. Rolt, *Isambard Kingdom Brunel* (London: Longmans, Green, 1957)

Mr. Peale an introduction to the man whom he esteemed as a model man for application, energy and sterling honesty. My uncle, in offering me a letter to Sir Walter, suggested that through him I might get a favorable introduction to Mr. Donkin. Although there was no man in England out of my own line of business that it would have afforded me more pleasure to meet than Sir Walter, I declined, feeling a delicacy of intruding as a mere curiosity hunter. I refer to this to relate a little incident that occurred on the outward voyage.

About mid-ocean we met a west-bound vessel. Our captain slightly altered his course to come within hailing distance, the answer to which came: "Bark ——, lumberman, of St. John's, New Brunswick; from London; homeward bound." This was at a time of great political excitement in England—in English phraseology, a crisis. Wellington had been invited to re-form a cabinet; in answer to the hail of "What political news?" came "Sir Walter Scott is dead;" to the question of "Any other news?" as the distance increased between the vessels, all we could catch of the reply was the reiterated, "Sir Walter Scott is dead." No possible calamity short of total shipwreck could be greater to the skipper of the lumbering lumber bark than the loss of the author whose writing had cheered the hours of his long and tedious voyages. It was a heartfelt tribute to Sir Walter Scott.

I spent considerable time previous to going to London in visiting mines, iron and general mechanical works in the vicinity of Manchester, Birmingham, Sheffield and Halifax. At one establishment I found them casting of iron, washing and beating engines [for paper making] the entire cistern in a single piece. There were no recesses or any provision for sand traps. This inclines me to believe that this important attendant to all good beating or washing engines is of American origin where they were in common use from my earliest recollection, and these unalterable cast-iron engines were the first I had ever seen where they were omitted.

During these excursions, which were made under the most favorable circumstances as to introductions, I had the opportunity of seeing several of Donkin's Fourdrinier machines in operation, and from the owners of two of the mills using them received letters of introduction to Mr. Donkin, in both cases without solicitation on my part.

On my way from Birmingham to London I stopped at Oxford, mainly to see the great printing establishments, said at that time to be the finest in the world. To Oxford I was accompanied by a friend from Birmingham, who introduced me to Mr. James Swann, of Ensham, a very courteous gentleman who had two expensive paper mills both equipped with Donkin's newest and most improved machines. He took us to his place where we remained a couple of days visiting with him both of his mills, giving opportunity of learning all then known as to paper making machinery. The beauty of these machines, and great perfection in performing their work, made me more desirous than ever to become favorably acquainted with Mr. Donkin.

It was at these mills that I first saw the Ibotson pulp dresser,[143] built by Donkin, in use. It only differed from the slit plate pulp dresser in use in the United States in being made of separate bars, the spaces between which were regulated by slips of sheet brass of a thickness to give the space required between the bars. My father had invented and patented in the United States a pulp dresser that we had successfully applied between the stuff chest and vat of the hand-making paper mills.[144] I took one of these to England with me, thinking it might be worth securing there by patent; at all events it would be useful as a favorable introduction in obtaining the information I was in search of. I sketched for and explained this device to Mr. Swann. who advised my sending the machine to Mr. Donkin, and advising with him.

He asked me if I was aware that simply exhibiting the machine would, in case of litigation, be fatal to a patent either issued to the inventor or introducer.

On replying that I was fully informed on that subject, he said I would be perfectly safe in consulting Mr. Donkin in confidence. He then asked if I had any friends in London who could favorably introduce me.

I replied no, unless it were John I. Hawkins [145] or Mr. Jacob Perkins, or Charles Leslie the artist.

He said Mr. Perkins would not do, for he knew Mr. Donkin was jealous of, and prejudiced against,

[143] See note 156 below.

[144] Patented June 6, 1832. No restored drawing exists, but an illustration was published in the *Journal of the Franklin Institute*. See figure 53.

[145] Not to be confused with "Old Blind Hawkins." John Isaac Hawkins (1772–1865) was born in England but spent a considerable part of his life in the United States. He was in London a patent agent. He is perhaps best known for his design of an upright piano. See *Minutes of the Proceedings of the Institution of Civil Engineers* (1865), vol. 25, pp. 512–514.

Americans, and he had reason to think of Mr. Perkins in particular. As to Mr. Hawkins no one could be better, but Hawkins was aged and somewhat infirm, and might not be able to go with me to the works. As to Leslie, he had never heard Mr. Donkin speak of him as an acquaintance, though no doubt he knew him by reputation.

I said that I already had two letters of introduction from parties owning and using Fourdrinier machines made by him.

If open letters of introduction there would be no impropriety in his asking to see them.

When I place them in his hand he glanced at the signatures and shook his head, saying that my having received the letters I was bound by etiquette to deliver them, but he did not think they would gain my object. He went to his desk and wrote to Mr. Donkin, placed it in my hands, and asked if it met my views. He simply told Mr. Donkin, by whom I was introduced to him, that I was engaged in America in the same line of business that he was; that he believed a free interchange of ideas would be mutually beneficial; that he could assure him that I would not intrude or be inquisitive into any matters that he was not disposed to communicate. He then advised my going to Mr. Donkin without any one with me, and in handing him the letters to be careful so to place them, that he would be likely to look at the others before opening his; he told me of many of the little peculiarities of Mr. Donkin, and told me to observe him closely as he read the letters . . . . [40]

After having seen in operation the admirable paper machines, from the Bermondsey works of Bryan Donkin & Co., the making his acquaintance, and, if possible, seeing the works was to me the principal objective point in going to London. And yet I had been there for over a week without having presented my letters of introduction. There seemed to be a fatality attending every effort I made. There was always something of interest to be seen. My friends made arrangements and appointments for me that I could not well avoid or put off.

Finally, one morning I got ready for an early start, but as I was stepping into a cab I saw my friend, Joseph Saxton, coming in great haste. He said he had come to take me to the Maudslay Works in Lambeth, exactly in an opposite direction from Bermondsey, where I was going. He came with an invitation from Josiah Field, the surviving partner of Henry Maudslay, the original founder of the works, who had died about a year previous. The works were then being carried on by Mr. Field and the sons of Maudslay.

Mr. Saxton said that there was then on the boring machine the largest steam cylinder ever cast at the works; that he particularly wanted me to see the boring machine in operation; that they would commence taking down to remove from the erecting shop to their destination the largest pair of marine engines they had ever constructed, being estimated, if I recollect right, at some 300 effective horse-power—mere dolls compared with the marine engines of the present day.

When I told Mr. Saxton that I was starting for Mr. Donkin's works, he replied that I would probably meet him at Maudslay's, for he knew that he was expected to meet a number of prominent persons to see the marine engines, among others Mr. Barton, director of the Royal Mint, whom Mr. Maudslay and Donkin had been associated with in establishing the English standard measures, and that Lord Brougham would probably be there with Mr. Sharp, the Attorney-General of Barbadoes, and his fellow commissioner, Mr. Reese, who had been my fellow passengers in crossing the ocean, and whom I had promised to notify of my arrival in London, but had not yet done so.

I was curious to meet Lord Brougham, not so much on account of his being Lord Chancellor, as for his reputed advanced ideas of civilization and his connection with the *Penny Magazine* which was then being published. Mr. Saxton thought it probable we should meet some artists whom he knew I was desirous of seeing. The temptation was irresistible; we at once set off for Lambeth, crossing the Thames by the Westminster Bridge; by the early start we would have considerable time to see the works before the arrival of other sightseers.

Mr. Field met us very cordially; showed us the collection of Mr. Maudslay's own hand work that had been carefully preserved. The most interesting was his work in producing a standard screw, and his original screw cutting lathe, said to be the father of all lathes, that by a combination of gear wheels and one guide screw any variety of pitch could be produced.[146]

After seeing all that was of interest in this collection, the record of Henry Maudslay's ingenuity, great appli-

[146] Maudslay's tools are now in the Science Museum, London.

cation and perseverance, one of his sons accompanied us through the works, first taking us to the boring machine on which the great cylinder was being bored. Here I must confess to a feeling of great disappointment, for the cylinder struck me as a mere pigmy compared with the cylinders of the North River and Long Island Sound boats of that period. I have no memorandum of its dimensions. It was for a short stroke not much longer than its diameter. There were at that time boats on the American rivers with condensing engines, whose cylinders would cover two of the one on the boring machine placed one on top of the other.

The marine engines in the erecting shop were also short stroke. The workmanship on them appeared to be of the highest possible character. This astonished me, after having seen the lathes and other machine tools, none of which lacked in care or accuracy in their construction, but totally inadequate for the character of work they had to do, as to weight, strength and firmness. The lathes were driven by raw hide or catgut round belts in grooved pulleys; most of the lathes were of the single Λ shape bar pattern, like the watch or clock makers' bowstring lathe, most of the turning being done by hand-fed slide rests. Some of these were of very large size, but all mounted high and lacking in firmness, as compared with the slide rests made by Rufus Tyler, of Philadelphia, nor could the lathes compare favorably with those made by Tyler or Mason and Baldwin, of at least six years previous to my visit.

As a boy I had worked on a Maudslay single mandrel ungeared lathe, with one of his slide rests that had been imported as something extraordinary, the lathe being driven by a great wheel with a man at [a] handcrank. I have the impression that this slide rest started both Tyler and Lukens to designing their improved one, which, for solidity and firmness, so increased the amount of work that the Maudslay rest was laid aside and the lathe transferred to the pattern shop as a light-running wood lathe long before I went to England. Therefore I was much surprised at finding that class of tools without any improvement in daily use.

I had been accustomed to see in our American shops, although many of their lathes had wooden shears with light cast-iron guide shears bolted on them, the rests or tool carriers traversed by chain or pinion in rack, with heavy suspended weight to hold them firm on the guide shears, turning off shavings of more than double the depth and feed of anything I saw doing in the Maudslay works. It did appear to me that tools were not keeping up with the requirements of the times, but I noticed under construction a heavy double shear engine lathe, and two planers in use. This was evidence that the proprietors were looking towards saving manual labor. I thought if they could see the festoons of great wrought-iron shavings from the lathes of Rush and Muhlenburg, of Bush Hill, Philadelphia, or of Kemble's West Point Works, New York, as hung in their offices, it would spur them on in that direction. [41]

(Dec. 10th, 1895) In looking over some old papers I have come across an old letter of mine from London in November 1832, evidently written after visiting the machine shops of Birmingham, Manchester, Maudslay's and Donkin's of London, in which I say I have not yet seen a lathe to equal the one we are building. This no doubt refers to the lathe at Cardington for turning drying cylinders for paper mills, which had a swing to turn cylinders up to 6 feet diameter. This fixes the date and shows that I must have planned and had the work under way before going to England which was in August 1832. [42]

The first planers I had seen in successful operation were at the shops of Sharp & Roberts,[147] Manchester, and their lathes were far ahead of Maudslay's, where the hand hammer, cold chisel and file were doing a much larger percentage of the work. Large flat surfaces, such as valve faces and seats, long and accurate guides or lathe shears, came from the cold chisel almost as perfect as they now do from our planers. This was explained on the principle of division of labor, men working a life time with hammer and cold chisel. When I took in my hand their heavy, short, stubby cold chisels, their short, clumsy, broad-faced, short handled hand hammers, I felt it would be impossible for me to handle such tools with any prospect of approximating their results; I would as soon expect to reach them with the stone cutter's round wooden mallet. The evolution in form and make of such tools had in America far outstripped England.

On returning to the erecting shop we found a number of gentlemen standing around the marine engines which Mr. Field was explaining to them. Lord Brougham was pointed out to me, at his side Mr.

[147] Richard Roberts (1789–1864), builder of perhaps the earliest planing machine for iron, in 1817, and of a back-geared lathe, about 1820.

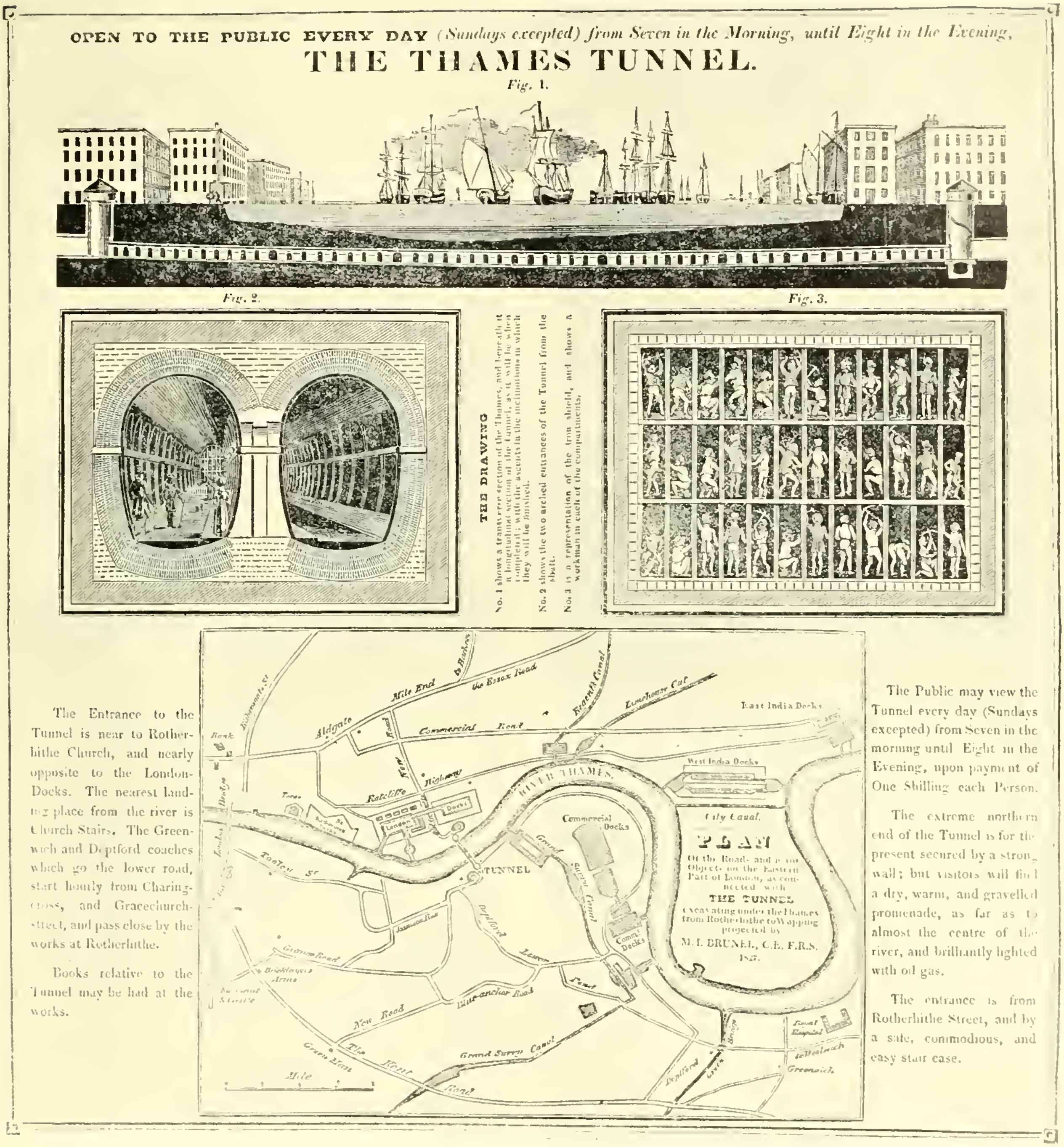

FIGURE 50.—Broadside issued in 1827 by Marc Isambard Brunel (1769–1849), builder and promoter of the Thames Tunnel. Original in division of mechanical and civil engineering, Museum of History and Technology, Smithsonian Institution.

Sharp, whose back was towards me. I at once advanced and addressed him.

He introduced me to Brougham as an American, and I was soon plied with questions faster than I could reply. I do not think his lordship had conceived a clear idea of the vast extent of our country and its resources. He thought it strange that any American of my age should not have seen the Falls of Niagara. On my stating that from Philadelphia it was a stage-coach ride of some 400 miles or more, or a long and tedious journey by the New York canal, to this he replied, "I understand that you have frequently been to New York, and I am surprised that when there you did not visit the falls." He evidently confounded the State and city.

When I afterwards related this to John Isaac Hawkins, he said there was much confusion in the minds of some of the most intelligent English as to the United States, and he related a circumstance that occurred in the office of Barclay, Perkins & Co., the great brewers. During the War of 1812 news of some reverse of the British forces had been received that greatly excited both Barclay and Perkins, and the latter exclaimed: "If I were Prime Minister I would soon end this war; I would enforce a strict blockade, surround the country, cut them off from all outside communication, and starve them out."

Mr. Hawkins replied that it was no easy matter to enforce blockade on over 3,000 miles of sea coast.

Then Mr. Perkins unrolled on his table a very large map of England, and a very small one of the United States, exclaiming: "Hawkins, you were so long in the States that you have become almost an American, and have caught their brag. Just look and you will see for yourself, that all the country this fuss is over is no larger than Yorkshire. To talk about 3,000 miles of sea coast is all nonsense." I do not relate this as it was told me in disparagement of Lord Henry Brougham, for a more interesting and generally intelligent man it has never been my good fortune to meet, but I tell it to show how much ignorance existed as to our country before the advent of ocean steamers and telegraphs. It is a well-known fact, that in the same War of 1812 in the armament and outfits for their fleets on the fresh water lakes, water casks were included.

I was disappointed that Mr. Donkin did not come, but I had the satisfaction of an introduction to Mr. Barton, that resulted in a cordial invitation to visit the Royal Mint on Tower Hill. I was also introduced to some prominent mechanical engineers. Several artists came in, but their stay was brief. On Mr. Reese, Mr. Sharp's associate commissioner from Barbadoes, coming in, he being the owner of several sugar plantations, getting his machinery from England, Mr. Field invited him to go through the works, and I was asked to accompany them. It was on this second round that I more particularly noticed the amount of labor and useless cost of work done on lathes not calculated for the work they were doing, and that could bear no comparison with those in the sugar mill and steam engine works of Fawcet, Preston & Co., of Liverpool; for heavy work the hanging heavy gearing on square or hexagonal shafts seemed to be almost the universal practice in England at that time. This required the work of hammer, cold chisel and file to cut two key seats to every flat, and the same in the flats of eyes or hubs of the wheels to be hung. It seems almost incredible to us of the present time that only 54 years ago England, that was looked on as the furthest advanced in mechanical engineering, still adhered to this practice, when we in America had long practiced turning shafts, boring wheels and simple keying, except by a few old-fashioned millwrights who hung onto the square ends to water wheel journals, or the wing gudgeons of wooden shafts on which the wheels were hung with wooden wedges with iron ones driven in to tighten them.

I believe the universal change the world over to turned shafts or axles with bored hubs and simple keys, is mainly due to the advent of railroads . . . . [43]

As we were leaving the Maudslay works, Mr. Brunel, of Thames tunnel fame, came in. After an introduction, I told him it was my intention to call on him, as I had a letter of introduction from his friend and brother engineer, Mr. Hartley, of Liverpool,[148] but had not the letter with me. This resulted in an appointment at 9:30 the next morning, at the tunnel. He said if I had not been an American he should not have named so early an hour. This I took as a compliment to our countrymen.

I was promptly at the tunnel at the appointed time and found Mr. Brunel already at his office, but not by any means in a state of mind to be envied. Work on the tunnel had for a long time been suspended. The pumps were at work, but the state of the air and water prohibited going into the tunnel at that time. Mr. Brunel showed me the plans and drawings, explaining everything clearly. He had encountered unforeseen

[148] Jesse Hartley (1780–1860), civil engineer of Liverpool, surveyor (constructor) of docks.

difficulties that his most careful borings and soundings had not developed. Neither had the previous drift way of 1807 and 1808.

The idea of carrying forward and completing as they advanced the full size tunnel without an advance drift, was certainly a bold and grand conception of Mr. Brunel's, and when the difficulties did occur, he had overcome them, and when all serious ones to be apprehended had by actual experience been provided for, he was shut down on, and the work suspended entirely, in consequence of financial difficulties. He said it was true that the cost so far had greatly exceeded his estimates, but this might partly be attributed to hue and cry of failure by engineers who were envious and by experts without either examination or knowledge. Every difficulty had been magnified; any increase in steepage or change in tenacity of the earth he was working through, the least softening or invasion by streaks of old river silt as they were encountered, were represented as insurmountable, and were made use of, alarming the operatives; in some cases men refusing to go on with their work. In this state of things a constant increase in cost, in the shape of advance in wages, had to be encountered.

Mr. Brunel was suffering as bold pioneers in great enterprises too often do; but it was evident he had not lost confidence in himself or in the wisdom of the plans he had adopted, or in ultimate success, whatever the capitalists, the bone and sinew of the enterprise, may have done. Young as I was, he seemed anxious, and took much pains to impress me favorably as to his plans and ultimate success of the enterprise. He made light of the difficulties, and in no manner boasted of his achievements in overcoming them. But he laid great stress on the great additional cost due to the suspension of the work, for had all that had been and was being expended on the maintenance of the work in its unfinished condition by continuous pumping, and other unavoidable outlays, been applied to the direct prosecution of the work, it would have been in a condition to disarm all skeptics. He was quite complimentary to America when he said he did not believe such a state of affairs could be brought about in that go-ahead country.

He based his hopes of completing the work on the large sums of money that had been expended, that, if abandoned, would be a total loss, and that, rather than that, he believed the amount required to complete would ultimately be raised, as the estimated cost was then based on actual experience. Nearly half the distance had been accomplished and at the time the work was suspended the center of the river had been reached. The time of my interview was about seven years after the commencement of the work. This fact alone is evidence of its great magnitude and the constant strain on Mr. Brunel's brain. It is not my intention to describe the work, for that has been fully done and must be familiar to most engineers. But I was much interested in the model of the great sectional shield, and in Mr. Brunel's description of the manner it was used to make the excavation of 38 feet in width by 26 feet 6 inches high under the bed of the river, in which excavation was built as the work progressed, the great double brick archways, or arcades as they were called in England.

Mr. Brunel gave figures of the cost of the work up to the time of suspension, which, on reducing to our currency, showed the cost to have been about $35 for every cubic yard of earth removed—this included work done, brick arches, etc. I give this entirely from recollection; the amount was so strongly impressed on my mind at the time, that I am satisfied it is correct as we then figured it. After this Mr. Brunel again referred to his statement of the accumulated expenses during the suspension, showing from them what would have been accomplished had they been applied on progressive work. [44]

15. A Visit to England. II: Donkin's Bermondsey Works

The secrecy with which much of the machine-building art was practiced in Europe during the period of its most fruitful development has put beyond our reach many of the answers to questions that we would ask. For example, who built the first effective metal planing machine? The 1817 machine of Richard Roberts, attributed and dated years later, exists. However reasonable the attribution and dating may be, the first published description of a metal planer was by Joseph Clement in the early 1830's. Meanwhile, there were many other skilled and enterprising craftsmen in whose secret rooms developments and innovations were being hammered out nearly in parallel.

It is for this reason, apart from Sellers's skill in constructing a life-size picture of the immensely admirable if faintly pompous and plodding Bryan Donkin, that this account of Donkin's Bermondsey shops is particularly valuable, and perhaps unique. Few others of the small number of visitors admitted would have noted the mechanical detail that makes it possible for today's mechanician to determine just what the shops were capable of doing, and more accurately to assess the contribution of the master. The comment of Andrew Ure, author of one of the standard mechanical dictionaries of the 19th centrury, is useful in its way but of little help in letting the mind's eye focus upon the machine tools of 1830. "I have had the pleasure," Ure wrote, "of visiting more than once the mechanical workshops of Messrs. Bryan Donkin and Co. in Bermondsey, and have never witnessed a more admirable assortment of exquisite and expensive tools, each adapted to perform its part with despatch and mathematical exactness, though I have seen probably the best machine factories of this country and the Continent."[149]

Bryan Donkin (1768–1855) has been curiously neglected by historians of technology, in spite of his very considerable contributions to the design and construction of the large and complex Fourdrinier paper machines and to the more general task of producing better tools with which to shape metals with precision.

He served an apprenticeship in John Hall's machine works in Dartford, several miles southwest of London. In 1801, when Hall was engaged by the Fourdriniers to construct the newly patented continuous-web paper machine of the Frenchmen Robert and Didot, the major share of building a machine model apparently devolved upon Donkin, who was by this time 31 years old. The entire development of the machine had been turned over to Donkin by 1802, when he took premises in Bermondsey, about two miles down river from the London Bridge.[150]

The new works prospered, and by the time of Sellers's visit, in 1832, Donkin had built more than 100 Fourdrinier machines.[151]

Donkin earlier developed and built a "polygonal" printing machine, forerunner of the much later type-revolving cylinder machines of R.

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[149] Andrew Ure, *A Dictionary of Arts, Manufactures, and Mines* . . . , 2 vols. (London, 1856), vol. 2, p. 336.

[150] See note 136, above; also *Proceedings of the Royal Society of London* (1854–1855), vol. 7, pp. 586–589, an obituary of Donkin. In Sydney B. Donkin, "Bryan Donkin, F.R.S., M.I.C.E., 1768–1855," *Transactions of the Newcomen Society* (1949–1951), vol. 27, pp. 85–95, reference is made to Everard Hesketh, *J. & E. Hall Ltd., 1785 to 1935*, which I have not seen.

[151] Ure (cited in note 149 above). At the time of Ure's article, probably 1834, 133 machines had been erected. There were 200 machines at work by 1855. See Donkin's obituary, cited in note 150 above.

Hoe & Co., of New York. Donkin's machine, employing a square "cylinder," which provided space for four flat forms of type, turned by "square" gears, and printing on a conjugate or complementary surface that revolved in contact with his polygonal "cylinder," produced 800 to 1,000 impressions per hour, but it was not economically successful.[152]

In 1812 Donkin applied his talents to the preservation of food in tinplate canisters, or cans, and by 1814 he and his old master, Hall, were supplying canned soups and meats to the Royal Navy.[153] Like other fine mechanicians of his day, Donkin spent much time and energy in attempts to approach perfection in the fashioning of lead-screws for dividing engines, and the present chapter suggests his preoccupation with the problem.[154]

He was active in the venerable Society of Arts and in the Institution of Civil Engineers, and while he had not by 1832 gained the status of fellow of the Royal Society—he became a fellow in 1838—it is clear that he was a man universally esteemed. The evidence favors the summing-up of his eulogist: "His life was one uninterrupted course of usefulness and good purpose." [155]

FIGURE 51.—Bryan Donkin (1768–1855). Portrait, 1829, courtesy of *The Paper Maker*, James L. Anderson, editor.

IT WAS ABOUT MIDDAY when I left Mr. Brunel. I went up the Thames to Old Wapping Stairs, the nearest ferry crossing to Donkin's Bermondsey shops.

I was so fortunate as to find Mr. Donkin in his office; I presented my letters as I had been advised to do by Mr. Swann. He opened the first one, glanced over it, and laid it open on his desk, and opened the second, treating it in the same manner. I could read nothing from his calm, impassive face, but on opening the third there was an evident change of expression; he read it very slowly, seemingly in deep thought. Before opening the letters he had asked me to be seated.

Still holding the last letter in his hand he turned to me saying, "This letter is from a most worthy gentleman whose requests I am always glad to respond to.

[152] The press is illustrated in British patent 3757, November 23, 1813, which was issued to Richard M. Bacon and Donkin; a perspective view is given in David Brewster's *Edinburgh Encyclopaedia* (1832), vol. 18, pl. 469; and a schematic sketch of the arrangement is shown in *A History of Technology*, (cited in note 140 above), vol. 5, p. 690. Another Donkin printing press patent was no. 4202, January 17, 1818.

[153] *A History of Technology*, vol. 5, p. 39.

[154] One of Donkin's dividing engines is in Science Museum, London. A description is in CHARLES HOLTZAPFFEL, *Turning and Mechanical Manipulation*, 5 vols. (London, 1843–1884) vol. 2, pp. 651–655.

[155] *Proceedings of the Royal Society of London* (cited in note 150 above), p. 589.

I had a letter from him a day or two ago in which he mentioned having given you a letter, and I have been expecting you to call on me. In this letter of introduction he states that you are engaged in the paper machinery branch of my business in America. You have seen in operation at his mills one of my latest and most improved machines; after they have left my shop I have no further control of them, and their owners are at perfect liberty to show them to whomever they please. I have in my erecting shop the widest and finest machine I have ever built to fill an order from France, which I will take pleasure in showing you. But the tools and various machines and appliances I employ in their construction have been the work of almost a lifetime, and I hope you won't take amiss my unwillingness to exhibit them." He then added: "I am glad you have not come under false colors, as I am sorry to say mechanics have done." This was plain talk, and I felt that it ended my hope of seeing his works.

As he got up to lead the way to the erecting shop, I mentioned to him that I had brought to England a paper pulp dresser or screen, invented and patented by my father in the United States, with the intention of patenting it in England, if, on investigation, I found it would be worth the expense of doing so, and as to the cost I had obtained all the information I required from Newton & Son. But having seen at work on two of his machines the Ibotson grate bar screen [156] working satisfactorily, I was in doubt what course to pursue; that if not patented, and left free to anyone, it might seriously interfere with the Ibotson patent, and as he was the maker of that, and knew all about their cost, I would be glad to have him examine my father's, and if willing to do so to give his candid opinion of their respective and comparative merits.

To this he replied by asking if I was aware of the danger of showing the machine to anyone before either caveating or patenting, that in case of litigation the testimony of anyone having seen it would vacate the patent; he would advise my entering a caveat before showing it to anyone.

He seemed pleased when I said he was the only person I had thought of, believing that in showing it to, and consulting him, I ran no risk, and that I should highly value his opinion, and that if he did not object I would have the box in which it was packed forwarded to him.

He made no reply, and we went into the erecting shop where stood, certainly, the finest specimen of workmanship that I had seen in England. It was the long web or Fourdrinier machine, 60 inches in width between the deckels. The machine stood as it was to be placed in the mill, with shafting and gearing all complete. Great care had been taken that in no place the wet paper should come in contact with iron, under the mistaken idea that such contact produced the rust spots so common at that time in English printing paper. The paper makers did not appear to have discovered that such spots were mainly due to want of thoroughly cleaning the rags, that broken needles, iron button eyes and such like things, after being ground up in the beating engines, passed into the paper and oxidized there; that the remedy that I have before referred to was sand traps in the beating engines, believing them to have been of American origin, had not been generally adopted in England, that the freedom from such spots in the high grades of the hand-made paper of the Whatman's and other mills doing that character of work, was almost entirely due to the care in selecting and cleaning the rags.

To return to the machine as it stood in the erecting shop, the press rolls were composition metal, in color that of gun metal or bronze. When I spoke to Mr. Donkin of their composition he made no reply. It was evidently one of his secrets. The web and felt-carrying rolls were also of composition metal, but in color nearer that of brass. The drying cylinders were cast-iron covered with copper. These were splendid specimens of workmanship. The bosses on the main driving shafts were turned, the eyes of the wheels bored and keyed on them; in fact, all gearing was either secured by set screws or was keyed on round shafts. Here was the first conclusive evidence of evolution in the right direction that I had seen. The mind of the great inventor who had perfected that wonderful machine for the continuous sheet of unbroken paper, had also been turned to simplifying its construction, and making all parts interchangeable.

After viewing the machine, in which I was not in any way limited in time, for Mr. Donkin seemed

[156] British patent 5964, July 29, 1830, by Richard Ibotson, of Poyle, Middlesex County, paper manufacturer. Ibotson's pulp dresser screen consisted of a series of parallel bars about 0.01 inch apart, through which the long fibers of small diameter were permitted to pass but which caught the "knots," or small globular masses of pulp often noted in older paper. The screens were jogged to induce flow of the paper stuff.

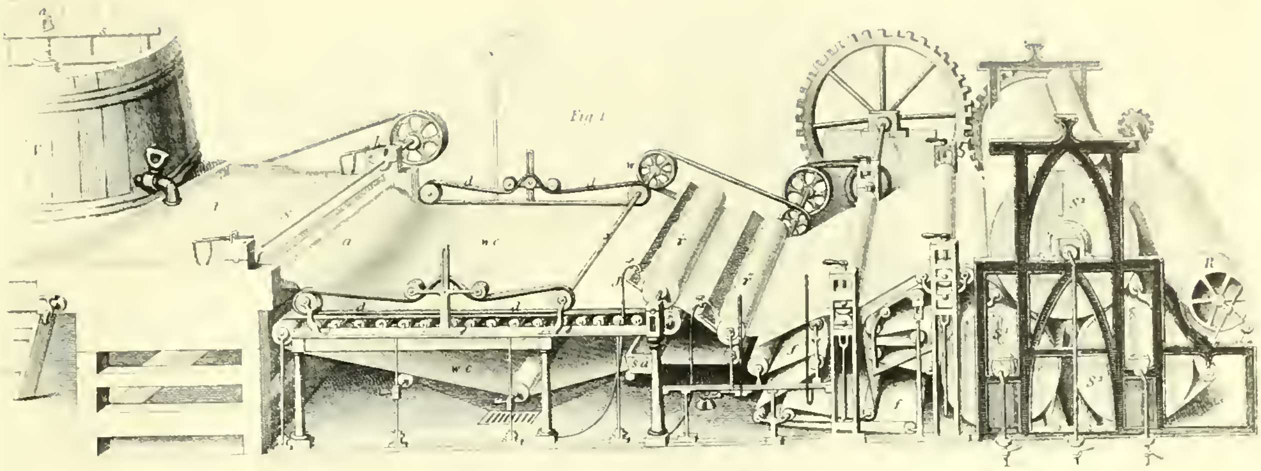

FIGURE 52.—Fourdrinier paper machine. Dilute pulp flows at left onto the endless wire mold (*wc*). As the upper half of the mold moves to the right, excess water drains through the mold, leaving a continuously formed length of paper. The paper is transferred to couching rolls, an endless felt, and finally to steam-heated drying drums and a paper-reel at the right-hand end of the machine. From Charles Tomlinson, ed., *Cyclopaedia of Useful Arts and Manufactures*, 2 vols. (London, 1852–1854).

to take pleasure in exhibiting it, he led the way back to the office. Of course, I, for the time, abandoned all hopes of being shown through the shops. When about leaving, he referred to the pulp dresser, and said he must again caution me showing it to anyone. To this I replied by repeating what Sir Walter Scott had said to my uncle, Rembrandt Peale, as to his friend, "Honest Bryan Donkin, the machinist," that with such an endorsement I felt that I ran no risk, and should send the pulp dresser to him.

His face brightened with a look of great satisfaction, as he said "that when Sir Walter acknowledged the authorship of the Waverly Novels, and said that for a long time it had been known to twenty people, none of whom had abused his confidence, he was proud of knowing that he was one of the twenty; he then added, the acquaintance, and, he might say, intimacy with Sir Walter had come about in a most natural way; he had frequent consultations with the Constables, the publishers of Scott's novels, on the subject of paper for that purpose, at which Sir Walter was often present."

He said that Mr. Swann, in his letter to him, had expressed a belief that it would be mutually advantageous to us to have a free interchange of ideas on paper machinery, and he laughingly added: "My ideas have gone to America in a machine I sent there to fill an order, and I learn they have already been copied."

I told him that so far we had been exclusively engaged on cylinder machines, and had never built a Fourdrinier; that at that time Phelps & Spafford were the only builders in the United States.

He asked what we got for a complete squirrel cage cylinder, naming a size. On my giving our regular price, he promptly said that he could not compete, pay freight and duty, for our price was less than he got at his works.

This I felt to be my opportunity, so I explained our mode of putting up the cylinders, the machinery and tools we used. He listened very attentively, but made no comments. I could not but admire his extreme caution and reticence as to his modes. At the same time his evident eagerness to learn what others were doing amused me, and I felt much like a man in the hands of an interviewer of the present day. But to divert, and at the same time lead him on, I remarked that I had been surprised at not finding the direct-

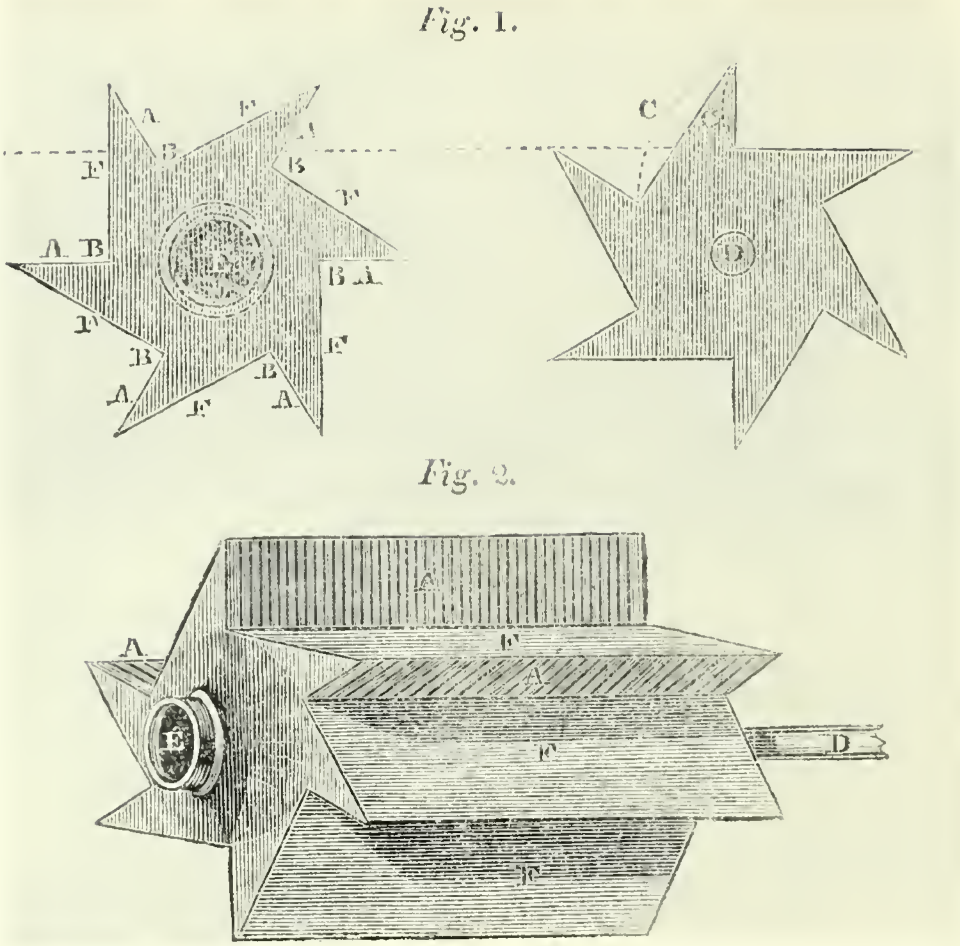

FIGURE 53.—Sellers pulp dresser, 1832. To remove "knots" (globular inclusions in the dilute pulp) the turning rotor was immersed in the stuff chest as indicated by dotted line. Acceptable pulp passed through parallel bar grids on surfaces (A) and was supplied to the paper machine through hub opening (E). From *Journal of The Franklin Institute* (December 1832), new ser., vol. 10.

acting guillotine paper cutter in use in England, when in America they had almost entirely superseded the plane or bookbinder's trimmer for all paper trimmed and put up at the mills.

He understood there were very serious objections to them, inasmuch as a chisel-edged knife could not be thrust directly down through paper, without turning or making a sharp edge on the lower side of every sheet.

Yes, I replied, if the paper is loose, but the pile of paper to be trimmed being pressed tightly together, the knife goes through it like shaving wood, and added, this you can try with a sharp chisel, when you have the paper pressed on a calender roll shaft, ready for the lathe.

He had never thought of this, but should certainly try it. He then asked if I would, for a consideration, sketch the most approved plan in use.

I replied that I would cheerfully and freely give him any information he wanted; the machine was patented in the United States, and at that time we were the exclusive builders, paying the patentee a royalty on each machine; that their introduction had been rapid; that in the United States there were very few mills without them; that printers and bookbinders had generally adopted them for pamphlet trimming.[157]

It was growing towards night, and as I had an engagement for the evening, and moreover, began to feel hungry, I again essayed to go, when Mr. Donkin asked if I had ever given a thought to the possibility of making an absolutely perfect screw. Mr. Saxton had told me this had been a hobby with Mr. Donkin for many years, and on the previous Sunday I had gone with Saxton to the Royal Observatory at Greenwich, where we had seen the great mural wheel that had been turned at Donkin's works, and graduated by Troughton with one of Donkin's screws.

I replied that when a boy I had been much interested by my grandfather's ideas and efforts in that direction; that to generate a screw of a certain pitch, instead of setting a sharp knife edge at an angle of the axis of the spindle to be cut, as I had been shown the day previous as Maudslay's design, my grandfather had drawn hard iron wire by light drafts to insure accuracy; that this he had wound like a spiral spring on an accurately-turned iron mandrel, with a fixed collar at one end and a loose one at the other, driven up by a screw nut, to force and hold the coils when wound in close contact. On this he had cast a fusible metal nut. I had found this in grandfather's shop with a number of wooden rods wound in the same manner with wires of various sizes; these latter he had explained as having been used in testing and correcting his wire gauge by the numbers of coils to the inch. The iron one, he said, was an effort to produce an accurate screw for his friend, David Rittenhouse. He did not say for what use but I infer it had something to do with Rittenhouse's astronomical work. I hastily described old John White's expedient for cutting press screws before the time of engine lathes that I described in my second paper.[158]

Mr. Donkin had evidently got on his hobby; he insisted on my stopping to see a couple of his screws for graduating. They were of steel, about 1¼ inches diameter and about 1¾ inches long, as near as I can recollect; one of 25, the other of 50 threads to the inch. This was firmly placed over the 25-thread one, so that 50 threads calipered them. In front a movable microscope, with a finely-graduated micrometer eyepiece; by sliding the microscope and turning the screws, the least possible variation could be detected. It was growing too dark to see this to advantage. Mr. Donkin spoke enthusiastically as to what Mr. Maudslay had done towards establishing standard screws; [159] but as to absolutely correct ones, he said: "We may have a screw with a deep or long nut on it, that works smooth and easy, and with the most delicate handling no imperfection can be discovered, yet, on using the screw for a dividing engine, errors would soon be apparent."

He asked if I had ever thought of or seen any device for testing irregularities or gain or loss of one thread over another?

None but a very simple one of Isaiah Lukens, town clockmaker of Philadelphia—a little sliding carriage parallel with the screw to be tested. This carriage had a fixed point in the groove or channel of the screw. By turning the screw it would be made to advance in either direction as the screw was turned. In this carriage in the plane of the axis of the screw was an adjustable stud or center that could be set at any number of threads desired from the carrying point. On this stud was a lever or index hand, as Lukens called it, the short end fitting into a channel of the screw, the long end resting on a graduated arc, adjusting the fulcrum stud so that the index hand pointed to 0. On turning the screw to advance the carriage by the fixed point, the least variation would be shown by the point of the index lever. There was also an arrangement to measure short inequalities by using the obliquity of the thread by either raising or depressing the lever on the center pin or fulcrum. I did not known what mode had been taken to correct errors when found, but I thought Mr. Saxton, who had served his apprenticeship with Lukens, would be able to give all information.

He had never spoken to Saxton on the subject, but he should certainly take the first opportunity of doing so. He did not then say what he had done, but only remarked that it was wonderful that minds over 3,000 miles apart should in any degree travel the same roads. He threw the covers off of some of his apparatus, no

[157] The paper-cutting machine was patented by Joseph Woodhouse, of New York, but not until May 30, 1835. There is no restored drawing. See JOHN W. MAXSON, JR., "Coleman Sellers, Machine Maker to America's First Mechanized Paper Mills," *The Paper Maker* (1961), vol. 30, no. 1, pp. 13–27.

[158] Chapter 5, above.

[159] That Maudslay and Donkin were friends is suggested by their joint British patent (no. 2948, July 24, 1806) for an epicyclic gear train, applied to a hoisting winch.

doubt with the intention of showing and explaining. But the increasing darkness, and my evening engagement, forced me to tear myself away. The shops were far out on the Blue Anchor road, some three or four miles from where I was stopping. I might be obliged to walk a long distance before I could catch a cab or omnibus.

On leaving, Mr. Donkin presented me with a one-foot boxwood scale of his own graduating, which I have had in almost constant use to the present time, and value it highly.

I found Mr. Saxton waiting for me for our evening engagement, but not having had a mouthful since an early breakfast, food must first be discussed. When I told him what an enjoyable afternoon I had with the great inventor, he asked: "Did he show you through his shops?"

"Only his erecting shop."

Then came: "I told you so; they are closed against all foreigners, particularly Americans."

"But," said I, "the end has not come. Tomorrow I am to send him the pulp dresser. He took my address and promised that after seeing it I should hear from him."

"No doubt," said Saxton, "and that will be the end of it."

To which I could only reply by using Jacob Perkins' favorite axiom: "We shall see; time proves all things." [45]

A few days after the pulp dresser was sent to Mr. Donkin's shops I received a note from him, saying he had been quite unwell and had not been to the shops for a couple of days, but he had examined the pulp dresser and would like to see me at his works, naming a time when he hoped to be able to be there. When I went there I learned that he was still too unwell to venture out, but he had requested that when I called I should be taken to his house, where he would see me. I found him suffering from a very heavy cold, so much so that I determined to make my stay very short.

He said he had examined the pulp dresser with much interest; that it was very ingenious, and could be furnished at a much less cost than the Ibotson bare screen as he was then making them, but should Ibotson adopt slit plates such as we had on our revolving pulp dresser, it could be made at less cost than ours; but he was making planers and tools for the Ibotson that would reduce the cost of their production, and at the same time insure greater accuracy than he had heretofore obtained by grinding on lap wheels. He named the royalty he was paying Ibotson on all he made. He showed me a list of all the Fourdrinier machines he had built, and also those he had already added the pulp dresser to, and the number that would still be obliged to have them of some kind. The one I had brought, if introduced either with or without patent, would to some extent be a dividing competitor and a cutter down of profits. He did not think, without personal attention in England, I could put it in the hands of anyone to manage with any certainty of being reimbursed the outlay of securing the patents. But he believed it would be to the interest of Ibotson to own and control it, either by patent or suppressing it. He had learned that Ibotson would be in London the next day, and at his shops about noon. His object in seeing me was to state the facts, and to suggest that he should be empowered to confer with him. This would necessitate showing the machine, but in doing so he would guarantee that I should in no way be injured. If I consented to this he would like me to meet them on the morrow, when he hoped to be able to go to the shops.

This being so arranged, I got up to leave, but he pressed me to stay. He was feeling better, and he felt a little friendly interchange of ideas would cheer him. Finding that I had considerable acquaintance among the artists it opened a subject that I was surprised to find him so well posted on, for I did not look for it in one whose whole life had been so intensely devoted to mechanical pursuits as his had been.

After considerable talk on general subjects far away from either civil or mechanical engineering, he asked if I had any experience in turning copper and leaving it perfectly smooth from the lathe tool?

Very little, I replied, but I had seen much of it done on calico printing rolls, in Baldwin & Mason's shop.

Then came the direct question: Do you think you could cover a well-turned drying cylinder, say 3 feet diameter by 6 feet long, with 50 pound copper, that is, copper weighing 50 pounds to a sheet of 30 by 60 inches, turn and finish it as perfectly as those I had seen in his erecting shop?

I said I could readily understand the difficulty of turning thin copper when not cemented or soldered to the cylinder, but I did not see any difficulty in accomplishing it without the use of the lathe further than in polishing after the copper on the cylinder had been drawn through a highly polished die, and only then to give it the appearance of having been turned, for, as finished by the die they were forced through, they would be left as near perfection as possible.

He asked me to explain what I meant by drawing cylinders, of the magnitude of his drying cylinder, or even supposing such a thing possible?

I replied that I did not see any difficulty, that it was only a question of size and power of the machine to do the work; that at the time of the partnership of my father and Jacob Perkins in building fire engines, copper cylinders from 3 to 8 inches diameter were perfectly finished by forcing through well-turned and polished dies; that on one occasion an air vessel of 16 inches diameter had been finished in the same manner.

He thought I had said drawing, and now I said forcing through dies; would I explain any difference between drawing and forcing?

None other than if drawn horizontally through a die, the great weight of the cast-iron drying cylinder acting as a central mandrel would seriously affect the uniform thickness of the copper and smoothness of the work; that this would be avoided by a vertical position and forcing upwards through the die.

He asked how I would proceed to do the job in that way.

I replied that after bending the sheet copper to the size to fit tightly on the cast-iron cylinder and brazing its union, taking care that it had been thoroughly annealed, I would close the upper end sufficiently over the end of the cylinder to insure its entering the die and holding it fast to the inner cylinder, then place it on the platform of a Bramah hydrostatic press with length of plunger or lift greater than the length of cylinder to be covered; the columns of the press would be the guides for the platform, and by having heavy screws and nuts on them they would at the same time hold the great die.

The next question was, Did I ever see or hear of anything of the kind?

No other than the old toggle-joint press that was used by Jacob Perkins and my father in drawing fire engine cylinders; that the Bramah press, that was then being extensively introduced in the English paper mills, was the natural sequence of the crude toggle-joint with all its wedges and keys. Suggesting the use of the hydrostatic press was only an application and no great stretch of imagination.

Probably not, said Mr. Donkin, having had the advantage of seeing a copper cylinder of 16 inches diameter successfully finished in that way. But

FIGURE 54.—John Dickinson (1782–1869). From *The Firm of John Dickinson and Co., Ltd.* (London, 1896). Library of Congress photograph.

without this to conceive of and put into practice on so large a scale required no little thought and much boldness in the necessary outlay—machinery that, if not successful, would prove a serious loss.

I remarked that since seeing the machine in his erecting shop I had learned some facts in relation to drying on iron cylinders without the copper covering. The finest qualities of copper plate paper, used by John Murray, the Ackermanns and Windsor & Newton, for the finest works of the engraver, were from John Dickinson's mills, and entirely free from iron mould or specks.

But what assurance, asked Mr. Donkin, have you that the paper was not dried on copper cylinders.

I replied the assurance of Mr. Dickinson himself: that I had dined and spent last evening with him, and the subject of drying paper by steam-heated cylinders had been fully discussed; that for gradual, steadily increasing heat with uniformity Mr. Dickinson gave a decided preference to iron over copper; that he had sketched his arrangement giving the number and size of the drying cylinders that he had found the most effective and reliable for his heavy plate paper; that he had promised me a set of tracings of his most approved dryer, with no other restriction than that I should not show them in England. He had said that he made no secret of his preference for iron dryers, notwithstanding the increased surface required over the ordinary copper ones, but I considered what he had said, as to the arrangement of his drying cylinders, and manner of working them, as confidential, being included in his request in regard to not showing his promised tracings in England.

Mr. Donkin was much surprised at Mr. Dickinson having been so free with me; he thought it most extraordinary, inasmuch as it was well known that he had more reliance on secretly working than on patents to protect him in his inventions, and of all paper makers in England he was the most rigid in enforcing the rule of non-admittance to his mills without a special permit from himself; that all of his machinery was made at his own shops under the same rigid secrecy.[160] I replied that he had offered me a letter to the manager of one of his mills, but would prefer accompanying me if I remained in London over the present week; that I should most certainly avail myself of this.

The reference I made to Mr. Dickinson's preference for cast-iron dryers without the copper facing I felt was unfortunate, for it seemed to cast a shade over Mr. Donkin, and he sat as if in deep thought; he suddenly roused himself, and said, if it was not intrusive or impertinent, he would like to know how I had met with and become acquainted with Mr. Dickinson.

Not at all, I replied: Mr. Charles Leslie,[161] the artist, had taken me to Ackermann's great artists' emporium, and introduced me to Mr. Ackermann[162] as a son of one of his old Philadelphia friends and grandson of Charles Willson Peale, the artist, who, up to the time of his death, had been a correspondent of their house. Many fine specimens of art were shown us. The subject of the satin-faced plate paper, then being made by Dickinson, of which the Ackermanns were large consumers, was freely discussed in a manner very interesting to me, so much so that I expressed a wish to meet Mr. Dickinson. Both Mr. Leslie and Ackermann proposed going to his city office at his great paper warehouse.

In this way my introduction was most favorable. We were taken through the warehouse among immense stacks of paper, and into a room where there was at work one of Mr. Dickinson's recent inventions—rotary cutters for cards, principally for playing cards, with greater accuracy and leaving a more perfectly rounded edge than was made by the ordinary shear cutting.

When I was introduced, it was as an American engaged on paper machinery, and being a young man, as a matter of course, Mr. Dickinson's principal attention was to the great artist, and to the large consumer of his paper; and I walked with them, listening and taking but little part in the conversation, until Mr. Dickinson asked me if I had ever met a Mr. Greatrake in America, who many years before had been taken from him by Mr. Thomas Gilpin offering a higher salary than he could at that time afford to pay.

On my replying in the affirmative, and that I was well acquainted with Gilpin, and thoroughly posted as to his cylinder paper machine, he then spoke of Greatrake as having been one of his most reliable and trusted employees; that it was a severe blow his leaving at the time he did, knowing that he had taken with him to introduce in the States his inventions, that they had together worked on for years, through great difficulties. He was very bitter on Gilpin for, as he called it, buying Greatrake to get his inventions.

Before we left, he asked me if I had ever met any of Mr. Greatrake's family. He referred particularly to a daughter, Eliza, who many years ago had written to his wife, announcing her marriage, since which time they had lost all trace of her.

I told him her case was a sad one; her husband was my mother's brother; that since the birth of her only child she had become a hopelessly confirmed invalid.

Mr. Dickinson would like his wife to meet me, and learn something of her old friend, and regretted that his family were at his Brighton house. He was going

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160 In an omitted passage, Sellers wrote that Dickinson, upon showing him "the working of his latest and most improved machine," had assured him that he "was the first American who, with his knowledge, had ever seen their operation" (*American Machinist*, December 4, 1886, vol. 9, p. 4). It is not clear whether this statement referred only to the latest machine.

161 Charles Robert Leslie (1794–1859), expatriate Philadelphian who apparently had known Coleman Sellers, George Escol's father, before departing for England in 1811 at the age of 17. See *Dictionary of American Biography*.

162 Rudolph Ackermann (1764–1834), coach builder, patentee in 1818 of the Ackermann steering linkage (still used in automobiles), lithographer, and publisher. See *Dictionary of National Biography*.

on Saturday, to spend Sunday, and urged me to accompany him; but I had other engagements. On the Monday evening following I had a note from Mr. Dickinson, inviting me to dine with him the next day, saying his wife and son had come up to London with him to stay over that day.

This outline of the way my acquaintance with Mr. Dickinson had been brought about, Mr. Donkin said most satisfactorily accounted for the freedom with which he had spoken of his machinery to me, knowing what I did of the machine Greatrake had put in operation for Gilpin. There was nothing further to conceal. He then added that Greatrake leaving when he did was a great loss to Dickinson; that he had been his right-hand man in carrying his plans into successful operation. It was true that the running two forming cylinders at the same time in different grades of paper pulp, making the fine, veneered plate paper, had been perfected long after Mr. Greatrake had left, but that being secured by patent, and a general description having been published in Newton's journal, accounted for his freedom in speaking of it.

After this, Mr. Donkin dropped back into a free and familiar discussion of the state of mechanics and their advance in England. Great and successful inventor as he was, and one who had done so much in perfecting whatever passed through his hands, and who was certainly the most progressive machinist I had met in England, yet he seemed to labor under false impressions, and not clearly to understand the condition of things that led to such rapid advances in mechanical pursuits in the United States. He made notes of the wages we paid for skilled labor and such cost of crude materials as I could give him. Then he came back to the squirrel cage cylinder, and said he could not see how we could afford them at the price I had named. As I had myself made many of them, I went fully into detail, and seemed to satisfy him that the higher wages naturally led to mechanical contrivances, and that, in the case of the cylinders, they were of the simplest possible kind, and yet as labor savers that portion of the cost was reduced below the cheaper labor in England; that, in the crude materials, the iron and bars, the saving was made in proportioning the parts to the work they had to perform, the American cylinder not weighing over two-thirds that of the English.

Laying on his table I noticed what appeared to be samples of pliers, nippers, and a few such like tools. I picked up a pair of pliers, and remarked that it looked like an American tool—not so clumsy as those I had seen in use in shops I had visited.

"Strange," said he; "they are samples from Stubs, of Sheffield, and they are sent as the American pattern," and, he supposed, were being introduced under that as a distinctive name.

He seemed greatly surpised when I told him they were fairly entitled to be called the American pattern; that the brothers B. & E. Clark, of Philadelphia, watchmakers, in addition to their watch and clock repairing business, kept a supply store of watch and clock makers' materials, including tools; and in my earliest recollection they were the only parties in Philadelphia that kept on sale Stubs steel files, etc. They were fine workmen and ingenious men, who either altered English tools or made those they used of such form and proportions as they found best adapted for the general work they had to do. Samples of these were sent to Sheffield to be duplicated, and for a considerable time they were the only parties who kept them for sale; but they had spread until they became universally adopted. That in Birmingham, I had noticed the same thing taking place in general hardware—the class being made for the American market materially differing from that for home consumption, being generally lighter and more elegant in form. That I had learned that in every case the change had been made to conform to patterns or drawings sent from the United States.

He spoke of the feverish state of excitement among his best skilled labor, owing to the glowing accounts they received from brother workmen who had emigrated, and he asked me as to their real condition. Men he said who, on the English plan of division of labor, were only perfect on a single branch, he did not believe it possible could find constant employment on that—in a comparatively new country.

I told him that he must bear in mind that America's start in mechanical art was at the point England had reached and without her prejudices. That the men who at home would resist the introduction of labor-saving machinery were glad to accept such as they found in America, as by it they were enabled to turn their hands to general work as it offered. I reminded him of the English prejudices that years before had led to the riots that destroyed the nail-cutting machines that Samuel R. Wood, of Philadelphia, was endeavoring to introduce in England. Wood was a member of the Society of Friends and non-combative, and he left England in disgust.

I said it would be impossible to estimate or realize what the rejection of the cut nail had cost England. Its invention in America filled a vacuum and was almost a necessity, not only as to first cost of the nails but as great labor-savers in carpenters' work; that I had noticed that in England every carpenter had in hand either brace and bit, gimlet or brad-awl, according to the work he was doing, for without them the square uniformly tapered hand-made wrought nail was the best possible form that could be devised to split the wood it was driven into, without first boring a hole to receive it; that its tapered form, if not driven through and clinched, would lose its hold on the least starting back—still they continued in common use; that on watching the joiners at work, I believed I was safe in estimating that for every English nail driven, the user of the American cut nail would drive four or five. That in patternmaking shops I had seen the wrought clout in use by having its head flattened edgeways by a stroke of a hammer, and then it made a ragged hole to be filled with wax or putty.

Mr. Donkin smiled as he said, "I have long been using in my pattern shop the American cut brads;" then he must understand the point; but I would give another instance of the fixed ways and prejudice of the old country that kept back improvements.

Mr. E. R. Sheer, a pianoforte maker of Philadelphia, in fitting work where wood screws had to be withdrawn and again driven in the same holes had found it difficult to make the common square-end English wood screw enter and follow the thread cut by the first insertion; he had mounted a clamp chuck on a foot lathe that would grasp the shank of the screw, then with file and chasing tool he tapered the end of the screw like that of a gimlet. He had given me several of these as samples, with the request that when in Birmingham I would induce some good screw maker to fill a considerable order of gimlet-pointed screws. I had gone to the makers with a prominent shipper of hardware through whom they received most of their American orders, and we had failed to induce any one of them to fill the order; they and their predecessors had always made wood screws as they were then doing, and they would have nothing to do with such new-fangled notions.

Mr. Donkin did not expect Mr. Ibotson before noon, and said if I could come to his shops one or two hours in advance he thought he could show me a shop that had abandoned some old fixed ways and made fair advances, and added—if it has not kept up with America. [46]

On going to the shops the following morning I found Mr. Donkin in his office, but still far from well, yet he went with me through the shops; he took great pride in showing and explaining his great engine lathe for turning the drying cylinders. It certainly, for solidity and fine workmanship, came nearer to the lathes of the present day than anything I had previously seen in England. It was calculated to turn cylinders of 4 feet diameter, which at the time it was built was thought to be the largest that would be required, but on one occasion the heads had been raised to take in a still greater diameter, and a larger size lathe was then being constructed.

I had seen in Manchester many efforts at tools to produce uniformity in various parts of cotton spinning machinery, but nothing to compare with the tools Mr. Donkin had constructed to obtain that end in the heavier machinery for paper mills. His screw bolts were mostly lathe chased, the nuts tapped in the usual way by hand, but afterwards screwed on mandrels and lathe faced. Hexagonal nuts and heads of collar bolts were reduced to standard size and finished by milling with double cutters. As we were going through the shops, a clerk handed Mr. Donkin a letter that had been brought in haste by a special messenger; he glanced over it, asked me to excuse him for a short time, calling on the room foreman to show me around during his absence. Then I noticed that, as at Manchester, the grindstone and lap wheel were much used in finishing work, but the planing machine then being introduced was destined soon to take their place.

Mr. Donkin soon returned with the open letter in his hand, and said to me, "Here is a case in point, showing the value and importance of, as far as practicable, making all parts of machinery interchangeable. Mr. —— has met with a serious accident to his Fourdrinier machine. The carelessness of an attendant allowing a tool to slip from his hand caused a break, that before the machine could be stopped was carried forward, doing serious damage to other parts of the machine; a messenger with a conveyance and the request that I lose no time in sending workmen with tools to make repairs. He has fortunately given in his letter a full detailed description of damage done, hoping that by so doing I would, in a measure, be prepared and that he would not be obliged to have his mill shut down for more than three or four days." He then added that in the short time he had left me he had dispatched a competent workman with duplicates of all the broken parts, and that by midnight he had no doubt the machine would be in running order. He spoke of having for years made a study of the practicability of making all parts of his machines of uniform size and shape, and having the work systematically done to rule by templets and fixed gauges. The key seats in light shafting were milled, but for heavy shafting and gearing the cold chisel and file were still doing the work.

At the noon hour, when the machinery stopped, I was taken into the storeroom, in which were arranged all the various parts of the Fourdrinier machine, with the exception of the frames, press rolls and drying cylinders. It was from this room that the ready-made duplicates to replace the broken parts had been sent.

I would here note that 54 years ago this was the first instance I had seen where making the component parts of machinery interchangeable had been reduced to an absolute system, that is now so universally practiced by all first-class machinists. [47]

16. A Visit to England. III: Ibotson's Pulp Dresser

Richard Ibotson, of Poyle, Middlesex County, a short ride northwest of the center of London, was the paper manufacturer who in 1830 patented a pulp dresser, mentioned in the last chapter, for removing "knots," or small globular masses of pulp, from the paper stuff being fed to the Fourdrinier continuous-web paper making machine.[163]

The bizarre adventure at "Crusty's" paper mill, related here, in which George Escol scampered over a plank to gain entrance at the back door after he had been shouted away from the front door, resulted from his consultations with Bryan Donkin about the merits of his father's pulp dresser.

From the storeroom we returned to the office, and soon Mr. Ibotson came in, and on being introduced it was evident that he had been prepared by letter for the business in hand. He was not long in coming to Mr. Donkin's views as to the importance of securing and controlling the right of our pulp dresser, but there was an obstacle in the way; a mill in Kent was running on the fine tinted papers for the bristol boards, then being extensively used by Dobbs, and the firm of De la Rue & Co. for their beautifully embossed boards or cards, which at that time was the fashion's rage. These delicately tinted papers were entirely free from knots and imperfections, and Mr. Ibotson had learned that the proprietor of the mill claimed to have invented and had in use a pulp screen or dresser greatly superior and less costly than his. If this was the case there would be no use in securing further rights.

He had been trying to learn the nature of the invention, but so far unsuccessfully, but what little he had learned had inclined him to believe it was an infringement on his patent working secretly to avoid payment for the right.

Mr. Donkin concurred in this view. He had built the Fourdrinier and other machinery for the mill, and had recently sent workmen to make some changes in gearing, who had not been permitted to go into the machine room. The owner of the mill was not remarkable for courtesy or refinement, and at other times was rather crusty, and still Mr. Donkin thought if I would be willing to go to the mill with a letter of introduction from Mr. De la Rue, who

[163] See note 156, above.

was the principal consumer of his paper, stating that I was an American traveler curious to see the manufactories of the country, that I had seen their embossing presses at work (I had been introduced to both Dobbs and De la Rue by W. H. Burgess, then the landscape painter to the king, and I found them most courteous gentlemen who had freely shown me their presses in operation) Mr. Donkin thought with such a letter I would be treated with civility and probably be shown through the mill. In that case a mere passing glance would be sufficient to tell whether the pulp dresser was an infringement on Ibotson or not. If I would consent to go Mr. Donkin would procure the letter from Mr. De la Rue; there could be no harm in that, but I must consider the matter.

I accompanied Mr. Ibotson home, arriving there after dark. During the evening, as the mill was running day and night, he proposed going through it to see some of his improvements.

Half stock at that time was bleached by the direct action of chlorine gas in chambers or chests in which Mr. Ibotson had made some arrangements of the slat shelves on which the half stock was placed to facilitate the handling, and to keep it so separated as to insure the equalization of the gas on all portions. By his arrangement he had shortened [the] time required, saved gas and consequently expense. These chambers were arranged on both sides of a railway passage, and as we were walking through, he told his manager to open the chamber that the gas had been longest cut off from, to show the condition of the stock and the inner construction of the chamber. The manager pointed out a chamber, but at the same time cautioned against opening it before morning, or at any rate to give it two or three more hours; but Mr. Ibotson raised the latch and as the sliding door fell, the heavy gas-like water poured on us. I was suffering the latter stage of full catarrh now known as hay fever, and the effect of inhaling the chlorine gas was so suffocating that it came near ending me. I was carried into the open air and pretty roughly handled to restore respiration. The dose was a heavy one, and both Mr. Ibotson and the manager suffered from it. The next morning the latter told me he had walked his room all night sipping new milk, his sovereign remedy. I then learned that to prevent such accidents on opening the chests, in cases that the gas had not been entirely expended or neutralized in the bleaching process, a trough opening into the outer air with gates or valves was provided for each chest, and these were usually opened some time before dropping the doors to discharge the stock from the chests. This unfortunately had not been done, and we suffered in consequence. Mr. Ibotson proposed connecting all these openings with a box trough and exhaust pan; I suggested instead, carrying the box trough at an acute angle into the water of the tail race, with its lower end cut to the angle at which it entered the water that I believed the suction of the rushing water, aided by the strong affinity of chlorine for the hydrogen of the water, would rapidly exhaust any chamber opened to it. I had the satisfaction long after of learning that this had been successfully adopted.

On returning to London I found the letter from Mr. De la Rue, and I took the evening stage coach for Maidstone, Kent.

The following morning proving pleasant, I walked out to the mill to deliver my letter and try my luck. The external appearance of the mill was rather forbidding; the windows of the main mill were small and high from the ground; the mill yard had one side protected by the mill, the other three by a high brick wall. The only entrance to it was by a high arched gateway, with a small door in one of the folds. The entrance to the mill was through an entry passing the office, with windows and glass doors so arranged that no one could pass in or out without being seen. The mill race flanked one side of the mill, passing the long one-story building in the rear, which the steam from its ventilators showed to be the machine room. This moat-like mill race—small windows and high yard wall—gave the appearance of a fortified place, or jail. It was hard to realize it was a paper mill, so unlike our light, airy mills. In front of the mill was hitched a horse, attached to a rather dilapidated gig; in the door-way stood a man who might be a stable boy watching the horse, or a sentinel guarding the entrance. Of this man I inquired where I could find the master. With his thumb over his shoulder he pointed towards the office. In an outer one were two clerks; one of them, in reply to a similar inquiry, answered as the man at the door had, by a thumb pointed to a kind of inner office or box.

I began to feel as if I was in a deaf and dumb asylum, but this feeling did not last long. The master sat at a desk that appeared to be covered with a confused mass of papers. He was a short, thick-set, shock-headed man, with a face disproportionately large for his head. As he turned from his desk, he evidently took my dimensions from head to foot. There was that kind of forced smile on his face that seemed to ask: "Have you come to order paper?" but not a word spoken.

I handed him my letter of introduction, which he opened holding it in his left hand, alternately reading a few words and scanning me. As he read on his brows contracted, his flabby cheeks became taut, the muscles at the corners of his mouth twitched; his shock-head rocked from side to side, his right arm jerked with a kind of pawing motion, calling forcibly to mind a bull lashing himself into a dangerous rage. Suddenly with a blow of the fist of his right hand, he crushed the letter into the palm of his left, and burst forth: "What does De la Rue mean by writing this to me, if he did write it? He knows as well as any man that I never admit strangers to my mill. I've told him so a hundred times, and now to send here and expect me to show my mill to (something that sounded like) a d——d Yankee."

In spite of disappointment, the disposition to laugh outright at the impotent passion the man had lashed himself into was almost irrepressible. I stood a moment in hopes the froth and scum would boil over, but, seeing no indication, I said that if I had been made aware of his rules and regulations I should not have intruded; that I had visited many manufactories, and heretofore had met with courtesy. I then added that on the way to his mill I had noticed crowds of people in hop fields, which was something new to me, and if I could venture, without danger of being expelled or arrested for trespass, I should like to learn something of the management of a hop crop.

He said, "You can go where you like, so it is outside of this mill, and the sooner you are off the better." On this, as we say here in the West, I sloped.

As I walked into the nearest hop field I tried to make excuses for the man's rudeness and insolence, it being the first case of the kind I had met with in England. I had learned that the man had worked up from a hand in a paper mill to become a proprietor of a mill, mainly through his skill in making with uniformity the beautiful neutral tinted papers then the rage for the kind of work turned out by Dobbs and the De la Rues. I had understood that this portion of the work was always done by himself, not communicating his secrets to any one of his employees; this would account for his exclusiveness—the dread of interlopers—but was no excuse for his insolence.

Looking back towards the mill, I saw him get into the gig, and drive off towards Maidstone, venting his passion through his whip on his horse, that he was urging on at a furious rate. The question with myself was how far I would be justified in surreptitiously obtaining the information I was in search of. By my understanding with Mr. Ibotson, if I found the pulp dresser was anything likely to supplant his and my father's, nothing further was to be done; but if Crusty's (as I must now call him) was an infringement on Ibotson that could legally be enjoined and damages recovered, then our trade was to be consummated. By it, Ibotson was to pay all expenses of securing a patent, as introducer, or to suppress my father's, at his option, to pay £200—£50 cash, the remainder in royalties—as the machines were introduced, whether under the Ibotson patent or my father's plan.

I felt that by spending a few days at Maidstone I could make the acquaintance of some of the operatives in the machine room, and by a little money in a social way get at the secret of the pulp dresser. Such a thought would not have been entertained for a moment had I been treated with common civility in being refused admittance. While studying on this, I again chanced to look towards the mill, and saw a plank thrown from a window of the machine room across the mill race, and a man, with the conventional paper-maker's square cap on his head, cross on the plank, and quickly run to a cottage nearby. I hurried to intercept him as he would return, and was just in time to meet him as he came out of the cottage.

Pointing to the mill, I asked him if he could tell me what that building was.

"A paper mill."

I then asked, "Do they make the long paper in sheets, as they do in America?"

"Do you be an American?"

"Yes."

"Did you ever happen to see John Hanlon? He is a papermaker, and he says in his letter that he works for Mr. Robinson, near Philadelphia."

"No, I have never met him; but I know Mr. Robinson." I said I had often seen them making sheets of paper in his mill. I took out my memorandum book, asked the man his name, and offered to carry any message to his friend Hanlon, through Mr. Robinson, whom I should certainly see on my return to America.

This opened the flood-gates, and had there been time, and I inclined to listen, I should have had a whole family genealogy, as well as that of the Hanlons, and how the man was saving every penny he could, and what he had laid by to take him and family to America.

When I got a chance to get in a word, I asked if he could tell me how long paper was made, and how the sheets were united so we could not discover the joints.

"Why bless you! they don't make sheets on paper moulds at all; it is just a long wire web, sewed together at the ends; and it goes over rollers right along, and the stuff runs onto it, and it shakes both ways, just like the mould; and it goes along, and the pulp is pressed on the felt by rollers; and so on it goes to the steam drying cylinders, and comes out paper—dry paper."

"How very curious! I should like so much to see it."

He said, "I would like to show it to you; and then you could tell John you had seen the machine I am boss of. But it would be all my place is worth, if the master found me out. He won't let anybody see anything in his mill. He is afraid they will steal his secrets. And today he is on the rampage; he has been cursing me, just because the color of the paper is a shade lighter than he intended, and I said it was not in the color he had put in, but in the new bleach he was trying; and the master don't like anyone to know anything but himself." We were by this time at the plank over the race, and I noticed how nervously the man was watching the turns of the Maidstone road; and I must confess to doing so myself.

I thanked him for the information he had given as to how long paper was made. I handed him a half dollar, telling him it was an American coin, given as a remembrancer of the American, who would certainly tell Hanlon that his friend was saving up to go to America. I then asked him if he had time to begin at the beginning and again tell me how the long paper was made; that I had been greatly interested in what he had told me, and I should like to know if they sifted the rags after they were ground, like flour was sifted in the corn mills?

Instead of answering, he asked if I could walk that plank—it was not strong enough to carry two, or he could steady me. He had three men and four girls in his room. There was no danger of their telling on him, for he was their boss, and they all hated the master like poison; but I could not stop over a minute or two, as the master might come back sooner than usual. He tripped over the plank, and I followed, feeling almost as guilty as if committing a burglary. We walked by the dryers and machine to the vat where the pulp dresser was working. The man, paper maker like, took up a handful of the dilute pulp, squeezed the water out of it, and handed it to me. I did the same, taking care that it was from the knot receptacle, for future examination.

Having seen all I wanted, I was in haste to get out, hurried on a short cut through a hop field, and came out through a hedge-gate onto the public road about a quarter of a mile from the mill, just as Crusty passed on his return.

The pulp dresser was a decided infringement on Ibotson's patent, differing in being circular with annular slits, instead of rectangular with bars and straight slits. The screening was done by the same up and down jogging motion precisely by the same means as Ibotson's; but it had in addition what was injurious instead of beneficial—an automatically revolving wiper to clean the surface of the screen and carry the knots into a receptable, from which they were taken back to the beating engine to be reground. This constant brushing made rolls of pulp and pressed fibers into the slits, clogging the screen and requiring more frequent cleaning than the Ibotson.

I returned to London the same evening. Mr. Donkin was much amused at my description of my interview with Crusty, and gratified at the result of the venture. The arrangement that had mainly been made by his intervention with Ibotson was carried out. After my return home I learned that the information gained, and the sketch I made showing the infringement, had enabled such a presentation to be made that legal proceedings were avoided by Mr. Donkin replacing the machine I had seen with an Ibotson.

During about a week that I remained in London, I had several very pleasant interviews with Mr. Donkin, all strengthening the opinion I have previously expressed, that he was the most advanced mechanical engineer of the time, and it is to his inventive ability, zeal and persistent application through a period of over 30 years, that the world is indebted for the perfecting of the crude ideas of Robert and Didot, and producing the self-acting endless web paper machine in such perfection by the year 1832, that in the 54 subsequent years no essential changes have been made, and now the great bulk of the paper of the world is produced on machines substantially as they came from his brain and hands at that early period. [48]

17. A Visit to England. IV: Perkins's Adelaide Gallery

The actors in this scene we have met before in Philadelphia. Jacob Perkins, now in his 67th year, had been in London for 13 years. Joseph Saxton, who was 33, had been there for about 4 years, and during much of that time he had been working for Perkins in his National Gallery of Practical Science, in Adelaide Street, West Strand.

To the dozens of mechanical-wonder exhibits that fairly showered from Perkins's hyperactive brain Saxton had added some of his own. His "paradoxical head" was the carved bust of a Turk so contrived that it remained intact even after a sword, wielded by an attendant, had apparently severed the head from the neck. He built a magnet that sustained a weight of 525 pounds. He devised a huge magnetic needle, several feet long, with a mirror mounted at one end, which by means of a reflected light beam demonstrated (in the words of Joseph Henry) "on a magnificent scale, the daily and hourly variations of the magnetic force of the earth." [164]

Saxton's "package express," mentioned below by Sellers, was called by its creator a "locomotive differential pulley." The full-scale system contemplated a railway, a carriage, a horse, and a differential pulley device so arranged that the horse, pulling on the disadvantageous end of a rope, could propel the carriage some ten times as far as he moved, and thus at ten times his own velocity. Patented by Saxton in 1832, [165] the invention was seized upon by John Isaac Hawkins, who laid down in Regent's Park an experimental railway upon which to try the scheme.

An indignant correspondent of the London *Mechanics' Magazine* characterized the contraption as a "friction machine" but the gauntlet was caught up by the mechanically inclined Benjamin Cheverton, who, while admitting that Saxton's scheme might not be economically sound, thought that mechanically it was the best locomotive system for railroads that had yet been devised. Perhaps the horse had the last word. At any rate, the idea produced a fortune neither for its inventor nor for its promoter.[166]

A fundamental contribution to the progress of electrical machinery was made by Saxton in 1833 when he devised a practical commutating system for a "magneto-electrical machine," which was the prototype of electrical generators.[167] It is possible that his commutator, which consisted of of wire-ends dipping successively into a small pool of mercury, was already at work in the "electric magnetic motor" noticed by Sellers.

WHEN I WENT TO LONDON in the fall of 1832 I took a letter from father to Jacob Perkins. I found him at the Adelaide Gallery where he seemed to have found his true level, the typical showman of that period. He received me very kindly, said he would have known me as the man grown from the boy who asked questions and would have an explanation of everything. He had at that time Joe Saxton as his right

[164] JOSEPH HENRY, "Memoir of Joseph Saxton, 1799–1873," *Biographical Memoirs* (Washington: National Academy of Sciences, 1877), vol. 1, p. 295.

[165] British patent 6351, December 20, 1832.

[166] *Mechanics' Magazine* (London, 1834), vol. 21, pp. 3–6, 106–108.

[167] Ibid., pp. 66, 96, 333. *Mechanics' Magazine* reprinted the report from the *Journal of the Franklin Institute* that told of Isaiah Lukens's building a Saxton machine for the Peale Museum and of substitution (by Jacob Green?) of a solid metallic commutator for Saxton's. A careful account of Saxton's machine is in HENRY (cited in note 164 above).

hand man in his exhibition and it was a very interesting one.

He had a long water tank in the centre of the room in which he exhibited various ways of propelling boats. He had one little boat with the ordinary paddle wheels propelled by clock work. He would have his visitors time it in the long tank and he would then take out the wheels and substitute his feathering wheels in their place. These paddles entered the water edgewise and came out in the same way, as he said "the skillful rower feathered his oar." He had Saxton's "package express," an arrangement of cords over differential wheels the draft being given at the periphery close to the contact with the rail—a pretty plaything. [49]

I do not think Mr. Saxton ever had the idea of applying this practically, but merely as an attractive feature to the exhibition; it certainly caused much amusement to take hold of the cord, and by a short draft hurl the little car from end to end of the long gallery. Saxton also had on exhibition an electric magnetic motor of his own invention and construction in which great velocity was obtained, the power being from battery, as in Page's engine, that at that time was exciting much attention in America.[168] [50]

[There was also] a hydrostatic machine to measure the compressibility of fluids; an arrangement of evaporating pans to show the circulation of water; but the great attraction was his [Perkins's] steam generator and steam gun, with which at certain hours or when there were sufficient visitors to witness it, a stream of leaden bullets would be shot the length of the room and flattened and shattered against an iron target. The show never lasted as much as a minute but an almost incredible amount of lead was shot. The bullets were about ½-inch in diameter. I had notes of the weight of lead thrown in a given time but I have lost them. His steam generator instead of being the round massive tubes used by Hawkins, were cast iron and square, as much as 5 or 6 inches on a side, the holes through their centres being not much if any greater than one inch in diameter. They passed from side to side in layers through the fire chamber of his furnace. With every stroke of his force pump a given quantity of water

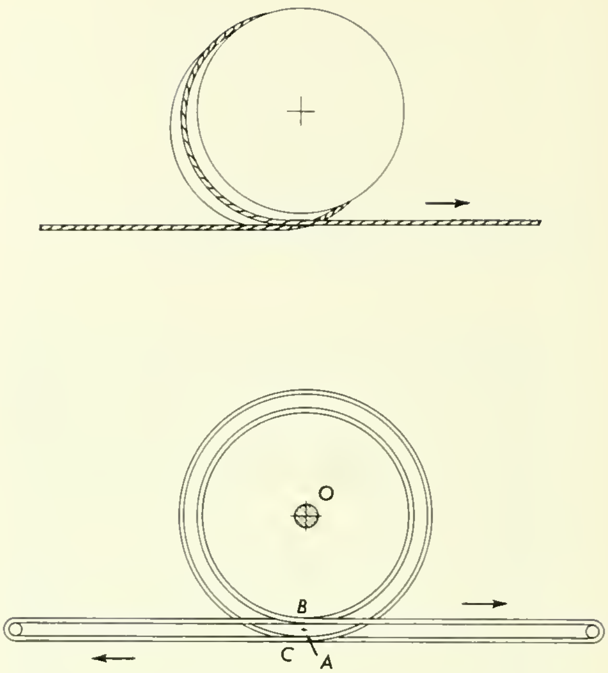

FIGURE 55.—Saxton's locomotive differential pulley. An endless rope (as shown in top figure) was wrapped around each of two concentric pulleys integral with the shaft O (lower figure). The rim of the carriage wheel (not shown) provided a pivot point at A. Force applied on rope produced turning forces in opposing directions at B and C, causing the shaft to move to the right about 10 times as far as horizontal ropes moved. This effect can be demonstrated by pulling thread from the lower side of a spool that rests upon a flat surface. After British patent 6351, December 20, 1832.

was thrown into the highly heated water in these massive tubes and a like quantity was discharged into tubes of still higher temperature in which it flashed into steam from which it passed into his great cannon or what he called his safety chamber in which he claimed to have a steam pressure of over 1000 lbs. to the square inch and from which his steam gun got its supply. I have no recollection by what device, nor the arrangement that let the bullets from the hopper into the barrel of his gun, nor how they were discharged so closely one after another as to appear like a stream of lead in their contact with the target.

[168] The reciprocating electromagnetic engine of Charles G. Page (1812–1868) was developed in the mid-1840's. See *Dictionary of American Biography*.

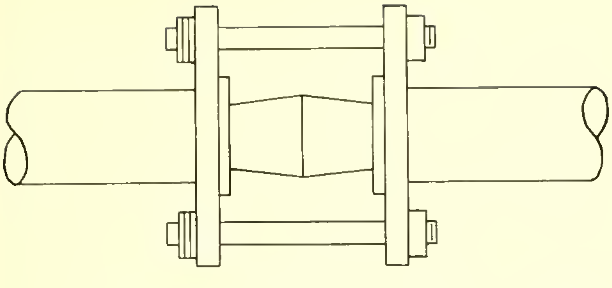

FIGURE 56.—Perkins's cone-joint. A steam-tight connection is made by the pierced double conical connector piece inserted in pipe ends held together by yoked flanges. After Robert Meikleham, *On the History and Art of Warming and Ventilating Rooms and Buildings*, 2 vols. (London, 1845), vol. 2, p. 284.

I must not forget another great attraction. He invited visitors to bring with them old steel files and he would saw them into pieces with a soft wrought iron toothless saw.

I have said that Mr. Perkins received me kindly, and through him and Saxton, who was my almost constant companion during my stay in London, I was favorably introduced to Brunel, Maudslay, Herbert, and many others and I had the opportunity of seeing much that otherwise would have been a sealed book to me.

On one occasion Mr. Perkins took me to the mansion of Sir——Sloan to show me how he had heated the grand house by a system of hot water circulation. "Time proves everything," was an adage with Perkins, which he repeated many times daily. On showing me the hot water pipes around the washboards of the many apartments he laid great stress on the absolute tightness of all the pipe joints and showed the great value of his double cone connections; here they had been in use for over three years and never a leak. "Time proves all things."

Here, as we Americans say, I came near putting my foot in it by thoughtlessly remarking, "Yes they even stood Hawkins' high pressure."

He was ready for me—"Ha-ha you have a good memory, don't you recollect that when his pipe flanges blew off that I invented my double cone junction for him." (I have no recollection of any other connection. They were certainly the same used in the Hawkins experiments as I first saw them.)

On another occasion he referred to poor Hawkins having had the idea of high pressure steam being generated safely by jets of water on highly heated plates of metal, but it was for him, Perkins, to conceive the idea of heating confined water to a very high temperature to flash with steam on its escape. These were the precise ideas I had received from the many talks I had with the poor old blind man when a mere boy . . . .

Having written so much about Perkins, however out of place it may be, I cannot refrain from giving the estimate that by later thought I would give of the character of mind of this truly great man, for he may be said to have stood alone in his line. At the time of my visit to England, he had been there some thirteen years, the first eight or ten years of which the mechanical world had been kept in a feverish state of excitement by what Perkins was doing and the effect it would have on the mechanical world.

It was never what he had done but what he was doing. He had undertaken to do far more than his contemporary workers believed to be possible, but the world at large believed and as his patents were issued they were capitalized and money for developments flowed in. There can be no doubt he had the faith himself with which he inspired the public, and when all elaborate efforts to demonstrate proved failures year after year it was natural that his patrons should drop off and he became as bitter against them as he was laudatory at the time he made them the gift of his minor invention, the riveted hose. This was the state of things at the time of my visit to London.

His own words to me were, "I was deserted when on the eve of perfect success as time will prove. I will be vindicated and all the theories I have advanced will be substantiated." He showed me many of his ingenious devices to overcome difficulties as they arrived. There was a perfect maze of them and if they could be all brought together and exhibited they would establish his character as a man of expedients and extraordinary ingenuity. I will cite but one instance, that of his high temperature steam, which carbonized all piston lubricants. I cannot venture to name all his devices to obviate this—they even went to a great number of experiments in metal alloys for metallic packing that would not need lubricating.

To sum all up, he certainly filled a useful place in advancing improvements in steam engines, for his schemes set many level headed men to thinking in the right direction. [51]

. . . . Wirt Robinson, nephew and chief assistant of Moncure Robinson (who was at that time chief engineer engaged in the construction of the Richmond & Fredericksburg Railroad of Virginia) was sent to England to examine the question of locomotive power, and to contract for engines for that first Virginia railroad. In company with him, I had visited all the shops that at that time were building locomotives, and he had contracted for several, one of which was being shipped on the Philadelphia packet ship, *Algonquin*, on which we had taken our homeward passage.

Some accident delayed the starting of the vessel for about a week; and although we had already been over the Liverpool and Manchester Railroad, all of this week's delay was devoted to examining it and its locomotives more in detail, often accompanied by engineers connected with the road. We had several very pleasant interviews with George Stephenson, who afforded us every facility. At that time he was having constructed for America a number of full crank four-wheel complex locomotives, with the cylinders under the smoke-box, without either trucks or pilot wheels. He explained very fully his train of reasoning and his experiments that led to his adoption of tubular boilers. He was no doubt the originator of the multi-tubular boiler to which the great success of the present system of locomotive engines owes so much . . . . [52]

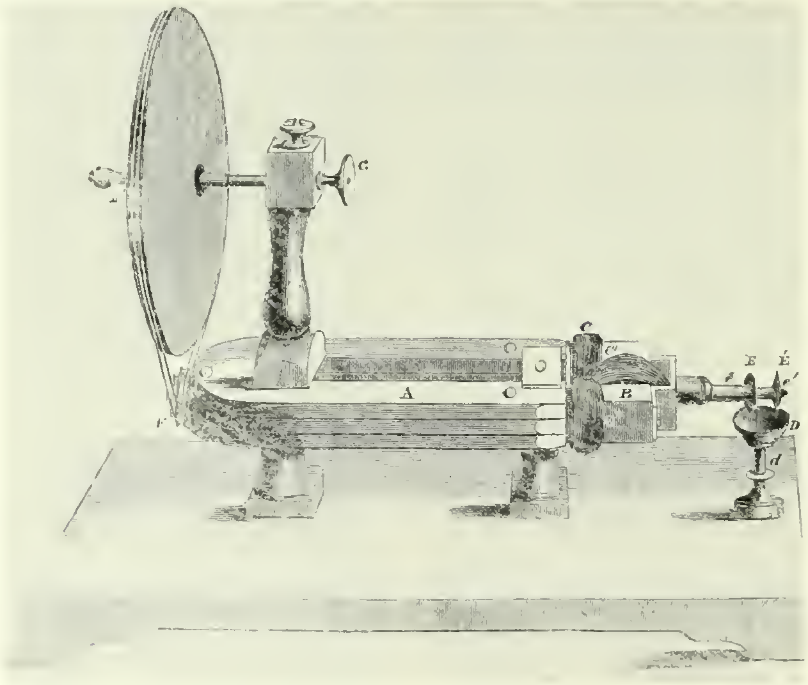

Figure 57.—Saxton's magnetoelectric machine, which was built for display in the Adelaide Gallery. The machine is a direct-current generator. The commutator consists of disk (E) and double-pointed needle (E'). The lower side of the disk is partly immersed in mercury in the cup (D). A current path is completed when a needle point makes contact, during a part of each half-revolution, with the mercury. From *Mechanics' Magazine* (London, May 3, 1834), vol. 21.

18. An American Counterfeiter

It remains for someone more diligent and more persistent, or perhaps more fortunate, in his search than I have been to exhume the external framework of the rousing good story of intrigue and perilous adventure that follows. The names of the participants, the exact dates, the location of the bleak island in the St. Lawrence River near Montreal, and the fate of the others in the counterfeiting ring—all these data would be interesting, but our ignorance of them detracts none at all from the irrepressible delight with which we read our final lesson in the higher branches of the art of papermaking.

Nicholas Biddle, then president of the U.S. Bank, had more faith in security against counterfeiting in the quality of the paper and its water marks, than he had in the most complicated and elaborate engraving. I have frequently heard him argue that engraving, no matter of what quality, could be secretly imitated with but little chance of discovering the operator, but that a paper that could only be produced by machinery of magnitude and of great cost, beyond the reach of the counterfeiter could not be hid away. Many curious devices in water marking were tried at his suggestion. At one time he brought us a specimen of French paper with a shaded water mark. It had evidently been made on a vellum-faced mould, most probably of soft copper wire in which undulations were formed by dies analogous to those used in embossing paper cards. The pulp deposited in the depressions made a slight difference in the thickness of the paper, which being reduced to the uniformity requisite to take a fair impression from the engraved plate, by compression in finishing caused the dark shade around the wire water mark sewed in the bottom of the depressions. These were very difficult moulds to make. The under facing or foundation wires that are about $\frac{3}{16}$-inch apart on the wooden bars of the mould had to be bent by hand to suit the depressed portions of the wire face. When these paper moulds were completed Mr. Biddle remarked that he now felt safe against the counterfeiters, for they must first obtain moulds and then some mill to make the paper, and he did not believe the owner of any mill in the country could be found so unprincipled as to join them.

How little he dreamed of what Yankee ingenuity could accomplish. Not long after the issue of notes printed on this security paper, the most perfect counterfeits the bank ever had to contend with were put in circulation.

It was several years before it was learned how the counterfeiters had obtained the peculiar water-marked paper, in fact not until the old United States Bank had become a Pennsylvania State Institution,[169] and when the facts were learned it was in so singular a way savoring more of romance than reality that I must be excused for what may run into a long digression in relating them.

During the frequent conferences with Mr. Nicholas Biddle, in hope of reaching some mode of preventing counterfeiting bank notes, I learned in confidence much of what had been done in the detective line and its results by an unsuspected officer of the bank whose position was high, and who had become so much interested in the pursuit that in disguise he affiliated

[169] This is probably the date from which one must start in order to track down court records. The United States Bank was succeeded by The Bank of the United States of Pennsylvania on March 1, 1836.

with some of the most desperate counterfeiters of the period; although both he and Mr. Biddle have passed away, reasons still exist why he must remain nameless. It was through his machinations that the most expert engraver and counterfeiter this country had ever produced was arrested with all his tools and machinery, including a simple and most ingenious eccentric lathe with which he reproduced the work of Spencer's mole lathe, that had never before been done by counterfeiters. The man was convicted and sentenced to the Eastern Pennsylvania penitentiary for a term that, at his age, amounted to a life sentence.

The judge in passing sentence, in my judgment, committed a most unpardonable vandalism in ordering the destruction of the unique eccentric lathe and other ingenious appliances, and in seeing the order carried out with the exception of a few burins and other small tools, which Samuel R. Wood, the then Warden of the Eastern Penitentiary, preserved.

Mr. Wood was a Quaker, and a most kindly disposed man; he became interested in his prisoner and had wormed out something of the early history of this ingenious mechanic who had gone astray—"through force of circumstances that should be taken into consideration when judging the man." These were Mr. Wood's own words when expressing to Mr. Biddle his belief that if by promises of shortening his term by procuring a pardon, his confidence could be gained, much valuable information tending towards the suppression of counterfeiting would result from it, but without some such course he was satisfied the imprisonment would be of short duration; for labor the man was listlessly picking oakum, and physically rapidly sinking. Mr. Biddle thought the experiment worth a trial. Soon after Mr. Wood reported that he had made no progress; he had tried kindness, but the man had become more reticent; to all his advances he only received muttered monosyllabic replies.

I suggested that he might probably be reached by giving him more congenial employment than oakum picking, and proposed substituting die sinking such as was then coming into use for stamping the corner of note and letter papers. Provided with samples and such tools of his as Mr. Wood had preserved, with him I had my first interview with the man in his solitary cell; he was sitting on the side of his cot, his fingers locked together clasping his knees, a bundle of partly picked oakum lay by him; as we entered the cell he glared at us; his high narrow receding forehead, aquiline nose, thin tightly-compressed lips, deep set piercing eyes gave him more the appearance of a caged eagle than a human being.

Mr. Wood explained that I had proposed work that he might find relief from oakum picking. He wanted none of it, nothing could kill time; at first he refused to listen to me; when he saw the kind of work he denied having the ability to do it; he had never done it or seen it done.

Then looking at me he burst forth in a perfect torrent. "Can you tell me what became of that red-haired fellow who was taken with me; he fought the officers like a very devil, and yet, though I know he was secured and ironed, he was not brought to trial with me; I see it all now, he was a fraud, it was a trick to trap me; if I was only free for a day, and could get my hands on him, his life should pay for it, and I would die contented."

Mr. Wood, to quiet him, said the man had a separate trial, and had been sentenced to a long term.

His reply was: "I don't believe a word of it, he was too smart for that; he was a splendid fellow with his pen; he never had his equal and never will again; he could raise a note that would defy detection."

I took from my pocket and held towards him his old burins and other small tools; he seized them with trembling hands, he fondled them as if they were living; their touch seemed to have totally changed the man—for when Mr. Wood took them from him, explaining that they could not be left with him, he at once agreed to try his hand at the work I proposed. In addition to his little tools he would require a light hammer, a small oil stone, a bench or stool with clamp or vise to work on. It was arranged that the dies and designs should be prepared.

His sentence, in accordance with the Pennsylvania system, was solitary confinement with labor. Hours for this new work were arranged, during which a guard was to be with him, who was to deliver to him the tools and work, taking them away at the expiration of the time. After leaving the cell, Mr. Wood said it was necessary for him to have the consent of the prison inspectors for this change of labor; as to that, he had no doubt they would meet the evening before the time fixed on to initiate the man at his new work.

When I went to the penitentiary with the dies and designs, Mr. Wood informed me that he had been unsuccessful in obtaining the concurrence of the inspectors, who believed the kind of work would keep the man in practice, and that on the expiration of his sentence he would resume his old business. Mr. Wood considered this absurd; for, said he, if the man lives and serves out his term, he will be considerably over eighty years of age.

The inspectors would not give way. Mr. Wood had not told the man of this decision, and preferred that I should do so, in hopes that by showing him the dies, and the preparations that had been made, he might be induced to talk more freely than he had done. As this was the last interview I had with him, and what was learned and resulted from it so far exceeded our expectations, that to be understood it seems necessary to state some things that had been learned in regard to the man and his work, through Mr. Biddle's amateur detective, and one of the hair-breadth escapes he made when in this pursuit, and the mode by which the man was finally secured.

Reliable facts learned were that, although the man was living among counterfeiters, and with them frequently shifting from place to place, he confined himself to certain portions of the work on the spurious plates, for fixed considerations, always exacting his pay in genuine money; that, when flush, he would sometimes go on protracted sprees until his money was exhausted, when he would return to his work; that, when on these spells of reckless dissipation, the counterfeiters kept a strict surveillance over him, fearing that in his drunken orgies he might divulge important secrets; that at that time he was with part of the gang working in a shanty on an island on the St. Lawrence River; there the bank officer went, accompanied by a member of the band, and armed with a forged letter of introduction, purporting to have been written by the master spirit of the gang as he was leaving the country for an absence of some weeks, representing him to be an expert penman, who would prove to be a valuable auxiliary. After a few exhibitions of his ability, he was heartily received among them, and for some days worked alongside of the man he had ventured so much to secure.

He soon made himself familiar with all their appliances, and learned many important secrets; but he failed to find any way of convicting without his own testimony, and to give that, divulging his identity as a bank officer, would simply be signing his own death warrant; for such was the desperate character of the gang.

Feeling greatly discouraged, not knowing which way to turn, early one evening he threw himself into his bunk, in the working room, only separated from the living room by a thin board partition. He fell into a troubled sleep, from which he was awakened by unusual sounds from the adjoining room. He was soon aware that there was an unexpected arrival; he distinctly heard an unfamiliar voice say: "This letter is a forgery; I gave no one an introduction; the man is a fraud or a detective, and we must run no risks; we must 'fix' him at once, so he can tell no tales."

This was hint enough; and he was not slow to act on it. He slipped out of a window, and although the river was running full of cakes of floating ice, he threw his boots and hat on the bank and took to the water. It was a desperate swim. But fortune favored him; for after over an hour battling with the cakes of ice, he landed on the Canadian shore, fully two miles below, nearly frozen to death, but, fortunately, near a cabin, to which he dragged himself, and found shelter for the night. A spurious story of wreck of boat and loss of companion satisfied the simple people, who gave him a bed, and while he slept dried his clothes. In the early morning, a store at a near railroad station furnished boots, hat and a rough overcoat—a little money paid for services rendered him, and before night he was comfortable in the St. Lawrence Hotel at Montreal, where he had left his baggage, when he started on this desperate island adventure.

For safety it was necessary that the counterfeiters should have evidence of his having been drowned. Keeping his room for a few days, consulting with the head of the police and a prominent member of the medical faculty, a corpse was procured, dressed in the clothes he wore on his escape from the island. In the pockets were put such small tools as would identify the body, which was represented as having been taken from the ice in the river.

The knowledge obtained on the island enabled the police to make a certainty of having some of the gang view it, as well as the clothes and pocket findings. This being done, the bank officer was safe, as the sequel proved; for, within a year, in the guise of a manufacturer of spurious money, and an expert in raising notes to a higher denomination, he was again in contact with the man—this time at Charleston, S.C. He then, by a liberal advance of money and promises of high price for work, induced the man to come to Philadelphia, where he represented that he had rooms in which the work could be done, so arranged as to defy detection.

The first lathe work required was for a $10 bill of the United States Bank. This he refused to do, but would execute entire a $5 bill, saying that by the Bank charter they were prohibited using notes of a less denomination than $10 after a certain date; that imitating an illegal issue was not counterfeiting. It was while the proof impressions of the $5 bill were being taken that the police broke in, securing both employer and workmen, with all the machinery and tools, and a partly-finished plate of $10 denomination, found on the work-bench.

I have seen the room where the work was done, and the arrest made, and all the ingenious devices for concealing work, machinery and tools, and the arrangement for escape of operators, apparently perfect, but which proved as perfect a trap as could be devised. When the man sprang for what he believed a certain way to escape, and was met by revolvers in the hands of resolute men, it was natural that his suspicion of treachery should center on his red-haired employer and fellow workman, who he saw so desperately struggling with his captors. [53]

When entering the counterfeiter's cell in company with Mr. Wood, with the prepared work in my hands, there was a gleam of satisfaction on the man's face, but when he was shown the preparations that had been made, and then told of the decision the inspectors had come to, the change was instantaneous to that of utter despondency. He muttered, "Then I must try and be content with oakum picking these long, long days, until death relieves me; but there is nothing in it to employ the mind and bring a single moment of the rest of forgetfulness."

I said to him that it had occurred to me that a man who had shown such ingenuity as he had in producing the facsimile of Spencer's scroll lathe work could make such valuable suggestions in the direction of preventing counterfeiting as would excite an interest in a direction that might shorten his term of imprisonment and find him employment that would put him beyond the necessity of pursuing so dangerous a business as engraving for counterfeiters.

His reply was: "There is no use in it, for there is nothing, no matter how complex, that one man or set of men can do, but others can and will be found to duplicate it."

I explained to him Mr. Biddle's idea that the greatest protection might be in a kind or quality of paper that could not be produced without extensive works and costly machinery that could not be worked secretly. This brought the first semblance of a smile that I had seen on the man's face, as he said: "I suppose Mr. Biddle felt secure with his shaded, water-marked paper; that no paper-maker could be found to imitate it. Why, I made that paper in a room not over 12 feet square, with only two wash tubs, a bucket, a basin, a plain wire-faced mould, just large enough to make a sheet for three bank notes, a common copying press, a few small sheets of polished zinc, and I cut up a well-worn woolen blanket for felts. By soaking and reducing to pulp a piece of the genuine bank note to be imitated, with my microscope I found the character of the linen fiber and the shreds of crimson floss silk, and their relative proportions in its composition. I found on sale a strong, heavy linen paper, hand-made, with a fiber closely resembling that of the bank note. I bought a quantity of it, soaked it in one of my tubs, changing the water to get rid of the animal sizing, and by hand reduced it to pulp. The threads of silk I got by folding and scraping on my knee a crimson silk pocket-handkerchief, just as lint is scraped. My second tub I used as a vat to mix the pulp to the proper consistency to form the paper when I dipped my mould."

On my remarking that he must have had some knowledge of paper-making, his reply was: "A little. Before I was apprenticed to the tannery, I was the layman's assistant in a hand-making paper mill; I carried the wet sheets and hung them in the drying loft. I tried my hand at couching, and occasionally the vatman allowed me to dip a sheet or two."

But you said you used plain moulds; how did you make the shaded water-mark with them?

"Oh, that was simple enough. It was evident the dark shade was from a slight thickening of the paper when formed on the mould by depressions in its face, and which, to take a uniform impression from the copper plate, must be reduced to an even thickness by pressure, which so consolidates the fiber in the thickened portions as to produce the dark shade. I should have adopted that way, but I noticed on the sheets of paper I bought some darker shades that held the same relative position on several of the sheets, but not on all of them. They were not like the spots caused by water dripping from the deckel when removed by a careless vatman. If from indentations or undulations in the wire cloth I should most probably have found the same shades in all the paper I bought, but no paper-maker would allow uneven face moulds to be used. There must be some other cause."

"I asked myself the question: what would be the effect if a careless workman allowed some spots of his mould-face to become clogged, and the interstices between the wires closed on the distribution of the pulp or fiber as the water drained from it? Shellac varnish and a camel's-hair brush soon solved the question, and I was not long in finding what portion of the wire face in connection with the wire watermark must be closed to produce the shading." He then added, "Explain this to Mr. Nicholas Biddle, and he will see how futile any effort at producing a water-marked paper that cannot be imitated will prove; there are more ways of killing a dog than by hanging him."

At this stage of the interview Mr. Wood left me alone with the man, afterwards explaining that as I had struck a chord that had made the man more talkative than he had ever been, his presence might be a restraint. After he left, I again expressed regret at the decision of the Inspectors; that I had hoped while working on the dies, to have seen him frequently, and learned his ideas as to the best mode of preventing counterfeiting, which would have been used, as I had suggested, to his advantage, but as he was not allowed to do that kind of work this would be the last time I should see him, and that I was sorry I could not say to Mr. Biddle that he would co-operate with him in his efforts to produce a note that could not be counterfeited, even though he believed that not to be possible.

Naming Mr. Biddle seemed to rouse a very demon within him, for he passionately exclaimed: "Nicholas Biddle is the last man I would have anything to do with. It was his red-haired emissary that hounded me to where you see me. I am what is called an unbeliever. There is not a particle of superstition in me, and yet all the time that fellow was winding me around him, helping me to perfection in my work, I had the feeling that we had met before. I should have seized and throttled him, and charged him with having tried to trap me on an island in the St. Lawrence, but I believed that I had ocular proof that the fellow was drowned. I saw his mutilated remains in Montreal. I saw the clothes he had on when he attempted to escape from the island by swimming the river. I saw some of my own tools that were taken from his pockets when he was dragged from among the cakes of ice in the river. If there is a devil that can take a human form, these two men were the same and that devil."

After he had quieted a little, I again advised his considering the possibility of obtaining a pardon by aiding in the efforts making to prevent counterfeiting. "No use, no use; you are asking me to do what is impossible." He then added, "I know from what you have said that you believe, with my ability, I might have had wealth and position by an honorable course, but you do not know how I was wronged by men then in high position, my family reduced to poverty, my character traduced, nor how sweet revenge is. I swore to have it, and I have kept my oath. By counterfeits undetected I broke their institution and reduced them as low as they did me, but at what a cost. For over thirty years I have been dead to my family and connections; I have lived the life of a dog; I have recklessly squandered all I ever made by hard work and degradation to utter misery; when entrapped I had no means for my defense, and was deserted by the cowards I had made rich, and had become bound to and entangled with beyond a possibility of escape. All they did for me was to procure indirectly the attorney that defended me, but it was of no use. That $5 plate would not have convicted me, but that devil had placed among my things the part finished $10 plate that I had refused to work on, and that I now am convinced was a genuine plate belonging to the bank."

Thinking he had exhausted himself, I was about signaling the corridor walker to notify Mr. Wood that I was ready to leave, when he stopped me, saying that if I knew the circumstances that led him into almost a life-course and his present position, I would not judge him so hardly. He had long ago resolved what was left in memory of his early life should die with him; but since he had been talking to me, he had been seized with the feeling that he must unburden himself, not in justification, for that was not possible, but in case of his death, which he hoped and believed would be soon; circumstances might occur that what he proposed to communicate might be used in a way to make some amends for his many misdeeds. With the long story that with marvellous volubility he poured into my ear, we have nothing to do here, save one point, showing what apparent trifles change man's destiny.

When depending on daily labor to support his family, he was in Boston. Wishing to take some present to his wife, he found that after paying stage-coach fare for over 100 miles to his home, he had just money enough left to purchase a set of silver teaspoons; but there was no time to have initials engraved on them before the stage would start. The silver smith gave him a burin, showed how to hold and use it, told him to smooth off the face of a copper cent to practice on it before attempting to letter the spoons. He was so successful that his neighbors were glad to have him letter their spoons, thimbles, etc. Then came names on dog collars, and finally, as a business, engraving plates for visiting cards, in what time he had from his labor in a tannery. This was his first step into a course of retaliation and revenge against the heads of the institution that he accused of having wronged him, whom he referred to in his previous outbreak.

The earnestness and fluency in telling his story was such that under ordinary circumstances would have carried conviction of its truthfulness, but I could not rid myself of the feeling that it was the outpouring of a diseased brain, and so represented it in repeating his story to Mr. Wood. But he took a different view; he thought an investigation following the hints given would develop more truth than fiction; at all events we must fully report to Mr. Biddle. When that was done Mr. Biddle agreed with Mr. Wood, and undertook to have as thorough an investigation made as possible.

About this time there came from John Dickinson, of London, specimens of his machine made safety paper, in which shreds of crimson floss silk were introduced between two laminae leaving the surface smooth and free to take the impression from the copper plate, instead of being mingled with the pulp, and thus incorporated in the body of the paper as was practiced in America. The samples were objectionable on account of being thicker than was used for American bank notes. But Mr. Biddle's active mind at once suggested the possibility of introducing between the laminae the fine fibres of crimson silk so woven as to form devices somewhat similar to line engraving, and from the device in one note to pass to the next either in straight or winding lines, so that when the notes were cut apart the silk could be seen in the edges. That if that could be accomplished a perfect safety paper would be the result. Much thought was expended on this idea, as the devices must be formed and inserted simultaneously with the paper making, and for this costly and complicated machinery would be required. This met Mr. Biddle's views, for in its complication and costliness he looked for safety; sufficient advance in plans was made to show the thing to be possible, and approximate estimates of mill and machinery were made, when the entire scheme was abandoned in consequence of a hand-made specimen to show what the general appearance of the center silk marked paper would be. This specimen did not carry out the idea of forming the devices of many filaments of silk that would pass from the device in one note to the next either in straight or waved lines that would show a floss edge when cut apart, but was made by a single strand, showing what could be produced without the aid of the machinery, that Mr. Biddle was looking to as the greatest safeguard. He pronounced the specimen beautiful, much beyond what he anticipated, but at the same time it was to his mind confirmatory of what the convict had said: "That what one man could do others could and would be found to duplicate."

The manner the specimen (Roman letters U.S. with a spread eagle between them) was made very simple. A plate of transparent glass had [170] floated over it, that, when dried, left a thin pellicle that was neither adhesive nor absorbent; over this was floated an adhesive gelatine so deliquescent that by breathing on it its surface became very sticky. This plate when prepared was laid over a clearly drawn design, then with a hollow pointed handle or pencil, similar to the ever-pointed lead pencil, a fiber of crimson silk from a freely turning spool in the handle took the place of the lead; the end of this fiber was pressed on and secured to the gelatine by a needle point in the left hand, the fiber being drawn from the pencil as it traced the design by gently breathing directly down on the plate; the gelatine was kept sticky and held the silk; partially embedding it; in making short turns when filling in the design with delicate traceries the needle point had frequently to be used, when the design was complete: for security, a dilute float of gelatine was given. The next operation was at a paper mill at the time making bank note paper; a very thin sheet was crushed on the post of felts, fanned for a few minutes to consolidate and partially dry it, then the silk design on the glass plate was crushed on to it transferring the silk from the plate to the paper; the perfect transfer was a delicate matter, and involved several failures. After being successfully made, a thin sheet was crushed onto it. The manner of finishing, getting rid of the excess of gelatine size, etc., is needless to refer to here. At the time the scheme was abandoned I thought it too hastily done; for I then and still believe it was in the right direction. The proposed use of many hundred filaments in forming the devices, with the floss edge to the notes could only be produced by complicated and costly machinery, and could not be imitated by hand.

[170] A word apparently was omitted here. The material that was floated over the glass plate to produce the "thin pellicle" is unknown.

I think it was about two years later that my sister, on her return from England, told me that on visiting a great institution she was taken into the engraving room, shown some exquisite machine work, and introduced to the maker and inventor as an American. She said his sharp features, deep-set, piercing eyes never could be forgotten. On some reference being made to Philadelphia, he asked if she was acquainted there. On her replying that it was her native city, he asked if she had ever met me.

When she told him I was her brother he gave her a piercing look, turned to his table, wrote a word or two on a scrap of paper, folded and handed it to her, saying: "Hand this to your brother, and say to him no deeds or words can express the gratitude I owe him; say all is well with me, he will be glad to know it."

Supposing the paper to be only the man's name, she put it unopened in her pocket-book. When she described her interview, the man and his work, and I opened the slip of paper and found on it only five letters, the surname under which the counterfeiter was convicted; who I supposed, if not dead, was serving his long term in the Eastern Penitentiary of Pennsylvania, I was amazed, as no other man could answer the description given.

I went to Mr. Biddle to learn if he could throw any light. On my reporting what I had learned from my sister, he said he was glad to have her confirmation to reports he had from London, and then went on to say that he thought he had told me the result of the inquiries he set on foot that had confirmed much of the man's story to be true. That about that time he had a letter from his London correspondent, who was the head of the institution my sister referred to, asking if he knew any man in America competent to do certain portions of the mechanical engraving, that could be induced to go to England; he had replied that the only man he knew was serving a long term in the penitentiary for counterfeiting; that he told as much of the man's story as he felt at liberty to, and said his belief was if the man could be released by pardon, taken away from all his former associates, placed in a position that would supply his wants under such surveillance as he would have in their institution, he believed he could fill the place to their satisfaction.

The reply came that, if the pardon could be obtained, they would take the risk. With this letter Mr. Biddle had personally gone to the Governor, represented the case, obtained the pardon, placed the man in charge of a trusty employe, who never let him out of sight until he left the steamer by the pilot boat outside the port of New York. All the accounts Mr. Biddle had received from London were favorable.

I will only add that his course was such that gained him confidence and respect; and when unable from age—probably premature, from early dissipation—to perform his work, he was maintained in comfortable circumstances by the institution he had faithfully served. Although it is now over fifteen years since his death occurred, reasons still exist why I am not at liberty to name him.

It affords me pleasure to pay a just tribute to the noble trait in Mr. Nicholas Biddle, who, so long as it was for the interest of the United States Bank, untiringly pursued the man known to be the most expert and dangerous counterfeiter of the time, but believing in reformation, rather than vindictive punishment, after the man had received a just sentence, instead of dismissing the matter from his mind, continued his investigations until he felt the world would be the gainer of the man's ingenuity if properly directed. He then lifted him out and gave him a chance, with the result as I have shown.

I speak knowingly when I say that during the most prosperous days of the United States Bank, with Mr. N. Biddle at its head, the internal improvements of the country, the prosperity of the manufacturer and producers, even to the humblest mechanic, found in him a friend and aider. [54]

Part III

Internal Improvements

At the time of Sellers's birth, in 1808, the first halting steps were being made toward a system of internal improvements. Along the eastern seaboard, roads of a sort existed, although nearly all commerce and many passengers were still carried in sailing vessels wherever navigable waters permitted. Many of the better roads were owned and operated by turnpike companies. It was possible to go by coach from Philadelphia to New York in a single day if one started before dawn and kept to the road until after dark. Two days were required to travel the 100 miles from Philadelphia to Baltimore. A few turnpikes, such as the gravelled road from Philadelphia to Lancaster, tentatively probed the interior of the great continent.

When the traveler approached the foothills of the Alleghenies, however, he found the going from rough to impossible. Emigrants, hauling families and belongings westward over the mountains, often were forced to add their brawn to that of their horses in order to drag their vehicles through the bottomless, sticky mud. Stage passengers frequently walked while the stage wagon was dragged along at a pace discouragingly slow.[171]

In 1808, Secretary of the Treasury Albert Gallatin laid before Congress a report calling for federal appropriations of nearly $20 million for roads and canals sufficient, in his considered opinion, to link the eastern seaboard with the western rivers and Great Lakes.[172] However, except for the National Road, finally completed from Cumberland, Maryland, to Springfield, Ohio, and partially completed as far as central Illinois, none of the many internal improvements that were undertaken during succeeding decades were paid for with federal funds. State governments were forced to engage in some works whose size or complexity exceeded the resources of private companies. The Erie Canal, begun in 1817 and opened in 1825, was a New York State work. The Pennsylvania thoroughfare from Philadelphia to Pittsburgh, combining canal, railroad, and inclined planes, was commenced soon after the Erie Canal was finished.

The Sellers brothers, George Escol and Charles, built two locomotives for the Philadelphia and Columbia Railroad, which formed the eastern division of the Pennsylvania works. Through his former schoolmates William Milnor Roberts and Solomon White Roberts, who were civil engineers on the remarkable Portage Railroad, which scaled the Alleghenies between Hollidaysburg on the east and Johnstown on the west, George Escol was thoroughly conversant also with that part of the great undertaking.

Sellers sets the stage, in the following chapter, for his experiences with railroads, locomotives, and locomotive builders.

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[171] A graphic description of conditions in Pennsylvania in 1817 is in Henry B. Fearon, *Sketches of America*, 3d ed. (London, 1819), pp. 184–196.

[172] *American State Papers*, 38 vols. (Washington, 1832–1861), class 10, miscellaneous, vol. 1, pp. 724–921.

19. Stage Line to Washington

The trip described here, from Philadelphia to Washington, may have occurred early in 1832. The railroad from New Castle, on the Delaware, to Frenchtown, below Elkton on the Elk River, was opened for horse-drawn traffic in 1831; locomotives were placed on the road in 1832.[173]

When the rivers were open for navigation, the traveler boarded a steamboat in Philadelphia, steamed down the Delaware to New Castle, changed to horse cars which took him overland to Frenchtown, and in another steamboat continued his passage down the Elk River, across Chesapeake Bay, and up the Patapsco River to Baltimore. In winter, the only public conveyances available were stagecoaches or, as in the present case, open-front sleighs.

From the commencement of the New York and Erie Canal by the State in 1817 until its completion, it was looked at with no little jealousy by the Middle and Seaboard Southern States, because, if successful, it would change the stream of immigration through them that was at that time peopling the valleys of the great western rivers. It was therefore not surprising that the question of maintaining their position made that of internal improvement in transportation the paramount one of the day. I remember well that this was almost the absorbing subject of conversation among all classes. Steamboats on the rivers had done much; still more was required . . . .

What Philadelphian, whose recollection extends back over a period of fifty years, does not remember the streams of produce-loaded great Conestoga wagons with their high, hooped white canvas covers or roofs, drawn by teams of four or six horses, that poured over the Lancaster pike into the city? These, in seasons of hard, dry roads, to avoid the payment of toll, came by way of the West Chester or other dirt roads, leaving in their wake for miles and miles clouds of almost impenetrable dust. These great wagons, backed to the curb on both sides of Market Street—the main thoroughfare of the city and one of its widest streets—their poles all slewed to an angle of some 45°, pointing in the same direction; the great feeding trough, that was carried hung on the back of the wagon, affixed on the pole, with horses on either side, feeding; turning many blocks of the main street into a horse stable, leaving scarce passing room for vehicles between this *Cheval-de-frise* of wagon poles. At that time, with the exception of the commerce on the rivers, the entire produce of the country and return merchandise was moved in road-wagons by horse-power.

The journey from Philadelphia to Pittsburgh in the fast mail coach was a fearful undertaking of three days and two nights. Six passengers were cramped in a coach, with mail pouches filling all proper leg room. Rather more comfort was to be had in the slower nine-passenger coach.[174]

The journey from New York to Washington was no mean undertaking, though, when navigation was

[173] *Bulletin of the Railway and Locomotive Historical Society* (1935), no. 38, pp. 60–61. See also U.S. Treasury Department's "Report on the Steam-Engines in the United States," H. Ex. Doc. 21, 25th Cong., 3d sess., pp. 9, 198.

[174] W. Hassell Wilson, in his "Notes on the Internal Improvements of Pennsylvania" (Philadelphia, 1879, reprinted from articles in *Railway World* in 1878), p. 32, mentioned an 1831 announcement in Pittsburgh newspapers of the "Reeside, Slaymaker & Co." express stage, seating six passengers, making the trip from Pittsburgh to Philadelphia in 2½ days, and a slower stage requiring four days.

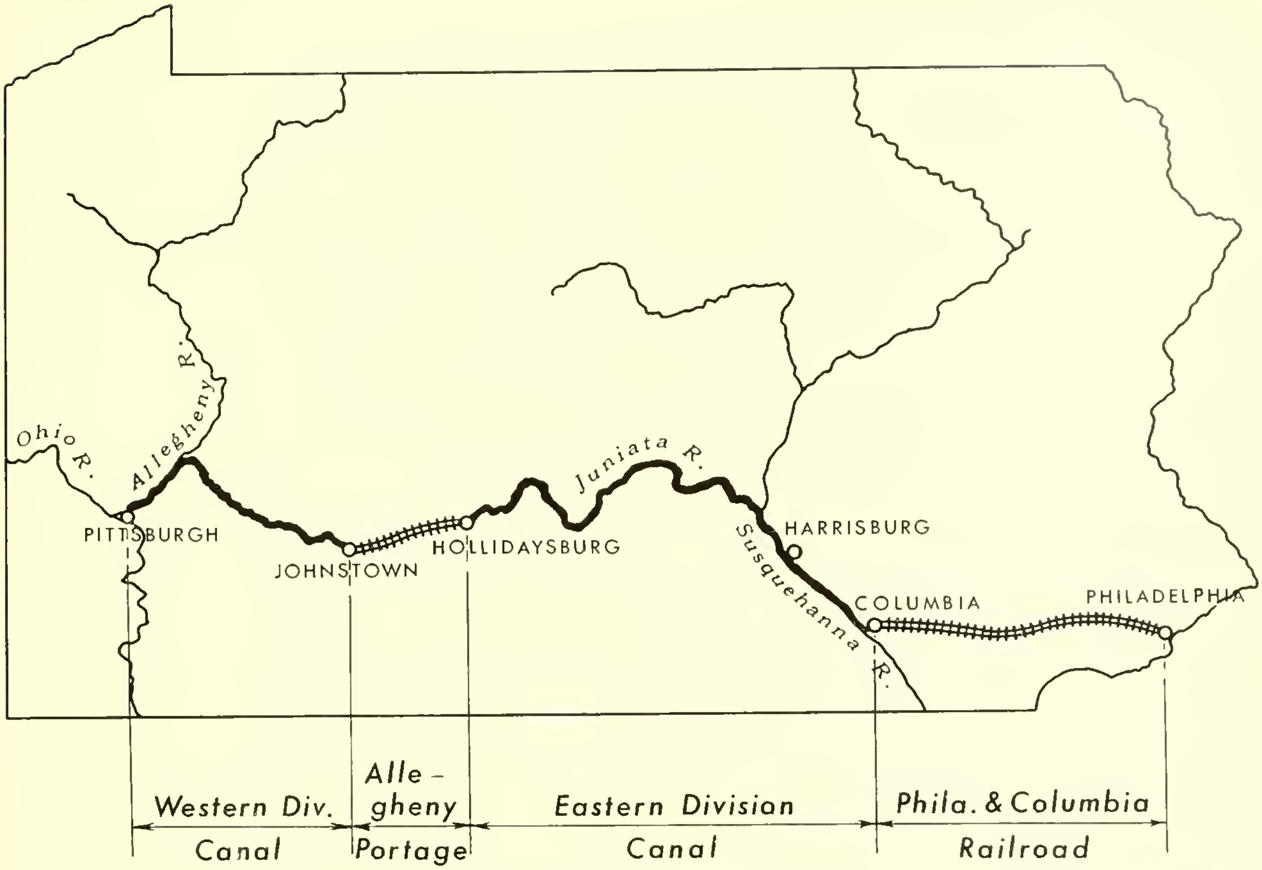

FIGURE 58.—Map of State of Pennsylvania showing system of canals and railroads from Philadelphia to Pittsburgh, 1834.

open, it was greatly eased by the steamboat from New York to New Brunswick, and from Trenton to Philadelphia on the Delaware. This was called the Union, or Stevens and Stockton Line. At the time of strong competition between it and the Citizens', or Gibbons', Line—that ran steamboats from New York to South Amboy, stages to Bordentown, and boats from there to Philadelphia—the furious driving on the coaching part of the line in clouds of dust was fearful; but the distance from city to city was made by daylight. Now it is made by rail in two hours.

From Philadelphia to Baltimore, by steamboat on Delaware to New Castle, from which place stage coaches had given place to four-wheel cars drawn by horses on a light strap rail on wooden stringers to Frenchtown, from there by steamboat to Baltimore, the time being about two hours longer than from New York to Philadelphia; the time from Baltimore to Washington by stage was about 3½ hours. This was summer travel; but in the winter, when the rivers were frozen, the entire distance had to be traveled in stage coaches.

On one occasion, when this state of affairs existed, I was obliged to go from Philadelphia to Washington, and thought myself very fortunate to be of a party with Mr. Reeside, the proprietor of the line, and at that time one of the largest mail contractors and stage line owners in the United States.[175] He promised us a quick trip, with relays of his best teams, the hardest stage to be with six instead of four horses.

We left Philadelphia an hour before daylight, in an open front coach on sleigh runners. The day was very cold, and before we reached Elkton, Md., a driving, blinding snowstorm set in, steadily increasing in violence. It was long after dark when we got to

[175] "James Reeside, U.S. Mail Contractor, 28 S. 3d St." (*Philadelphia Directory*, 1830).

the Susquehanna, opposite Havre de Grace. The river was frozen, and had to be crossed on the ice.[176] There were sleds to be pushed by men, or drawn by a single horse to a sled; these were to take over the mail, passengers, and baggage of the six coaches that had left Philadelphia in the morning. Of these, the Reeside coach was the only one that had arrived.

Some of the sled men refused to venture in the storm; all considered it dangerous. The road tracks were covered by the falling snow; gaping airholes were on every side; the night very dark, the driving snow blinding, and the only guide the sound of a constantly-tolling bell on the Havre de Grace side. Mr. Reeside encouraged us to venture, and advised walking behind the sleds instead of riding on them. He had confidence in the men taking us safely over in this way. All but two passengers, who refused to go before daylight, started.

When about midway of the river, the bell either stopped tolling, or its sound was carried by on the wind that had increased to almost a gale. Soon the sled pushers, that had kept well together, became confused and called a halt; then, by the dim light of poorly-constructed candle lanterns, they groped about, feeling with their hands in a vain hope of finding old tracks in the ice. They were evidently off of the road. Mr. Reeside urged them to push on, offering to take the lead with only the direction of the fiercely-blowing northeast wind for his guide. No one of the party had a compass. The men, knowing the danger of the airholes, held back.

"Then," said Reeside, "stamp about and keep your blood circulating, or you will all freeze." He then sat down on a sled, pulled off one of his heavy boots, thrust into it some crumpled newspaper and sheltering a lantern from the wind under his cloak, set fire to the paper. As it blazed he shook it about in the boot, which, when well heated, he pulled on to his foot; then went through the same operation for the other foot. Several of the party followed his example. It was a lesson that I have profited by several times since. His next move was to demolish a sled to make a fire, but before it was kindled the wind lulled, and we again heard the tolling of the bell. It was then evident that the pushers had got considerably off the track. By slow and cautious work they landed us safely. There was not a temperance member of that party who refused a hot whiskey punch of Reeside's brewing, to brace and warm up while a hot supper was preparing. We afterwards learned that the rest of the stages had been stopped by the storm, and laid over for the night at Elkton.

From Havre de Grace to Baltimore in regular stage coach, arriving there after daylight, and Washington by noon—over thirty hours of hardship in accomplishing what is now done within five hours on the railroad, regardless of the seasons, with ease and comfort to the traveler. This is what the country owes to the labor and skill of its civil and mechanical engineers, backed by the capital of far-seeing men, who were to reap the profits from its accomplishment.

At the time I am writing of, Pittsburgh and Wheeling were great distributing centers for what was then considered a vast emigration to the Western Territories and new States. They were fast settling in and filling the valleys of the great rivers, the natural roadways. On reaching these places on the river their hardest labor was over. The keel boat, the flat, and the few steamboats then running were for those who had the means to use them, and those who had not, built for themselves small family boats, often not over 4 or 5 feet by 10 or 12 feet, protected by bent poles and wagon covers from the weather. In this way thousands moved to their destined new homes. I have seen more than a score of these floating tents gliding down the stream, or tied up to the shore, by camp fires to cook their family meals, within a single reach of the crooked Ohio. The bulk of these emigrants had come from across the ocean. The most thrifty moved with wagons and teams, but a large portion, with a single horse attached to a crazy cart or wagon, and not infrequently a favorite cow, brought from the old country, in the shafts, did the duty of a horse in hauling the household goods, and occasionally a helping lift to the mother and her infant, all the rest of the family tramping on foot . . . . [55]

[176] The river was bridged at Havre de Grace in 1867. See *Scientific American* (June 1, 1867), vol. 16, pp. 348–350.

EDITOR'S NOTE: In addition to the published works cited in chapters 20–24, a large and important body of manuscript material on the Pennsylvania works is in the Pennsylvania State Archives. See HUBERTIS M. CUMMINGS, *Pennsylvania Board of Canal Commissioners' Records . . . Descriptive Index* (Harrisburg, Pa.: State of Pennsylvania, Department of Internal Affairs, 1959), 235 pp.

20. Philadelphia and Columbia Railroad

Work on the Pennsylvania improvements started in 1826.[177] Stirred to action by the evident advantages to New York of the Erie Canal, and fearing loss of western trade that funneled through the seaport city of Philadelphia, the Pennsylvania legislature had in 1824 formed a canal commission whose duty it was to determine a route for a continuous canal from Philadelphia to Pittsburgh.

Reporting back to the legislature early in 1825, the commission recommended a crossing of the Allegheny mountains that required, in addition to innumerable locks, a tunnel some four miles long. By 1826, the possibility was being considered of a portage railroad over the mountains. After several surveys had been made by various engineers, construction of a system of inclined planes with connecting graded railways was undertaken in 1831.

Meanwhile, portions of the canals of the central and western portions of the Pennsylvania works were placed under contract. In 1828 the legislature authorized construction of a railroad over the eastern division, from Philadelphia to Columbia, on the Susquehanna River. Locating parties, under the direction of Maj. John Wilson (1789–1833),[178] completed location of the line during that same year.

When the entire Pennsylvania system of improvements was opened for traffic in 1834, it was in four divisions, as follows:

(1) Philadelphia and Columbia Railroad, a graded railway with inclined planes near each of its terminals, in Philadelphia and Columbia (total length, 82 miles).

(2) Eastern Division Canal, commencing at Columbia, proceeding north through Harrisburg

[177] The Pennsylvania works, from Philadelphia to Pittsburgh, are described in J. Elfreth Watkins, *History of the Pennsylvania Railroad Company, 1846–1896*, 3 vols. (Philadelphia, 1896), vol. 1, pp. 53–201. This work was never formally published, although the text was set in type and engravings were made of the illustrations. Copies (of bound page proofs) are in Smithsonian Institution, Washington, and in Association of American Railroads, Bureau of Railway Economics Library, Washington, D.C. There are several published memoirs by engineers who built parts of the original works: *Notes on the Internal Improvements of the State of Pennsylvania, by W. Hassell Wilson, C. E., and Reminiscences of the First Railroad over the Allegheny Mountain, by Solomon W. Roberts, C.E.* (Philadelphia, 1879, reprints of articles appearing in *Railway World* during 1878; Solomon Roberts's *Reminiscences* were published also in *Pennsylvania Magazine of History and Biography*, 1878, vol. 2, no. 4, pp. 370–393); W. Milnor Roberts, "Reminiscences and Experiences of Early Engineering Operations on Railroads, with Especial Reference to Steep Inclines," *Transactions of the American Society of Civil Engineers*, (August 1878), vol. 7, pp. 197–216. See also W. Hassell Wilson "Notes on the Philadelphia and Columbia Railroad," *Journal of The Franklin Institute* (May 1840), vol. 29, pp. 331–341. A useful summary of the eastern portion of the works is in John C. Trautwine, "The Philadelphia and Columbia Railroad of 1834," *Philadelphia History* (City History Society of Philadelphia), 1925, vol. 2, no. 7, pp. 139–178. A monograph on the Pennsylvania works from an economic standpoint is Avard L. Bishop, *The State Works of Pennsylvania* (New Haven, 1907, reprinted from *Transactions of the Connecticut Academy of Arts and Sciences*, November 1907, vol. 13, pp. 149–297). Descriptions by visiting foreign engineers are in David Stevenson, *Sketch of the Civil Engineering of North America* (London, 1838), chapters 6 and 9; Michel Chevalier, *Histoire et déscription des voies de communication aux Etats-Unis*, 2 vols. (Paris, 1840–1841); and Franz A. R. von Gerstner, *Die inneren Communicationen der Vereinigten Staaten von Nordamerika*, 2 vols. (Vienna, 1842–1843). An intelligent analysis of the Pennsylvania works by Julius Rubin is in Carter Goodrich et al., *Canals and American Economic Development* (New York: Columbia University Press, 1961), which appeared after I had completed this passage.

[178] John Wilson was born in Scotland, attended the University of Edinburgh, emigrated to Charleston, South Carolina, in 1807, and after serving in the War 1812 was appointed a major in the

to the Juniata River, crossing the Susquehanna at the mouth of the Juniata, and following the Juniata to Hollidaysburg (total length, 171 miles).

(3) Allegheny Portage, from Hollidaysburg to Johnstown (total length, 37 miles).

(4) Western Division Canal, commencing at Johnstown, proceeding by way of the Conemaugh, Kiskiminetas, and Allegheny Rivers to Pittsburgh (total length 104 miles).

Covering a distance of 394 miles, the passage required from 4½ to 6 days. There were 115 locks in the eastern and 65 locks in the western division canals.

The Philadelphia terminus of the Philadelphia and Columbia Railroad was at Broad and Vine Streets, a few blocks north of the Center Square. The railroad proceeded west and then northwest,[179] crossing the Schuylkill near Peters Island on the first Columbia Bridge, a 1000-foot long wooden structure near the foot of the inclined plane.

The inclined plane, employing stationary steam engines and hemp ropes to wind the cars up and down two parallel tracks, rose 187 feet in a distance of slightly more than half a mile. The graded railroad proceeded from the head of this plane by way of Downington, Coatesville, and Lancaster to Columbia, where it ended at the head of another, somewhat shorter inclined plane, which eased the cars down to the town of Columbia, on the east bank of the Susquehanna.

Several rail and tie configurations were used on the railroad. A few miles of the road consisted of flat iron bars, 2½ inches wide by ⅝ inch thick, fastened to continuous longitudinal granite sills; there were a few miles of wooden string-pieces, plated in the same manner; most of the way had English rolled "Clarence" rail, not unlike the present rail pattern except for the absence of the bottom flange. The rails rested in vertical notches at the top of cast-iron chairs, or supporting brackets, to which they were secured by wedges; the chairs were supported on stone blocks 2 feet square and 1 foot thick, spaced 3 feet on centers. The gauge, 4 feet 8½ inches, was maintained by wooden crossties spaced 15 feet apart.[180]

The railroad was, according to a contemporary observer, "almost a continuous series of curves," [181] due mainly to the locating engineers' attempts to avoid extensive earthwork in order to keep the cost of the line as low as possible. When the line was located, it was expected to be merely a public way for privately owned horse-drawn cars subject to tolls collected by the state. The early use of locomotives was not anticipated.

WHILE MR. TRAUTWINE [182] was superintending the laying of the first T-rail that ever came to America, and was then called the Stephenson wrought iron rail,[183] in contradistinction to the cast iron fish-belly rail then in use, the same kind of work was going on beyond the head of the inclined plane. The rails were being laid and keyed in cast iron chairs, secured to large square blocks of lime stone, and partly on long stone cross-ties, the chairs being fastened to the stone by iron bolts, leaded in holes drilled in them. This work and that on the wooden truss bridge across the Schuylkill, the inclined plane with the engine house and machinery at the head of the plane, were all sources of great interest and attraction to the Philadelphians and the people of the surrounding country.

On one occasion, in company with Mr. Trautwine and his associate Elwood Morris, we crossed the

U.S. Corps of Topographical Engineers. This information is from a very short sketch of his life in the introductory matter of his son's (W. HASSELL WILSON's) *Notes on The Internal Improvements of the State of Pennsylvania* (cited in the preceding note).

[179] The present Reading Railroad line follows, west of Broad Street, the route of the Philadelphia and Columbia.

[180] STEVENSON (cited in note 177, above), p. 240, wrote: "There are hardly two railways in the United States that are made exactly in the same way, and few of them are constructed throughout their whole extent on the same principles . . . ." He illustrated (pp. 240–248) two of the constructions used in the Philadelphia and Columbia, as well as those used in several other roads.

[181] *American Railroad Journal* (June 20, 1835), quoted in WATKINS (cited in note 177 above), vol. 1, p. 129. After inspecting the road in 1836, the editor of *American Railroad Journal* wrote: "The unfortunate location of the road is very evident, frequent and short curves are introduced so uniformly, that it would be supposed that such a location was to be preferred to a direct one" (*American Railroad Journal*, July 30, 1836, vol. 5, pp. 465–466).

[182] John C. Trautwine (1810–1883) is best known for *The Civil Engineer's Pocket-Book* (Philadelphia: Claxton, Remsen & Haffelfinger, 1872; 21st ed., 1937). Sellers described an inci-

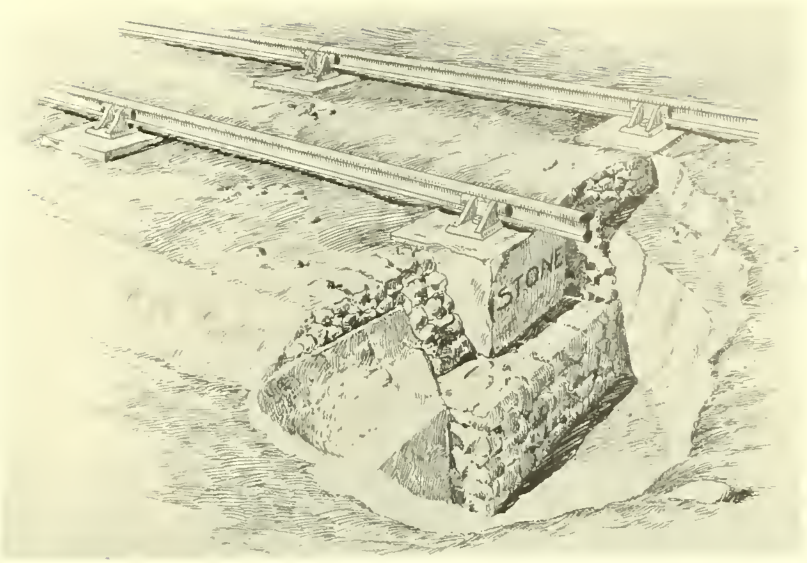

FIGURE 59.—Detail of Philadelphia and Columbia Railroad's "Clarence" rail. The rail was secured by wedges to cast-iron chairs, which in turn were fastened to stone blocks. The blocks were laid in a carefully prepared rock-filled trench. Stone blocks were spaced more closely than indicated in this sketch, however. Compare with figure 63.

Schuylkill and walked to the head of the inclined plane, there we found a large collection of citizens who had come in carriages, on foot, and in skiffs by way of the Schuylkill, all greatly interested in work so new to them. Major Wilson, then chief engineer, stood in the center of quite a crowd; he seemed to be a good deal annoyed by the questions he was plied with; many of them no doubt of a character to annoy, but the high standing and character of the questioners were such that civil answers must be given.

While this was going on my attention was called to a group slowly advancing toward us; among them was my father. He and the others seemed much amused at the quaint actions of a respectable farmer, a broad-brimmed and broad-skirted member of the Society of Friends, who was known to be as level headed a man as was to be found. He would go down on one knee, put his head near the ground and look along the line of the road, then he would straighten up, hold his cane, that had a cross-head handle, between his thumb and finger; making the cane a plumb bob, he would look along its cross-head, evidently making his own observations and commenting on them; which, together with his quick and quaint actions, was the cause of merriment to those with him; when they joined the group around Major Wilson, to whom our Friend was formally introduced, and at once began, "Friend Wilson, I notice that thee has run the road between here and Friend ——'s farm, first to right, then to the left and again to the right and left, much like a long letter S or a dollar mark ($), where the straight lines would be the shortest; what is thy object for doing so?"

The Major, either knowing or suspecting his questioner to be a farmer, chose in answering him, a familiar illustration. He said, "If you take a potato in your hand in a few minutes you could learn the number of its eyes, and all its lumps and irregularities. Our potato is bigger, but, as engineers, we have to make ourselves as well acquainted with it before we

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dent in which a Pennsylvania canal engineer, who was experimenting with hydraulic cement, was visited by Trautwine and Sellers: "Mr. Trautwine's note-book, which was his constant companion, even during his school-boy days, was out at once, and he eagerly noted all of Mr. Huffnagle's formulas and the results, as far as he had gone with his experiments. It is to this peculiarity of Mr. Trautwine of not allowing anything to escape being fixed in his note-book that the engineers of the present day are indebted for their constant companion, his 'Civil Engineer's Pocket-Book,' with its vast stores of useful information on every subject that can possibly come within the range of their profession." *American Machinist*, (March 14, 1885), vol. 8, p. 5.

[183] Sellers's nomenclature is confused. The Stephenson rail was a wrought-iron edge-rail with a fish-belly web. Robert Livingston Stevens (1787–1856) is credited with designing the T-rail, now the standard section of American railroad rails. The rails actually laid between the Schuylkill River and Broad Street were of the Clarence pattern, in 1831 called "edge rails" by W. H. Wilson. See his manuscript notebook, dated 1831 (no pagination), in Pennsylvania Railroad Library, Philadelphia. Carefully documented and beautifully illustrated, this notebook is a primary source for details of construction of the Philadelphia and Columbia. The Clarence pattern apparently took its name from the Clarence Railway in Durham County, England.

can locate our road, as you would with the potato held in your hand. Then, in locating we have an *axiom*, that we try as close as possible to adhere to. That is, to make our cuts so that they shall furnish the earth for the piles, thus we 'kill the two birds with one stone.' "

"But," asked our friend, "does thee not take into consideration the additional length of iron, and the stone blocks, and the labor expended on them?"

The reply was, "Certainly, but in this case it does not amount to much."

"But," said our Friend, "it takes more power to haul a load over what thee calls curves than on a straight line, and I think this ought to enter into the calculation of first cost." He stooped down and picked up a stone, and, holding it towards Major Wilson, continued: "Thee cannot carry this stone twenty steps and back without expending some power. Now, if thee counts the number of times thee carries it back and forth for a single hour, thee would find how much longer it would take thee to add only one step further to each trip. This is what I mean by the constant loss during all time, and then thy curves will give great additional trouble to the mechanic when he comes to construct steam engines to run this road and accommodate themselves to running around the curves."

By this time it was evident the Major was more than annoyed; he was excited, for he replied rather petulantly: "My good Friend, I would have you to understand that this railway is not being made for steam power; it is a State road for the benefit of every one, just as any turn-pike road. The State may furnish wagons or cars, or individuals may put their own on the road, and every farmer may attach his own horses and haul his produce to market, and if I have my way no steam engine shall ever run on the road." He turned his back on the Friend and entered into conversation with some one else in a manner to show his determination to end the palaver.

The honest old Quaker flushed as if his feelings were hurt, and stood for a few minutes as if silently communing with the spirit within. Then he spoke in a subdued manner as if he was talking to himself: "Well, for the life of me I don't see the use of the inclined plane to get down to the Schuylkill, for by starting at Friend ——'s place it would be easy to strike the river a little above Fairmount dam, or if (naming another farm) by way of Mill Creek Valley through Friend Mayland's place to the river above Gray's Ferry bridge."

Major Wilson heard this, and, turning quickly, and in no gentle terms said: "You don't know what you are talking about. It seems to me that you are only talking to hear yourself talk."

The reply came very slowly: "*May-be so, may-be so*, but one thing I certainly do know, if I do not know all the knobs and bumps on what thee calls thy big potato—though I was born and have lived all my life among them—I do know that God never created water that could run up hill, and that the water from His living springs and His refreshing rains—all that is not drank up by the hungry earth—from the first place I have named finds its way into the Schuylkill above Fairmount dam, and the springs and the rain fall west of that by way of Mill Creek, and this tells me the natural routes to get down as well if not better than thy three-legged *spy-glass* can tell thee. I am an old man and may not live to see it, but there are others present that will, when the inclined plane and all its works will be abandoned and the road will take one or other of the routes that I have indicated. I have walked out the road as now making, and have noticed all its ups and downs and its circumbendibuses, and know that with fewer of them and at less cost, by heading the running water it could have got down. That is all I know;" and he walked away.

In relating the above, I have endeavored to condense the substance of a vast deal of by-play into simple collocution. The impression made at the time was strong, and has been kept alive by frequent reference to it in conversation with Mr. Trautwine, and on more than one occasion we together have seen numbers convulsed with laughter by Ellwood Morris's inimitable mimicking of the old Friend and the Major, frequently with additions and embellishments.

I have not told it, although the Friend's predictions came true as soon as the old State Road, which has so aptly been styled the Parent of the Pennsylvania Central, passed into its hands. Nor would I detract from the sterling integrity, perseverance and skill of our early engineers. We are all naturally disposed to follow leads. The great canals of the world made tunneling a necessity; much talent and skill was expended on them. To the tunnels the master spirits of the Liverpool and Manchester added the incline plane; our following was natural, and Pennsylvania was not alone in doing so on her Columbia and her Portage Railroad. The Charleston & Hamburg, the Lawrenceburg & Indianapolis and others might be cited, all of which planes have been superseded by

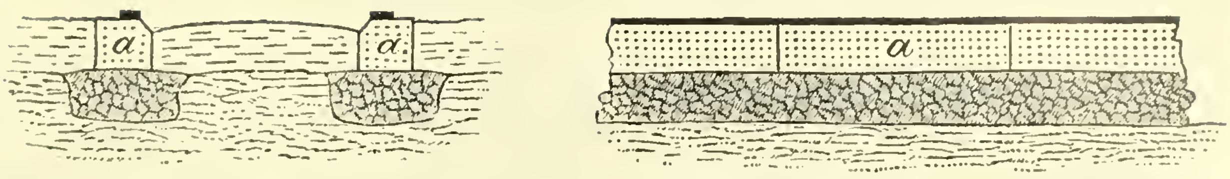

FIGURE 60.—Detail of roadbed of Philadelphia and Columbia Railroad. A few miles of railway consisted of strap iron rails secured to a continuous line of granite blocks (*a*). From David Stevenson, *Sketch of the Civil Engineering of North America* (London, 1838).

gradual grades, worked by the ordinary locomotive. Major Wilson was filling the wants of the time constructing as he said a "railway turnpike." [56]

The rapidly increasing traffic on the Pennsylvania road, even before the completion of the Portage and and opening of the through line to the West, was sufficient to demonstrate the error that had been committed in constructing the Peters Island incline plane. The inclines on the Portage might be sufficient for through trade for many years, but the local trade between Philadelphia and Hollidaysburg, eastern end of the Mountain division, had increased to such an extent that it was evident the incline plane, at the Philadelphia end of the road, would soon be taxed beyond its capacity. Locomotives had not been in use on the road over one year before the delay to passenger trains became very annoying, and such pressure was brought on the Canal Commissioners that they ordered surveys to be made, with the object of substituting for the incline plane gradual grades that could be run with locomotives.

The citizens were not idle; a branch road to avoid the plane was chartered, called the West Philadelphia Branch, a company organized, surveys made, and some little work done; financial trouble caused its suspension.[184] Henry R. Campbell, then chief engineer of the Philadelphia, Germantown, and Norristown R. R., was mainly instrumental in forming a company to build a branch to cross the Schuylkill river, at or near Morristown [sic], and come into the heart of the city by the Germantown road.[185] Much of this branch was graded, materials, including the iron, purchased, and on the ground, when the same financial troubles that caused the suspension of the West Philadelphia stopped this work; it was never resumed. The iron was sold by the sheriff.

Mr. Baldwin's first locomotive, built for the State, was put on the road in the spring of 1834. It was the third engine of his build, a six-wheel engine, one pair of drivers back of the fire-box, and a four-wheel swivel truck. If my memory is not entirely at fault, there were two English engines received about the same time, and Wm. Norris put on his first effective engine.[186] This was also a six-wheeler, but differing from Baldwin's, in having the drivers in front of the fire-box, and of course a much greater weight on them. I think it was about the third engine of

[184] The route of the West Philadelphia Railroad Company was located by Henry R. Campbell in 1835. More than 10 years later, when the legislature agreed to rerouting of the Philadelphia and Columbia to avoid the Schyulkill inclined plane, the unfinished West Philadelphia Railroad was taken over by the state. See WATKINS (cited in note 177 above), vol. 1, pp. 143–147.

[185] Henry R. Campbell was chief engineer of the Philadelphia, Germantown, and Norristown Railroad from 1832, locating engineer for the West Philadelphia Railroad Company (see preceding note), and consultant for the Philadelphia and Columbia Railroad in 1837. See, respectively, *W. Hassell Wilson* (cited in note 177 above), p. 30; *American Railroad Journal*, (December 26, 1835), vol. 4, p. 430; and H. R. CAMPBELL, *Report of Surveys Made to Avoid the Inclined Plane and for the Improvement of the Eastern Division of the Columbia and Philadelphia Rail Road* (Philadelphia, January 1837). I have not been able to confirm this enterprise of the Philadelphia, Germantown, and Norristown Railroad, nor have I located this Morristown, if indeed it is not merely a typographical error.

[186] The first Baldwin locomotive commenced running on June 28, 1834. The second was delivered in September. Three English engines, built by Robert Stephenson, arrived in 1835. Two were in operation by June 20, 1835. A Norris locomotive was on the road before October 30, as was a locomotive built by George Escol Sellers and Charles Sellers. See WATKINS (cited in note 177 above), vol. 1, pp. 124–129.

Norris' build, and the one that I have before referred to [187] as having climbed the Peters Island incline plane. I have no notes as to the grade of that incline, but my impression is that it was 1 foot in 17.[188]

There was nothing practical in running the locomotive and tender up this heavy grade, further than demonstrating the traction of plain wheels on the rails, but from it dates an entire change in American practical engineering.[189] William Milnor Roberts, identified as he was with the system of the Portage road, wrote for the particulars of this performance of the Norris engine, and from them he made elaborate calculations, verifying them by experiments on the Portage inclines. He came to the conclusion that grades up to 100 feet per mile [190] could be successfully operated with properly constructed locomotives, and even higher grades by the aid of an auxiliary or helping locomotive, and that any of our mountain ranges could and would be crossed without stationary power.

Mr. Welch, as chief engineer of the Portage, did not agree with Mr. Roberts in this, but in view of the increased business, which he foresaw must eventually press on the Portage, he had various plans to increase the capacity of its inclines, his favorite one being simply doubling the tracks and machinery. He was much annoyed by the persistent predictions of his assistant, William Milnor Roberts, that with properly constructed locomotives heavy grades of 100 feet per mile, or even greater, would be successfully overcome, and with the aid of an auxiliary, or helping engine, be found more economical than the inclines with stationary power that had cost the State so much labor and expense; that long before the inclined planes would be taxed to their capacity they would be superseded by regularly graded roads. We all know these predictions came true, but the change did not take place as soon as Mr. Roberts anticipated, for he at that time thought it would be within ten years, but the planes continued in operation for a period of about twenty years, answering all the purposes for which they were intended, and, what is remarkable and speaks volumes in favor of their construction and careful operation during that time, without a single serious accident.

After the achievement of the Norris engine in climbing the Peters Island incline there was much correspondence between Mr. Roberts and his friends in Philadelphia. I now regret that I have not preserved letters to them showing that at that early period he urged utilizing as much as possible of the weight of the locomotive for traction by connecting the wheels. In one of his letters he expressed himself about in this way: "I, as a civil engineer, make no pretensions to being a mechanical one, but I have satisfied myself that the power evolved in the steam engine is in all cases greater than the traction due to its entire weight, therefore as much as possible of it should be utilized for climbing the heavy grades necessary to overcome our mountain chains." Mr. Henry R. Campbell was one of the correspondents to whom I refer; he took up with great avidity the use of heavier locomotives with a more even distribution of weight on the drivers, and increased traction; two or three years later he obtained a patent for an eight-wheel engine with four connected drivers and four-wheel truck, the type of the standard American passenger engine of the present time . . . .[191] [57]

187 In chapter 27, below.

188 The chronology is in error. Norris delivered the *William Penn* in October 1835; his *George Washington*, delivered in July 1836, was the one that climbed the incline (Watkins, vol. 1, pp. 129–130, 137a). The grade of the plane was 1 in 15, or nearly 7 percent; that is, a rise of 187 feet in 2,805 feet (W. Hassell Wilson, cited in note 177 above).

189 Based on a presupposition—imported from England and accepted uncritically by American engineers—that a railway locomotive was not capable of negotiating a grade steeper than about 1 percent, that is, 1 foot in 100. This idea was fixed in George Stephenson's mind by the experiments that he and Nicholas Wood made in 1818. A paper by someone on the basis, rise, and fall of this principle is long overdue. Some materials are in Nicholas Wood, *Practical Treatise on Rail-Roads* (London, 1825; 2d ed., 1838); Thomas Tredgold, *Practical Treatise on Rail-Roads and Carriages*, 2d ed. (London, 1835); and Samuel Smiles, *The Life of George Stephenson, Railway Engineer* (London, 1857).

190 Nearly 2 percent.

191 U.S. patent dated February 5, 1836. This was just before the Patent Office fire of 1836. Restored patent drawing is in U.S. National Archives.

21. The Portage Railroad

The Pennsylvania Portage, connecting the eastern and western division canals of the great Pennsylvania works, extended 37 miles from Hollidaysburg, on the eastern slope of the Allegheny ridge, to Johnstown on the western slope. A total of 10 inclined planes, from 1,500 to more than 3,000 feet in length, connected by graded railways, overcame a rise of 1,400 feet in 10 miles from Hollidaysburg to the summit, and descended 1,175 feet in the remaining 27 miles to Johnstown. The cars were dragged up and let down each plane by ropes running over winding drums driven by stationary steam engines in the head house. The locating engineers were careful to point out to squeamish commissioners and legislators that the maximum gradient of the planes (10 percent), was less than that of some hills on the Philadelphia and Pittsburgh turnpike road, which crossed the mountains hard by the Portage.[192]

Boldly conceived and ably designed and constructed, the Portage Railroad was favorably viewed by many visiting engineers, native and foreign. For example, David Stevenson, the Scottish engineer, uncle of Robert Louis Stevenson, wrote of this "mountain railway, which, in boldness of design and difficulty of execution, I can compare to no modern works I have ever seen, excepting, perhaps, the passes of the Simplon, and Mont Cenis in Sardinia; but even these remarkable passes, viewed as engineering works, did not strike me as being more wonderful than the Allegheny Railway in the United States."[193]

George Escol Sellers was more intimately concerned with the Philadelphia and Columbia Railroad, for which he and his brother Charles built two locomotives, but he knew the Pennsylvania Portage at first hand. His boyhood schoolmates and companions William Milnor Roberts and Solomon White Roberts were principal assistant engineers to the chief engineer, Sylvester Welch. Sellers's account of the Portage Railroad is substantially accurate in all details, and it is valuable as a background against which his locomotive work can be more clearly seen and better appreciated.

Early in the year 1834 the entire line of the Pennsylvania mongrel improvements, part canal and part railroad, between Philadelphia and Pittsburgh, was opened for freight and passengers, and worked, with the exception of steam on its inclined planes, by horse or mule-power. The small four-wheel freight cars, limited as to capacity and load, not to exceed three tons per car, were mostly owned by individuals or firms who also owned the canal-boats and horses. The road was built for and used as a public highway, charging toll.

It was not long before breaking bulk at Columbia, reloading from the cars into the canal-boats, and again at Hollidaysburg from the canal-boats on to cars, and, after passing over the portage, or Mountain Railroad, division to Johnstown, again transferring to canal-boats, with the damage from handling certain kinds of freight, and greatly increased cost of transportation on all classes of freight, was a state of things that called mechanical ingenuity into play. The first success was in making the box or car body independent of the trucks, so arranged

[192] The references cited in note 177, above, are useful for information on the Portage.

[193] David Stevenson, *Sketch of the Civil Engineering of North America* (London, 1838), pp. 185–186.

as to be easily and securely attached or disengaged, and the building of open canal-boats with low-down decks. On the arrival of the cars at Columbia the box bodies were loosened from the trucks, and, together with their freight, hoisted by cranes, swung over and deposited on the low-down decks of the canal-boats; and again, in the same manner, transferred from the boats to trucks at Hollidaysburg, and, after crossing the portage to Johnstown, again into canal-boats.

The system of the portage railroad consisted of ten inclined planes and eleven levels—the height overcome in the ten miles between Hollidaysburg and the summit tunnel being 1,339 feet, and the descent to Johnstown, in 26½ miles, 1,171 feet. This entire work was constructed in the most permanent and best possible manner known at the time. The double-track incline planes were heavy wooden stringers, secured to stone foundations, and laid with flat bar rails. The levels between the incline planes were laid with what was then called the Stevens T-rail [194] of about 40 lbs. per yard, keyed into cast-iron chairs, which were bolted to sandstone cross-ties, alternating with sandstone blocks. These stone blocks did not extend under both rails, as the cross-tie stones did; they were about 12 inches deep, and had a base equal to about 20 x 24 inches; the chairs were set three feet apart. All the masonry of the road was of the finest and most substantial character. The Conemaugh Viaduct, which, I believe, is still in use by the Pennsylvania Railroad Company, was a great point of attraction to engineers as well as to travelers.

As to the steam engines and machinery of the incline planes, the fact that they were in use for about twenty years, and frequently taxed to their utmost capacity without a serious accident, fully attests the completeness of the plans, care in their construction, and use. Hemp ropes were used on the inclines, it being before the day of wire ropes.[195] The usual number of cars drawn up the inclines, while the same counterbalancing number was being let down, was four of these small four-wheel box cars, which were then taken from the head of one incline plane to the foot of the next, or *vice versa*, by horse-power.

At the time the portage railroad was under construction, it was a subject of much discussion among all classes, and the general opinion was that it would prove a failure. Sylvester Welch, the father of the scheme and chief engineer in its location and construction, was often sorely beset by influence brought to bear on the canal commissioners, and even after exhaustive surveys had been made and the route located, still other surveys were ordered with a vain hope of finding a practicable route without the inclined planes, with gradients not to exceed 40 ft. per mile, that being the extreme limit then thought practical to work with safety even with horse-power by doubling teams. In later years when Mr. Welch was engaged on the Covington & Lexington Railroad, of Kentucky, he used to relate the difficulty he had to satisfy the canal commissioners that his system of inclined planes and levels was no complication, as they conceived it to be, to persuade them to allow the work to go on. They admitted the simplicity and effectiveness of the Peters Island incline plane on the Columbia road, yet feared his on account of what they termed its complication, when he insisted that in fact it was but a repetition of simplicity.

The fact that my schoolmates and most intimate friends were the chief assistants of Mr. Welch, made me take great interest in the progress of the surveys and work, concerning which I was kept constantly posted. William Milnor Roberts had charge of the division from Hollidaysburg to the Summit, and the work on the east end of the great Allegheny tunnel, and Solomon W. Roberts of the west end, and the work from there to Johnstown; and Edward Miller had charge of the machinery of the incline plane. No engineers are better known by their lifelong works than S. W. and W. Milnor Roberts, who though of the same name were of no blood relationship. W. Milnor's life was sacrificed to his profession in South America at so recent a date that most engineers must be familiar with the circumstances of his undertaking the great South American works at his advanced age, under a binding contract for four years' service.[196]

Although most of my life has been devoted to mechanical engineering, the intimacy with my early civil engineer friends was always kept up; and at the frequent meetings with both of the Roberts, the subject of their first work, the *Old Portage* was never

[194] Actually, edge rails of Clarence pattern. See note 183 above.

[195] Wire rope, manufactured by John A. Roebling, was used as early as 1839 (W. MILNOR ROBERTS, cited in note 177 above, pp. 206n, 208n).

[196] Both Solomon W. Roberts and W. Milnor Roberts are noticed in *Dictionary of American Biography*.

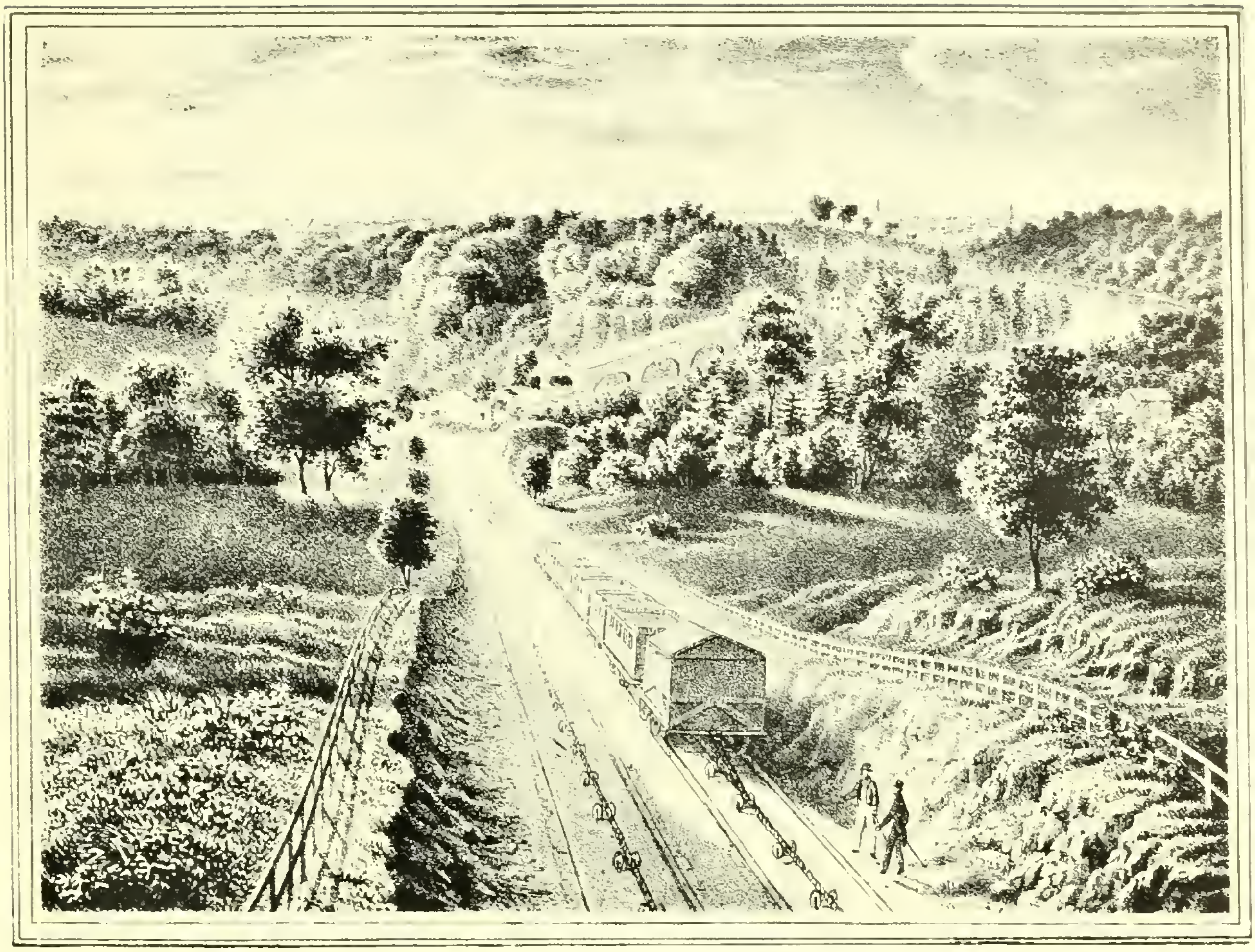

FIGURE 61.—View of Belmont inclined plane on Philadelphia and Columbia Railroad, looking east. The first Columbia Bridge over the Schuylkill is at upper center; Philadelphia can be seen in the distance at right. From J. C. Wild, *Panorama and Views of Philadelphia* (Philadelphia, 1838). Library of Congress photograph.

tiring, and it is from these reminiscences that I have drawn more of what I have written on the Old Portage than from my own observation, as I only visited it twice during the time the Roberts were on it. On one of these occasions W. Milnor Roberts referred to the great trouble he had in the effort to substitute locomotive power for horses on the levels between the inclines.

The Portage had not been operated over one year, when a locomotive built in Boston was received. At that time moving grain in bulk to the Eastern markets had not been conceived of; it was all racked, loaded into canal boats at Pittsburgh, and at Johnstown it and other heavy freight such as flour, pork, and whiskey in barrels, was transferred on open four-wheel platform cars and covered with canvas or tarpaulins. The sparks thrown from this wood-burning Boston locomotive set fire to the canvas covers, and necessitated carrying a man with broom and buckets of water to every two cars of the train. The same kind of canvas-covered cars were also on the Columbia Road for the same class of freight, but as the wood burning locomotives came into use in place of the horse-power the canvas-covered cars had to be taken off. By the end of the second year all the eleven levels of the Portage were operated by locomotives.

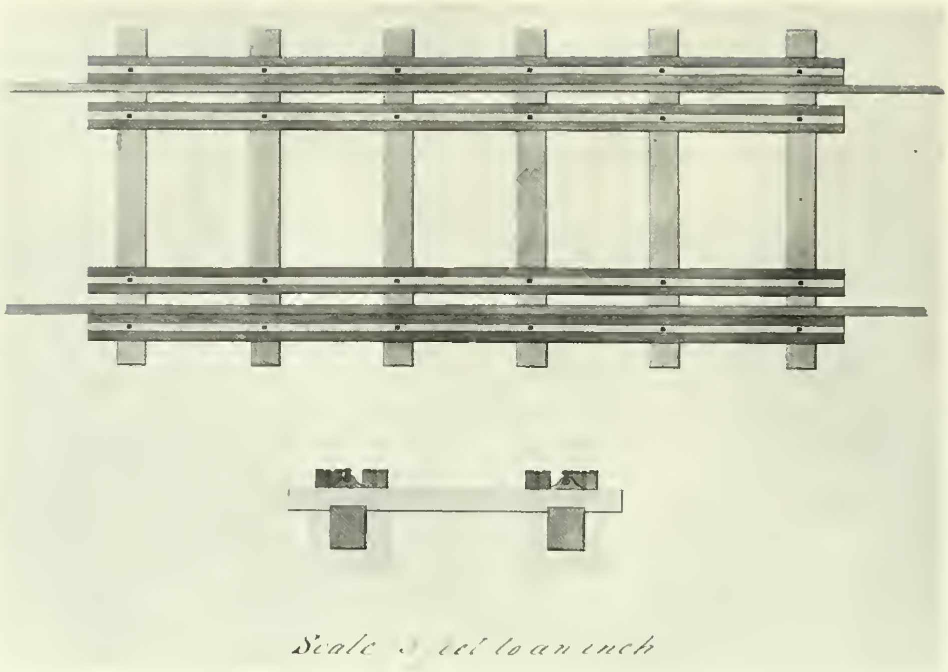

FIGURE 62.—Grade crossing on Philadelphia and Columbia Railroad. Two longitudinal bearing timbers, of locust, were bedded in broken stone. Locust crossties carried chairs for "Clarence" rails. White oak "guard rails" were shoed with flat iron bars ⅝ inch thick and 2¼ inches wide. The estimated cost of this crossing, excluding the cost of rails and chairs, was $60.30. From manuscript record book of W. H. Wilson, preserved in Pennsylvania Railroad Library. About 60 pages of the record book are devoted to the Philadelphia and Columbia Railroad and an equal number to the Philadelphia and Reading; there are many illustrations of bridges, tunnels, track, and switches.

The next expedient to save the expense and delays of breaking bulk and handling freight, was making canal boats in sections. This ingenious device answered a good purpose, notwithstanding the increased dead weight of the permanent cabins and water-soaked hulls, over the movable box-car that had to be hauled over the portage. At first they had to contend with great opposition and prejudice on the part of shippers of fine goods. Much was said at the time about damage caused by leakage of the square truncated ends of the boat sections in consequence of racking and drying [of] the cars and opening of the caulked seams. This was, no doubt, greatly magnified by competing transportation firms. Any one who will take the trouble to look over the advertisements in files of Philadelphia and Pittsburgh papers, say from 1835, can form some idea of the rivalry between the different transportation firms or companies.

The boat sections for freight going west were loaded in Philadelphia warehouses, hauled by horse-power to the foot of the Peters Island incline; from the head of the plane they were mostly taken by locomotives to Columbia, for at the date of their advent locomotives had nearly if not quite supplanted horses on the Columbia or State road.

In the published history of the Baldwin Locomotive works from 1831 to 1881 they give the date of the completion of their first engine for the State road as June 1834; it was fully a year before this that the Long & Norris engine was tried on that road, and if my recollection is not entirely at fault there were two Norris engines and two or three imported

FIGURE 63.—Roadbed of abandoned Portage Railroad. Note the closely spaced granite blocks. From an original photograph in division of transportation, Smithsonian Institution.

English engines working on the road in the fall of 1834.[197] Floating the boat sections from their trucks into the canal basin at Columbia, bringing them together and uniting them into full canal boats, was always a sight of great interest to travelers, as was also their transfer to trucks at Hollidaysburg.

For the traveling community the small coaches or cars seating from 20 to 26 passengers were a great improvement for comfort over the old stage coach, though destructive to the proverbial stage coach conviviality; but this was in a measure made up on the canal boat portion of the routes, where passengers were at ease with full liberty to walk about or lounge as they liked; groups were formed, games indulged in, and not unfrequently rival races on the tow path.

As to the passenger canal boats they were a marvel of ingenuity in their arrangement for accommodation and comfort of the traveler; they might be termed the forerunners of the Pullman sleeper and dining car. Much was concentrated within their hulls and miniature cabin; comfortable, broad omnibus seats along the sides, with space between for camp stools, without greatly interfering with the passage; a long dining table was set, and fair meals furnished at reasonable rates for way passengers, those for the through passengers being included in the fare. At night rows of berths one above another along the sides of the cabin were arranged, a curtain separating the ladies' from the gentlemen's cabin, and all were intended to be and supposed to be made comfortable, and, barring mosquitoes at certain seasons, no one had a right to complain, as all these comforts were furnished without extra charge.

[197] His memory apparently was at fault. The chronology is given in note 186, above. However, a Norris locomotive, the *Green Hawk*, built in 1832, was the first locomotive on the road; and the *Black Hawk* was in successful operation before Baldwin's *Lancaster* was completed. See WATKINS (cited in note 177, above), vol. 1, pp. 114, 120; also, see note 205 below.

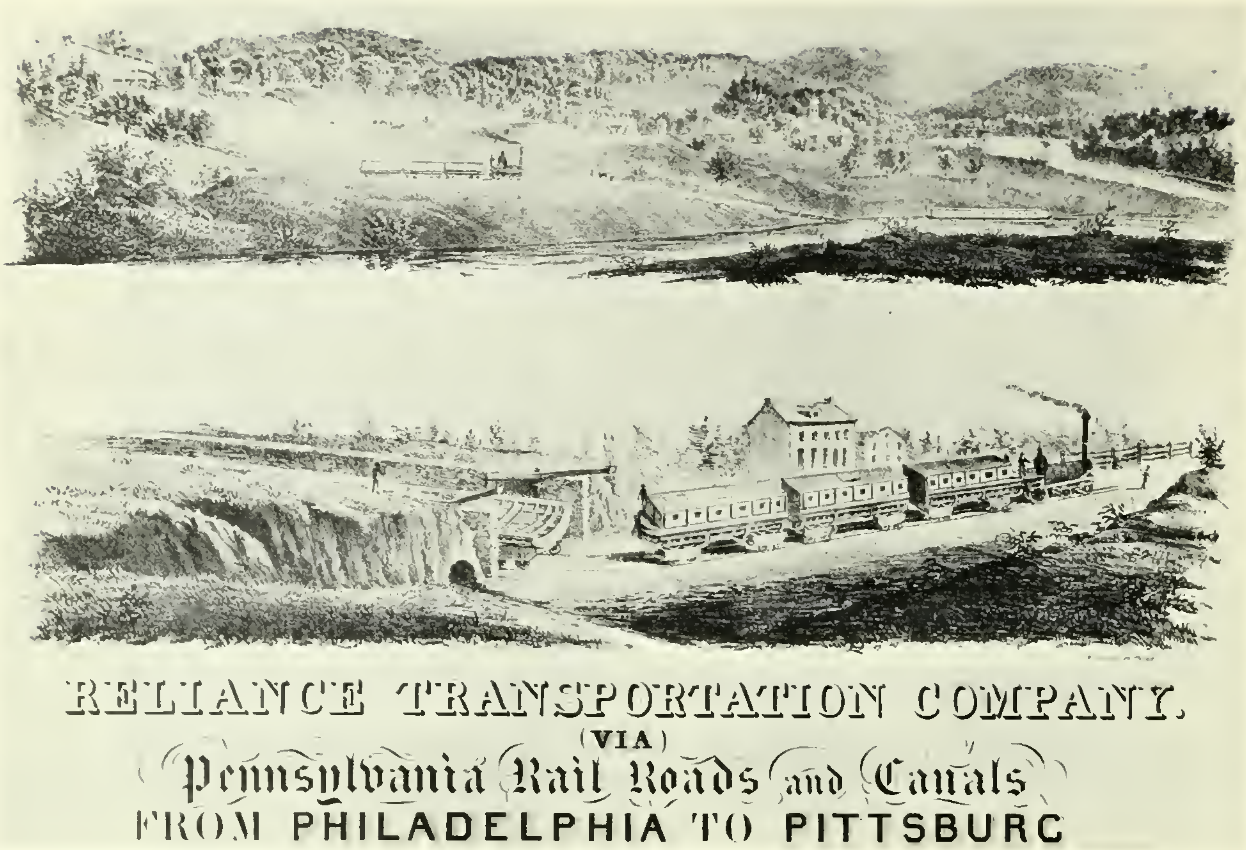

Figure 64.—Portable iron boats, 1839. A Reliance Transportation Co. advertisement in 1839 stated that "those boats are built of ROLLED IRON, in sections susceptible of being connected when on Canal, so as to form a boat, and separated when on Rail Road to answer as car-bodies, resting on cradles made to fit the curves of the boat and placed on eight-wheel cars, which when connected are passed into canal by INCLINED PLANES OT LIFT LOCKS, no hoisting machinery being required, as the water floats the boat from the cars. . . . The improvements in transportation between Philadelphia and Pittsburgh within the last 50 years have advanced with rapid strides. Our drawing represents the first Pack Horse prostrate beneath a burden of some three hundred pounds weight, next the saving of horse power on Canal, on which one horse is capable of doing the work of 500 pack-horses, and next represents a Locomotive propelled by steam moving heavy cars BURDENED WITH FREIGHTED BOATS, bounding up the towering heights of the Alleghanies, startling the deer from its lair, and striking with awe the Indian Hunter as the fiery meteor with its lengthened train flits across his path." Photo from copy of broadside in division of transportation, Smithsonian Institution; text quoted from advertisement in *A. M'Elroy's Philadelphia Directory for 1839*. (A review of the history of Pennsylvania sectional canal boats is contained in Jessee L. Hartman, "John Daugherty and the Rise of the Section Boat System," *Pennsylvania Magazine of History and Biography* (October 1945), vol. 59, pp. 294–314.)

The quiet gliding of the boat along the valley of the Susquehanna with its beautiful ever-changing scenery, and the wilder valley of the Juniata was very enjoyable. In fair weather, and moonlight nights, the roof or deck of the boat would be well covered with passengers, using their trunks for seats, but ever mindful of the call of "low bridge" from the helmsman, (and some of them went so low that the trunks on the roof barely cleared them as the boat passed under) the ducking and contortions of the passengers, sometimes throwing themselves flat on the roof, was always a source of amusement. On nearing the Portage all was excitement, particularly among those crossing for the first time; for the old portage or mountain crossing was one of the greatest wonders of the world in its day.

On the landing of the canal boat at Hollidaysburg, passengers would rush for the cars to secure the most favorable seats for seeing. Many of those crossing for the first time, and all the timid ones, while the cars were being fastened to the rope of the incline would make for the side walk and go up on foot; some would walk up the second incline, but by that time all would gain sufficient confidence to trust themselves to ride. On one occasion I was one of four to carry an invalid lady in a chair to the top of the first incline, and then to so surround her in the car that she had partly ascended the second before discovering it; then she was terror-stricken, and made a great effort to faint, but failed in the attempt, the mountain air being too exhilarating. She finally subsided, and I really believe enjoyed the rest of the passage, except the tunnel.

The estimated capacity of the incline planes was ten trains of four cars each way per hour. I have timed them when pressed to their utmost; unavoidable delays at the top for the descending, and at the bottom in making up the ascending trains, brought the average number of trips not to exceed 7 per hour. Mr. Miller thought that an excessive average for a length of time: though with everything favorable 10 had been accomplished in a single hour.

Several prominent engineers of England and France came to America for the express purpose of witnessing the working of the American Mountain Railway. I met with two of these, who both spoke of it as the grandest conception that had ever been ultimated.[198]

Even Charles Dickens, who, on his first visit to America, crossed the Portage before it was superseded by the Pennsylvania graded road, although he was oblivious to the bevel-edged plate glass mirrors, and gorgeously new furnished and upholstered canal boats for his especial use, and that of his party, an old friend of mine, long since departed, who was one of the party, said that Dickens was, no doubt bored by intruders on the route, but he showed more interest and animation on the Portage than at any time during his intercourse with him; that he could not say enough in praise of the boldness of the design, and the grandeur of the scenery, frequently recurring to it; but he disgusted one who had been prominent in embellishing the canal boats, and who lost no opportunity of calling his attention to them by saying, "Very nice, very nice, but rather stuffy-bluffy and somewhat disagreeably odoriferous." Probably the fumes from the kitchen and the wine bins did not harmonize.[199] [58]

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[198] The works of Stevenson, Chevalier, and Gerstner are cited in note 177 above. W. Milnor Roberts (cited in note 177 above), p. 204n, mentioned also General Bernard.

[199] A special boat was not provided for Dickens, though he was given choice sleeping accommodations: "a shelf in a nook . . . in some degree removed from the great body of sleepers." The rest of the passengers slept on "three long tiers of hanging book-shelves, designed apparently for volumes of the small octavo size." Dickens's account of his American journey in 1842 is focused upon people, sleeping and eating accomodations, incessant spitting of tobacco juice, and jails and public institutions, but his descriptions of travel by canal, railroad, stagecoach, and steamboat are useful and always thoroughly delightful. (Charles Dickens, *American Notes for General Circulation*, 1st ed., 2 vols. London, 1842. There have been many reprints, and a paperback edition, Premier Americana, d128, was published in 1961. The Eastern Division Canal and the Portage Railroad are described in chapters 9 and 10.)

22. Cardington Locomotive Works

The first shop building at Cardington was erected probably in 1829, about the time of the dissolution of the Sellers and Pennock fire engine partnership. On the extensive Sellers property in Upper Darby Township, Delaware County, just west of the present Philadelphia city limits, the shop was located at the site of the old Marshall Saw Mill, where the Marshall Road crossed Cobbs Creek.

The shops were built to provide facilities for the construction of textile card machinery designed by John Brandt, of Lancaster. Brandt, who had devised a machine that set card teeth in the leather backing more firmly than could be done by hand, was induced by Coleman Sellers, George Escol's father, to come to Philadelphia to manufacture the card machines. Presumably the name Cardington came from the product of the shops.

Brandt remained in Philadelphia for only about a year. Coleman Sellers continued the card machine business, however, and enlarged the shops in order to build paper machinery. The foundry and large machine tools required for paper machinery were used as well for general machine work. After Coleman's death in 1834, the Cardington shops were run by George Escol and his elder brother Charles.

Meanwhile, Brandt had accepted a position with the Philadelphia and Columbia Railroad, and at his suggestion the railroad contracted with the Sellers brothers to build two locomotives. The successful completion of the locomotives led to the building of steam engines and other machinery for the U.S. Mint. The Cardington shops prospered for a time, but the Sellers brothers were unable to weather the depression following the general financial panic of 1837. Within little more than a decade after their commencement, the Cardington shops were sold by the sheriff. According to George Escol Sellers, the property was bought by John Wiltbank, a Philadelphia brass founder.[200]

In the year 1834, the foundry and machine shops then carried on by my brother and myself, were mostly engaged on work for iron furnaces, rolling-mills, flour-mills and machinery for paper making. To turn the drying cylinders for the latter, we had constructed what at that time was considered a mammoth engine lathe that would turn 9 feet in length and 4 feet 10 inches diameter; also for finishing the housings for paper-press rolls and calenders, we had built and put in operation the first iron planing machine in the State of Pennsylvania. If I recollect right, there were then only two others in the United States, one in West Point, N.Y., shops, and the other in Dr. Nott's Novelty Works.[201] This primitive machine had a capacity for 8 feet length by 4 feet wide and 3 feet high. The bedplate was driven by

[200] Memoirs, book 1, pp. 14–15, 34, and book 4, pp. 66–67.

[201] The West Point Foundry of Gouverneur Kemble had shops in New York City at the foot of Beach Street, from 1817 until 1838 when all operations were consolidated at Cold Spring, near West Point, New York (Kemble, cited in note 71 above). The Novelty Works, named for the steamboat designed by Dr. Nott, president of Union College in Schenectady, was operated by James Stillman, who was joined in 1842 by Horatio Allen (see note 100 above).

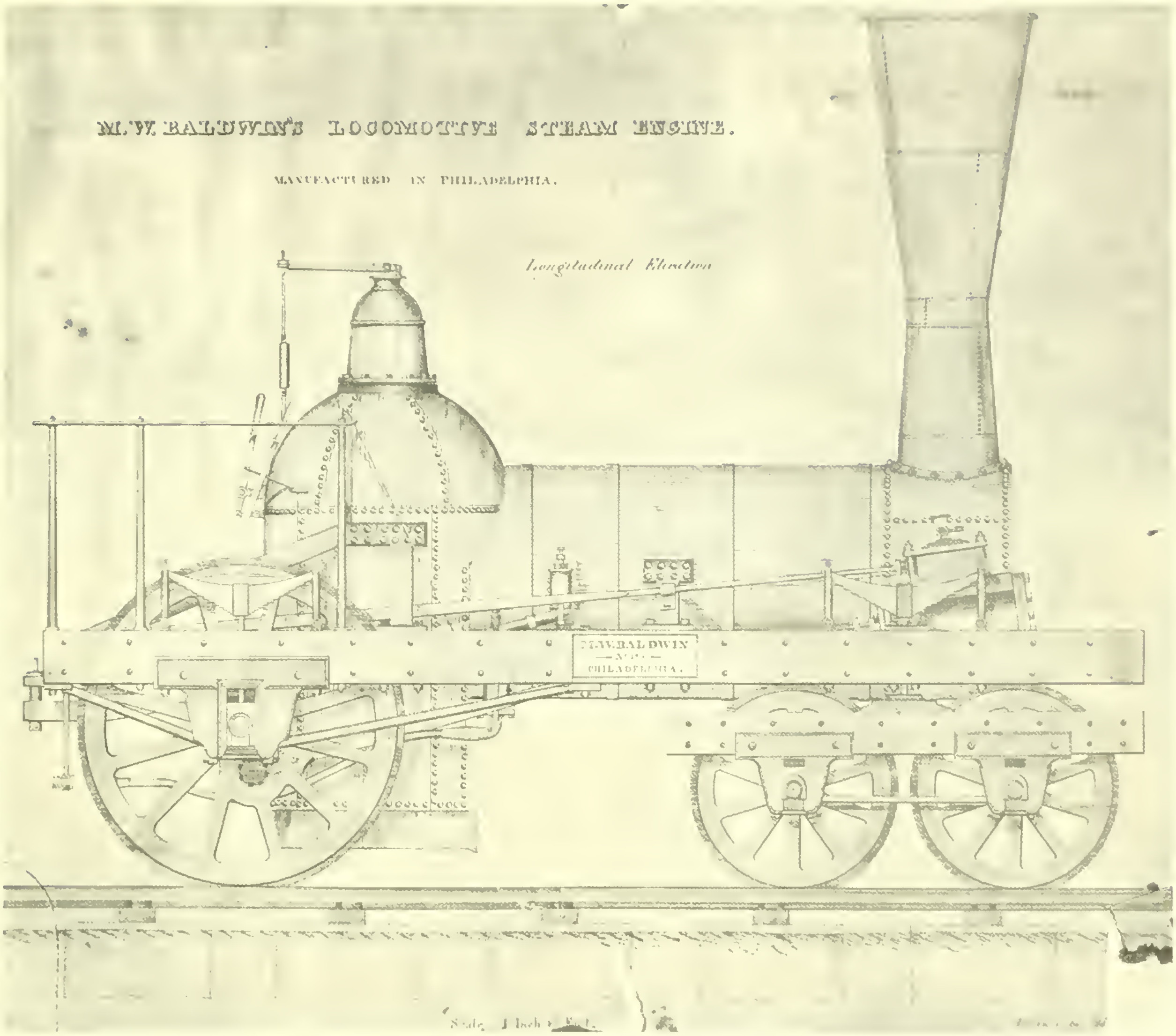

FIGURE 65.—Baldwin Locomotive, 1834 to about 1840. Although this is a drawing of Locomotive No. 125, it is typical of locomotives built by Matthias W. Baldwin from about 1834. The drawing is in the division of transportation, U.S. National Museum. *USNM 307506; Smithsonian photo 26799-B.*

screw; the only thing automatic about the machine was reversing the screw to run back the bedplate at an increased speed. Both the down and cross feed of the tool were by hand. Primitive as this machine was, it did good work, if it did take its time to do it; it was a great advance from the hammer, cold-chisel and file.[202]

In the latter part of the summer of 1834, James Cameron, brother of the Hon. Simon Cameron, at that time chairman of the Board of Canal Commissioners, called on us and said he had been informed by John Brandt that we had the above described lathe and planer, both well adapted for locomotive

[202] The hammer, cold-chisel, and file were still widely used (see note 100 above). A remarkable variation, used in Hoe printing press works in 1834 for planing ribs of press beds, involved hauling a smith's plane, similar in appearance to a carpenter's plane, along the work by a winch. See STEPHEN D. TUCKER, *History of R. Hoe & Co., New York* (typescript copy in Library of Congress), c. 1890, p. 7.

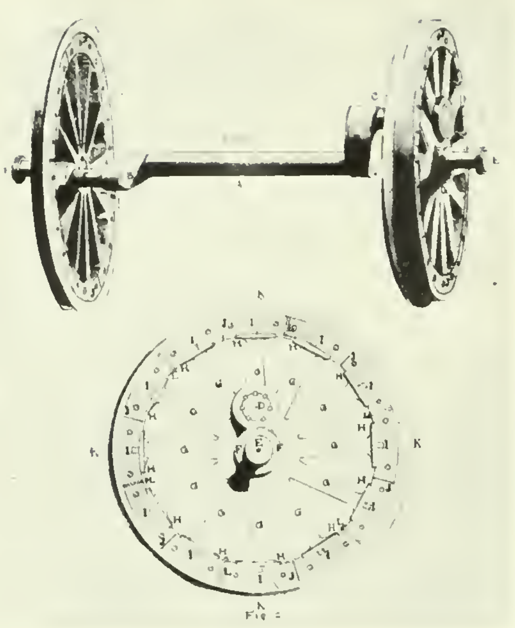

FIGURE 66.—Baldwin's half-crank for "inside-connected" drive, with connecting rods and cranks located between driving wheels, and with axle journals outside of driving wheels. One arm of the crank was formed by the driving wheel itself. From U.S. patent, September 10, 1834, restored drawing. National Archives photograph.

work, and asked if we would undertake the building of some locomotives for the State railroads. As the paper machinery and other work was slack, we took the subject under consideration, and a few days later I accompanied Mr. Cameron to the shops at Parkesburg to see and consult with their engineer, and with Mr. Brandt, foreman of the shops.

We rode from the head of the incline plane to the shops on the open platform of the locomotive "Lancaster" (this was before the day of cabs). It was the first engine Mr. M. W. Baldwin had built for the State, and had been but a short time in service. It had a high dome boiler, one pair of driving-wheels back of the firebox, with half crank axle [203] and four-wheel truck; the driving-wheels were cast-iron center and spokes with wooden rim or felloes and wrought-iron flange tire. The frame of the engine was wood, cornered and plated with sheet iron; axle-boxes in cast iron slide pedestals with springs for both driving-wheels and truck above the frame of the engine; the cylinders much inclined and placed outside the smoke-box.[204] I have given the description of this engine as it was the type of what the commissioners required, and that what follows may be better understood.

The result of this trip was that we undertook to build some engines for the State road; the commissioners stipulating that the boilers should be dome boilers, one pair of drivers back of the fire-box, and cylinders outside of the smoke-box; drawings to be made and submitted for their approval. Brandt was very pressing that we should undertake to build these engines. He proposed while making the drawings to give me the advantage of what experience he had with the English locomotives,[205] with the Baldwin engine, and one of Norris' that was then having some changes made on it, not having given entire satisfaction, after which it ranked as the most reliable and effective freight engine of its time. Before commencing the drawings I had several discussions with Mr. Brandt, and while making them he several times came down to the city and remained over night with me. It soon became evident that requiring the driving-wheels to be placed back of the fire-box was more due to Mr. Brandt's opposition to full cranks in front of the fire-box, with the cylinders, valves and their connections under the smoke-box,[206] than that urged by the commissioners of unequal distribution of weight and its injurious effect on the rails.

It was also evident that full cranks could not be placed back of the fire-box and the cylinders outside of the smoke-box, without reducing the diameter of the boiler and narrowing the fire-box to an extent that was not admissible.

203 "Half crank" refers to the arrangement of crank arms on the axle of the driving wheels. A "full crank" is a conventional crank, with crankpin between two crank arms. The half crank dispenses with one of the crank arms, letting the driving wheel serve as the missing crank arm. This design, shown in figure 66, was employed by Baldwin for many years.

204 But inside the frame, with connecting rods going to the half cranks just inside each driving wheel. Axle bearing boxes were outside the driving wheels.

205 Unresolved is the question as to where Brandt gained his experience with the English locomotives. The English engines did not arrive for the Philadelphia and Columbia until early in 1835 (see note 186, above). There were a number of other Stephenson locomotives in use on American railroads by this time, however; for example the *John Bull* on the Camden and Amboy Railroad, now in the U.S. National Museum.

206 This was the arrangement of the Stephenson locomotives.

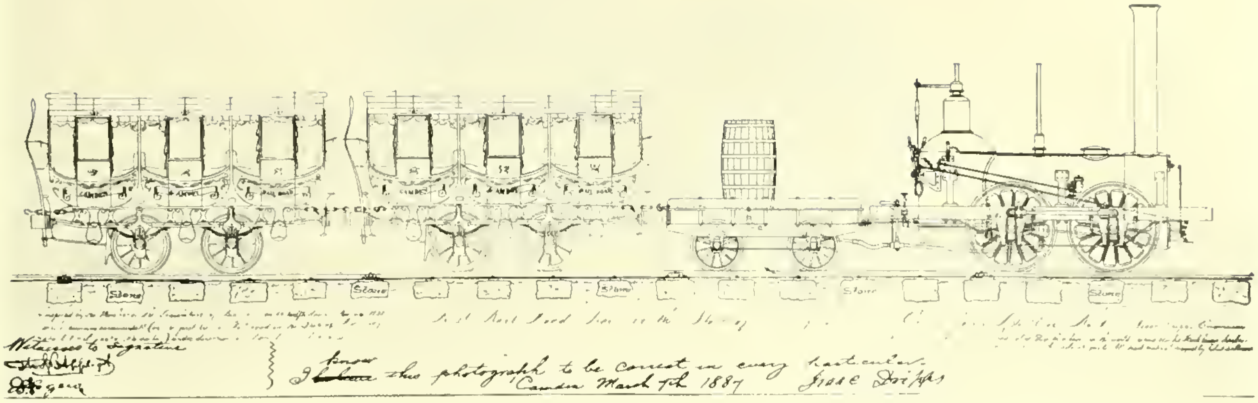

Figure 67.—English locomotive, *John Bull*, 1831. Inside-connected, with full cranks, this locomotive is shown as built by Robert Stephenson & Co. for the Camden & Amboy Railroad. Origin of this drawing is unknown, but it was attested to in 1887 as being "correct in every particular" by Isaac Dripps, engineman of the locomotive on its first official run. Drawing in division of transportation, U.S. National Museum. *Smithsonian photo 25012–A.*

I proposed outside connections, but that would not be listened to. The Baldwin half crank must be adopted; this we refused without written consent from Mr. Baldwin, which Mr. Cameron undertook to procure, saying they would pay a reasonable consideration for its use. Mr. Cameron returned, saying that Mr. Baldwin had applied for a patent for the half-crank, that he had made the invention for his own protection, and it was not for sale on any terms.[207] In this dilemma I again unsuccessfully urged outside connections. I then proposed to equalize the weight by another pair of drivers back of the fire-box, connected by outside cranks, in the manner of the English four-wheel engines, the front pair of drivers having full crank axle. I made a sketch of this which met with Mr. Cameron's approval, but Mr. Brandt would not give way in his objection to the cylinders with steam connections under the smoke-box—he had so much trouble with the English engines. He finally joined me in advocating outside connections.

Mr. Cameron said the commissioners were not willing to risk experiments. I urged that outside connections was no experiment, that Stephenson's Rocket, Hackworth's, in fact most of the early English locomotives were outside-connected. This argument was used against me and its adoption; for, said they, "Stephenson and others would never have abandoned it for full crank unless there had been some radical defect. The fear was that the wide spread cylinders would produce such oscillation as to be injurious to the track if it did not cause the engine to jump it.

We offered to build either as I had suggested, with full cranks and two pair of drivers, or outside connections and one pair of drivers back of fire-box; but it was not until we guaranteed against injurious oscillation that the latter plan was accepted. Having reached that point, a cross-section drawing was called for to give the spread of the cylinders, to ascertain if they would pass through the tunnel, as it [the tunnel] was being driven on the Lancaster and Harrisburg road, connecting with the State railroad. Supposing all difficulties had been met and overcome, I made the drawings and submitted them, but I was mistaken; my drawings called for an iron frame instead of a wooden one, that up to that time was the only frame

[207] Patent of September 10, 1834, illustrated in fig. 66.

in use;[208] it was objected to on the ground of its having too much rigidity. I argued that the boiler was the foundation to build to; that the springs would give all required elasticity.

After considerable delay the iron frame was approved of; then arose another difficulty—the diameter of the journals of the driving axle would be the same as that of the axle, the face of the hubs of the driving wheels coming in contact with the brass boxes, would draw the oil from the journal and dissipate it by its centrifugal force, and, consequently, the journals could not be kept from cutting. Various plans were suggested to remedy this imaginary difficulty, one of which was a single collar central to the box, the increased diameter of which would draw the oil towards it; it was not adopted, though Brandt, at that time, was experimenting with it for car axles.

Believing that admitting of inside journals for the drivers carried with it the journals for the truck axles, which brought the truck frame [209] directly under the engine frame, accordingly I made the drawings: a wooden truck frame plated with iron; cast-iron pedestals to carry the axle boxes; a pair of long vibratory springs over the frame, the ends of the springs resting on the axle-box pins. On the center of these springs were rollers as side bearings for the truck between the springs and the iron engine frame. This was objected to, and outside bearings for the truck axles insisted on. As there was no outside wooden frame to place the truck springs over, as in the Baldwin engine, a wooden outside truck frame, with cast-iron pedestals with a separate spring to each journal was adopted. These journals being outside the wheels, they did not come under the frame of the engine. Being satisfied the engine would run more steadily if the front weight was carried on the center of the truck instead of by side bearings on its frames, without consulting the commissioners, we adopted a wrought-iron cradle with a center socket in which rested a steel-faced wrought-iron center pin. As this was the first center-carrying truck ever constructed, I shall, further along,[210] relate the trick we were compelled to resort to, to gain for it even a trial.

Before undertaking to build these engines we had a verbal agreement with Moses Starr,[211] the then only boiler maker in Philadelphia prepared for that kind of work, but by the time the drawings were taken to him, he had contracted to furnish boilers to Baldwin to the full capacity of his shops for some months. Accompanied by Mr. Brandt, I went to New York, and there contracted for two boilers, and even for these the work was divided; the boiler maker not being prepared to bore the flue sheets after turning the flanges; they were bored at the West Point shops.

On this trip Mr. Brandt proposed going to Albany to see the locomotive on the Mohawk & Hudson Railroad. When there, we rode on an English four-wheel engine, with full crank axle, wheels about four feet diameter, connected drivers by cranks and rods outside the frame. We also saw in the shops an engine with inclined cylinders placed on the foot-board, four wheels, inside cranks and outside connected. This was shown us as the first successful locomotive run in the State of New York,[212] and was built at the West Point works. We also rode on another engine, built a year or two later at the same works. This was shown as the first four-wheel pivoted truck engine, designed by John B. Jervis, the chief engineer of the road; it had one pair of driving wheels back of the fire-box. The cylinders were outside of the smoke-box, to give room for the full cranks and connecting rods; the fire-box was narrowed and lengthened. With the exception of the half cranks and dome boiler, this was the type of the engines then building by Baldwin. We also rode on a truck engine built in England from American drawings.

I expected to have found in New York round iron that would finish for 6-inch diameter driving axles; also flat iron for the frames, but neither were then kept on hand. We got the frame iron drawn at one of the Pennsylvania charcoal forges, and finished in our own shops. The axles we piled, of charcoal iron, taking the heats in a hollow-fire on an open hearth, and forged under an old-fashioned trip hammer of about 200 lbs. weight. The flange tires

[208] A wrought-iron-frame locomotive, built by West Point Foundry Association for the Tuscumbia, Courtland, and Decatur Rail Road was mentioned in the *Mechanics' Magazine and Register of Inventions and Improvements* (New York, January 24, 1835), vol. 5, p. 4. Mr. John White, of the Smithsonian Institution, has told me that this was undoubtedly the *Comet*, the last locomotive built by West Point.

[209] This refers to the frame of the 4-wheel pilot truck.

[210] Chapter 24, below.

[211] In the 1835–1836 Philadelphia directory Moses Starr was listed as blacksmith; in the 1840 directory the listing was Moses Starr & Son, steam engine and boiler makers. His shop was in Frankford, on Shackamaxon below the Frankford Road. See figure 68.

[212] The *De Witt Clinton*, built in 1831 for the Mohawk and Hudson Railroad.

FIGURE 68.—Advertisement in *A. M'Elroy's Philadelphia Directory for 1840.* Library of Congress photograph.

we ordered from Low Moor works, England, giving the outside diameter 4½ feet, the thickness to be as heavy as they rolled. They came in straight bars so short as to take two bars for each tire, and not exceeding 1⅜ inches thick. We had expected to have received them bent and welded. This was another unexpected operation to prepare for, but having good smiths we did not meet with any serious difficulty.

The driving wheels were a subject of much discussion. The rigid manner the road was laid—T-iron secured in cast-iron chairs bolted and leaded to alternate stone blocks and stone cross-ties; intended for an everlasting roadway on which the farmers could haul their produce to market with their own teams at slow speeds; every cast-iron chair on its stone foundation being an anvil on which a quick moving wheel would hammer out the rails; this rigidity of road must be overcome by a certain elasticity in the locomotive; the commissioners seemed to have been carried away by Baldwin's combined wheel center and spokes of cast-iron with deep wooden felloes. This, it was argued, gave the required elasticity. I proposed slightly recessing a cast-iron rim under the tread, letting the tire have its bearing under the flange and about one inch of its outer edge. Objections were raised to this, but led to making the cast rim of the wheel sufficiently deep to admit of recessing to take in well seasoned segments of white oak forming a bottom, and side-supported felloes of about 2 inches deep within the rim. These segment-felloes, when secured in place, were turned, leaving just so much fullness that the shrinking tire would compress them and have its bearing on both the wood and the cast-iron rim of the wheel.

The spokes or arms were flat, with ribbed edges. The spans between the spokes opposite the crank-pin, at Mr. Brandt's suggestion, were provided with bosses to receive bolts to secure in place counter-weights which we proposed putting on after the engine was in service. This he did about two years in advance of the Rogers hollow-spoke counter-balanced wheel, which has been frequently referred to as the first effort at counter-balancing. After our wheel patterns were ready for the foundry I became so apprehensive that the wood felloes, subjected to the heat of the tire, after it had shrunk and seated on the iron rims so as to prevent the escape of the gases, would lose their tenacity, in fact, be converted into red charcoal, that I had the core boxes and joints altered, to so narrow the recess for the felloes that the tire would have sufficient bearing on the iron rim, even if the wood was left out; in fact coming to my original proposition of simply recessing; to lessen as much as possible the injurious effects of the confined heated gases on the wood, the holes for the tire-fastening bolts were drilled as escape holes. Years afterwards I was shown a section of one of these tires that had been worn and turned down to about ¾-inch in thickness.

It showed a very perceptible setting or sinking into the recess; as to the wooden felloes, I was informed that very little of them was left, and what was, was in loose pieces falling about, the greatest bulk having escaped in dust through a bolt hole. [59]

23. John Brandt, Master Mechanic

Sellers was some 20 years junior to John Brandt, the Lancaster blacksmith who, after a sojourn in Philadelphia, became well known in his day as a builder of locomotives.

As a partner in Sellers, Brandt, & Company, formed in 1828 to exploit his card machine, Brandt went to live in the "first stone mill put up at Cardington the east end of which was finished as a dwelling for Brandt and his family . . . ." George Escol and his brother Charles boarded with the Brandts while the mill was getting under way.[213]

As related below, Brandt stayed in Philadelphia only about a year. He was with the Philadelphia and Columbia Railroad in the Parkesburg shops from 1833 until 1838, at least.[214] He went from the Philadelphia and Columbia to the New York and Erie Railroad, but the dates are uncertain. In 1854, he was superintendent of the New Jersey Locomotive and Machine Company, in Paterson, and while there built locomotives for the Philadelphia and Columbia, New York Central, and other railroads.[215] In 1857, he was back in Lancaster. According to the Lancaster *Whig*, the "celebrated locomotive works" of that town were "under the supervision of Mr. J. Brandt, one of the widest known and most successful constructors of engines in this country." [216]

In the view of the present editor, who is a member of the generation that has seen the passing of the steam locomotive, Mr. Brandt is representative of the hundreds of lesser-known men who helped raise the impressive giants of the rails to their zenith. The boldness and audacity of these men, tempered by a finely developed intuitive sense of fitness, are aspects of the American character that we would do well to hold onto.

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213 Memoirs, book 4, pp. 66–67, and book 1, p. 14.

214 *American Railroad Journal* (August 15, 1838), vol. 7, pp. 134–136.

215 *American Railroad Journal* (January 7, 1854), vol. 27, p. 2.

216 Quoted in *American Railroad Journal* (April 4, 1857), vol. 30, p. 217. The Lancaster Locomotive Works built some 8 or 10 locomotives a year from its founding in 1853 to 1857. John Brandt apparently had two sons, John, Jr., and Abe. See M. Luther Heisey, "Locomotives—Made in Lancaster," *Papers of the Lancaster County Historical Society* (1940), vol. 44, no. 1, pp. 1–10.

In the fall of 1834, about the time we had undertaken to build engines for the State road, I was called to Lancaster to advise with the canal commissioners. Mr. John Brandt being there, asked me to ride with him on the "Lancaster" with a freight train, as far as to where it would side track to allow the passenger train to pass, and then to take it to the city; but it was ordered otherwise, for we had not gone over fourteen or fifteen miles with the "Lancaster," before it, with the train, came to a standstill. We were on the foot-board at the time, and Brandt held the throttle lever. The cause of the stop was soon evident. The center loose spindle of the hand lever rock-shaft was placed back of the dome of the boiler above the fire-door; this spindle extended into a hollow portion of the rock-shaft some 10 or 12 inches, and was lubricated through several small holes drilled in the upper side of the rock-shaft. This spindle had become fastened in its socket, causing the breaking of one eccentric-rod and the bending of the other.

Brandt at once commenced taking off the rock-shaft, saying if he could get the spindle loose, he thought he could run the engine and train to the side track that was not over a mile ahead, working the valves by the hand levers. Considerable time was lost in the effort to loosen the spindle and get the rock-shaft apart by heating the hollow portion and cooling the spindle end, but with the appliances at hand it resisted all efforts. The nearest blacksmith shop was on a country road over a mile away. A flag-man was sent back to stop the passenger train, with directions to cut its engine loose from the train, and push the disabled engine and train to the side track. This arranged, the fire was drawn from the Lancaster.

Mr. Brandt, myself and two others started for the blacksmith shop, each carrying his portion. Our course was over fences, and across fields. On rising ground, in full sight of the railroad and not over a quarter of a mile from it, we came to a farm house, at which a hog-killing frolic was going on. Brandt was acquainted with the German farmer, who offered to hitch up his team and take us to the smithshop. He said he had some tools in a little repair shop, that Brandt was welcome to the use of—a good strong vise, blacksmith's bellows, anvil and tools, but no coal. "If the bellows and hearth are in order," said Brandt, "I can straighten these rods and make the weld with brands from under the hog-scalding kettle," which was then in full blast.

It was not long before he was at work with great earnestness. My portion of the job was to loosen the spindle, by stretching the outer shell of the rock-shaft with a hand hammer. A pretty long and tiresome job, but successful. When the spindle was got out, it did not show signs of either heating or cutting, it was simply dry blue cemented for about four inches of its length between the oil holes, which seemed to have been stopped by a thin scale in contact with the spindle, a case of dry sticking, such as is often experienced with ground glass bottle-stoppers; the original fit had been a little too nice to admit the oil.

From our elevated position we saw the four-wheel English locomotive cut loose from its train of a four-wheel box baggage car and five four-wheel passenger cars, that could seat twenty-six passengers each.[217] For over an hour the English engine was puffing away in a vain effort to push the "Lancaster" and train to the siding. She could start the train back on a down grade, slack the connecting links and bump the cars together again; but as to going ahead, it was the old story of one step forward and two back. The accident happened about 4 p.m. on a short fall day; it was long after dark when the repairs were completed. Brandt, with the brands from the hog-scalding fire, with poor tools and improvised helpers, had made a good weld. It was near eight o'clock when the engine started in good running order.

While these repairs were going on in the little workshop or stable lean-to, the farmer's wife was not backward with her true German hospitality, for she came with a jug of pure water and a square quart bottle of homemade bitters, pressing it on us with the assurance that "she is nice, she is goot." The daughters and guests at the lard rendering and sausage making, came with coffee, hot corn-cakes, and other nice things, which we ate standing without stopping our work, using the hands of the fair ones to put the food in our mouths in a manner that caused much merriment and many Pennsylvania Dutch jokes.

The passenger engine with its train, felt its way to the city, with a couple of common lanterns hung on the front bumpers, for it was before the day of cow-catchers, now called pilots, or headlights. This was railroading fifty-one years ago, on what is now the great Pennsylvania Central . . . . [60]

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[217] Again, there is the difficulty with the English locomotive as mentioned in notes 186 and 205 above. I can only assume that this trip occurred after the English engines arrived, in the spring of 1835.

John Brandt is best known to the engineers and master mechanics of the present time as an early master mechanic of the New York and Erie Railroad, in charge of the shops at Piermont, and by the locomotives afterwards built by him at his shops in Paterson, N.J., but little is generally known of the early history of this self-taught inventive mechanic.

My acquaintance with Mr. Brandt dates back to the year 1826; he at that time was carrying on a common jobbing blacksmith shop in Lancaster, Pa.; at the same time my father and elder brother were engaged in manufacturing card clothing for wool and cotton carding machines, also in drawing fine brass and copper wire and weaving wire cloth for facing paper moulds, and for covering paper cylinders, this being about the commencement of the transition from hand to machine-made paper. The business of wire drawing and making paper moulds was commenced by my grandfather, Nathan Sellers, during the early part of the revolutionary war. He was in the service from which he was honorably discharged by special act of Congress in order that he might make moulds for paper making. He was sent under military escort to York, Pa., where, under guard, he made the first pair of paper moulds made on this continent, and on which the paper for congressional use and for printing the continental currency was made.

About the close of the war, the manufactory of hand cards for cotton and wool, and the clothing for carding machines was established in connection with the wire works. The cards were all hand set; that is, the sheets of leather were pierced with holes to receive the wire card teeth on a machine for that purpose. The wire was cut into uniform lengths and formed into the teeth on other machines invented and constructed by my grandfather. I will here note that these machines were so perfect in plan and construction that they continued in use without alteration or improvement for nearly half a century, until superseded by machine set cards. In hand-setting when every tooth had to be separately picked up. and, by nimble fingers, put in the holes pierced to receive them, it gave employment to many hundred children, and often to women, at pick-up work as their aid to bread winning. The work was taken home, and returned when finished. The register of names and residences of those employed exceeded 3,000; the number having work out ranging between 300 and 500.

Some time previous to the time I am writing of, a machine had been invented for doing the entire work, and was in use to some extent, but owing to the shape and largeness of the pierced holes in the leather and consequent looseness of the teeth, had not then supplanted the more costly hand process.[218]

Early in the year 1826 Mr. James Humes of Lancaster, Pa., who at that time was carrying on a cotton factory, came to us for new clothing for some of his machines, bringing with him a sample of machine-made fillet or ribbon card that had the teeth more firmly set in the leather than the best hand-made. He represented it as the outcome of the brain and workmanship of an ordinary jobbing blacksmith who had never seen any of the machinery then in use for doing any part of the work of card manufacturing.

My father was so well pleased with the sample that, learning from Mr. Humes that John Brandt, the inventor and maker of the machine, had offered it for sale, he went to Lancaster and found points in the machine of great merit, but it was not constructed in a thoroughly workman-like manner. But as an invention of a man with the few opportunities Brandt had, my father considered it wonderful.

I think it probable that had Brandt seen the machines then in use, he would not have struck on a new track and worked out what he had done, the great merit of which was, so firmly holding and supporting the wire staple tooth that without bending it could be forced through the leather without it being pierced, but not without leading as it passed through the leather and making irregular work, but would with accuracy follow a puncture no larger than the wire, thus the teeth could be as firmly set as required. This he accomplished by so shaping the end of the die or former on which the wire staple was bent by side benders grooved to the size of the wire being used, that as the die was drawn down and out the pusher following the shape of its end, both die and benders being in contact with the leather, there was no possibility of bending the staple as it was thrust home. The second bend or hook of the tooth was then made and the leather moved into position to be pierced to receive the next tooth.

Feeding in the wire, cutting it into proper lengths, seizing and holding to the die, bending into staple, piercing the leather, thrusting in the tooth, drawing out the die as the pusher advanced, making the second bend or hook of the tooth, moving the leather into

218 Oliver Evans reportedly designed and built before 1780 a card machine that set teeth at the rate of 3,000 per minute. See Bathe and Bathe (cited in note 46 above), p. 8.

position for the next tooth, were nine distinct movements, requiring certainty and great accuracy, most of them concentrating to a single point. This first machine he ran at a speed of about 100 teeth per minute, or say, 900 distinct operations.

All these movements he got from cam studs on a brass barrel, not unlike the barrel of a hand organ or musical box. My father explained to him the separate cams on a single shaft that gave all the motions to our old card tooth-making machines, and showed him that steadier and less jerky motions could be got in that way with increased speed than from his short stud cams on his brass barrel.

It was proposed that he should go to Philadelphia and see the old card-teeth machines, before commencing others which he had undertaken to make for us. His original machine was purchased, though not expected to be of much use. After making some alterations on it he brought it to the city. When he saw the old machines he was struck with their simplicity, and at once proposed radical changes in making new ones.

He asked to be left alone with the old machine that he might study the cams. Soon after this I found him with an old machine taken to pieces. He was busy with his pocketknife carving out of shingles the forms of the various cams. I offered to make for him drawings of any parts he wanted, and then discovered that he did not understand the simplest plain drawings. His pocketknife was his pencil, and his habit was to carve models out of wood, and to adjust parts by trial, a kind of rule of thumb.

After he had undertaken to build the machines for us, it was decided that my elder brother, Charles, who was a superior worker in metals, should go to Lancaster and remain there working on the new machines with Mr. Brandt. For this purpose he went to Lancaster in 1827. Early in 1828 the first machines were completed, and Mr. Brandt, with his family, removed to Philadelphia, and the firm of Sellers & Brandt was formed for the manufactory of machine cards.

It was in the winter of that year while Mr. Brandt, with the assistance of my brother and myself, were engaged in constructing more card machines, he making all the forgings, that he came to me with a proposition. He said no man could be a good working mechanic without being able to make his own forgings, at any rate so far as to forge his own tools and temper them. He proposed to take me as a scholar, if I would, in return, give him some instruction in machine drawing. He went on to say, that with proper attention and desire on the part of the apprentice to learn, a few weeks would make a better smith than the customary four or five years' apprenticeship. He said he had given over three years of his life to doing the work of the commonest laborer for what little instruction he got.

He proposed that I should be helper, blow and strike for him, for a week; then take the hand hammer, and he would blow and strike for me the next week; that at the end of two or three such terms he would guarantee that I could handle iron and steel as well as he could. There was something so original and novel in his proposition, that I at once acceded to it. The work to be done was mostly light steel forgings and he had enough of his wooden patterns ready for some six or eight weeks' work.

The second week, when my turn had come to take the hand-hammer, he handed me a sheet-iron template, giving size and form for a breast-brace of about 3½ inches crank, or swing of 7 inches. He wanted me to try my hand at forging one, saying I would always find it a useful tool. With the template he gave me a piece of wire bent to the shape, showing he had marked on it the portions to be forged 8 square, and the round for hand grip; also a wooden model of the socket end. He told me to straighten the wire, and it would help in forging, giving the proper length of each part. Then, to my surprise, he handed me a bar 1¼ inches square, of charcoal forged hammered iron, to forge a brace whose 8-square portions were but ½-inch and the round ⅝-inch, and the spindle end about ⅜-inch diameter.

I asked why not forge the socket-end, drill and square the taper hole for the bits, and weld this to a bar nearer the size?

To this he replied that no good smith would drill the socket end, he would punch and work it on a steel mandrel; then for the brace no rolled iron will have sufficient stiffness without making it too heavy. This charcoal iron is free from flaws, is the right size, and when drawn down it will have great stiffness.

I tried to induce him to take the hand-hammer, but he reminded me that it was my turn, and that I must remember our bargain. If I was afraid to take the "bull by the horns I could never learn how to hold him." Although I expected failure, the brace was forged, and the steel end of spindle successfully welded.

This was my first job in that line, and now as I write, that brace lies before me, having stood the service of 57 years, and is as good now as the day it was made. It has always been one of my favorite tools. As I look back over that long period, I can see Brandt as helper doing more towards its production than the head hammerman.

I thought it would be an easy task to make a good mechanical draughtsman of a man who, with such facility, carved with his pocket-knife the forms he wanted to produce with his hammer, but I was mistaken. He took hold with great earnestness, handled his instruments well, and soon learned to copy line drawings with neatness and accuracy, but it was purely mechanical, for he did not understand the simplest drawings. He said he was often mortified by not being able to understand sketches. A verbal explanation of any portion of a machine was clear to him, but the moment a sketch in illustration was made all was confusion.

It was by mere accident that I discovered his mental difficulty. All his thinking was, if I may so express it, *full size*. The trouble was in reducing to a given scale and carrying both in his mind at the same time. Up to the point of this discovery it would take pages to describe the various devices I resorted to, but now all was plain sailing. By working him on full-size drawings, it was not long before he understood them and became quite proficient.

But some ludicrous things occurred. I will cite but one, premising that he was full of a dry kind of humor, that, at times, was difficult to distinguish from earnest. He showed me a full-size drawing of a crank, made on thin sheet iron and asked me to reduce it to half size.

"Why don't you do it?" I asked. "You have two centers on a line."

"Yes, I know, and I have done it, but it don't look right. I want you to do it."

I did so, and he took it, remarking that it looked too small.

I said: "Measure from center to center, and you will find it right."

"Yes, but"—and away he walked, and soon came back with both cut out, saying: "I have weighed both. There is something wrong. The half-size does not weight one-fourth as much as the full-size!" [219]

[219] The reader who does not immediately see the point of this tale is reminded that when all dimensions of a plane figure are reduced by one-half, the area becomes one-fourth of the original area.

Tables of areas and superfices only perplexed him. It was evident that the books I gave him to study only confused him. At one time he became very despondent. He said he felt his own ignorance; that he was too old to begin, too old to go to school, but if I could find him a private teacher, that could be trusted and keep his secret, he would make a trial, although over 40 years of age. If he could only be taught how to learn, he thought he could do the rest; but he was sensitive on the subject, and did not want it known that at his time of life he was beginning.

My friend, John C. Trautwine, at that time in Strickland's office, became much interested in Brandt, and together we consulted Prof. James P. Espy,[220] who had been Mr. Trautwine's mathematical preceptor, who, after an interview or two with Brandt, without his knowing the object, agreed with us that the first step in instruction must be entirely oral. He thought among his pupils he could find a capable one that would devote two or three evenings a week to the work. This was done. Brandt remained in Philadelphia from the fall of 1828 until the spring of 1829. During these months his studies were privately and profitably pursued. In the spring he moved to our card works in Delaware county,[221] but his wife was discontented. They were what is known as Pennsylvania Dutch. In October 1829 the partnership was dissolved, and he returned to Lancaster and resumed his old business of blacksmith.

When, in the fall of 1833, I learned that he had taken the position of foreman of the Pennsylvania Railroad shops at Parkesburg, I went to see him. He then said he was afraid he had given way to the persuasion of Mr. James Cameron, at that time chairman of the board of Canal Commissioners, and feared he would not succeed. I found his office walls covered with working models of eccentrics, rock shafts and steam valves, *all full size*. When I rallied him on adhering to full size, he replied: "It is best, I think, that way."

After showing me his models, he called my attention to the exhaust of the English locomotive I had

[220] James Pollard Espy (1785–1860) was employed in Washington as a meteorologist from 1842 until his death. In collaboration with the Smithsonian Institution he collected telegraphic information on weather data at various stations, making possible the mapping and forecasting of weather conditions. See *Dictionary of American Biography*. The Smithsonian Institution owns an oil portrait of Espy.

[221] Cardington.

come up on.[222] He said it was all wrong, a 9-inch cylinder with only 3-inch length of valve ports. It always went by screaming, pish, pish, pish, like boys throwing gravel against a board fence, and he declared that if he ever built an engine, the ports should be at least as long as two-thirds the diameter of the cylinder. I relate this to show the bent of his thoughts at that early day. He did not prove a failure. He was soon found by other railroad managers, and we next know him as master mechanic of the New York and Erie.

I visited him at Piermont, spending several days with him in the shops and on the road, but have no memorandum to fix the date. He, at that time, showed me his plans for a 10-wheel locomotive, with three pairs of drivers, and a 4-wheel truck, which he had designed for the central or heavy grade division of the Erie Railroad. He had tried without success to get permission to build some at the Piermont shops. He was directed to exhibit his plans and get bids from locomotive builders, and had taken them to Baldwin, who raised many objections, and declined bidding, but the Norris works looked more favorably on his plans. He left his drawings with them, which were returned with their bid. Previous to this he had shown his drawings to Mr. Millholland,[223] of the Reading Railroad, who was enthusiastic, and expressed his opinion that they would be particularly adapted to the heavy coal traffic of the Reading.

At the time of my visit he had not got authority to order any for the Erie. He said he understood that Millholland was having a 10-wheeler built by Norris, and he (Brandt) had no doubt it would prove to be the most effective freight engine. He was very particular in calling my attention to the details of his drawings, saying, if I should ever see the Norris engine, he would like me to note how nearly it conformed to his drawings.

Some time after this, on meeting Mr. Millholland, I learned that the 10-wheeler was in service, and its performance was even better than he had anticipated. I rode over part of the road with him on the "Susquehanna." In detail the engine differed considerably from Brandt's drawings, as I recollected then, and Millholland remarked, "that after the engine was put on the road some alterations had to be made that would not have been required *had Mr. Brandt's plans been closer adhered to.*" I have related the above in order to award Mr. Brandt credit he richly deserves as one of the pioneers in advancing the American locomotive to its present perfection.

We next find him located at Paterson, N.J., carrying on locomotive works. The engines he there turned out are known to most of the present master mechanics. At Paterson he and his family were as restless as when at Philadelphia. He sold out and returned to his old home at Lancaster, where he erected shops and started locomotive works, but did not live to see them in successful operation. [61]

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222 Again, the English locomotive before 1835.

223 James Millholland (1812–1875). See *Railway Gazette* (August 28, 1875), vol. 7, p. 362, for obituary. Millholland was "master of machinery" of the Philadelphia and Reading Railroad from 1848 to 1864.

24. The Sellers Locomotive

The *America*, first of the two Sellers locomotives, was delivered to the Philadelphia and Columbia Railroad in the late summer of 1835.[224]

In order to reinforce his own memory as to the exact date, the author wrote to his brother Charles and asked him for evidence that would fix the date. Charles replied: [225]

Our first locomotive was put on the Rail Rd. in 1835, I ran it for one week before we asked the Commissioners to take a trial trip to Lancaster and back.

The nearest date I can fix on was when field corn was in the milk in good condition for roasting ears. I know this because one of the two shop hands I had with me went into a field, when I stopped the train to do something to the engine, and roasted them in the ash box.

The second and last Sellers locomotive, called *Sampson*, probably was delivered during the same year. Soon surpassed in performance by locomotives from the shops of Matthias Baldwin and William Norris, however, the Sellers locomotives were within a year or two placed in ordinary. Eventually they joined the hundreds of other locomotives that have, in some detailed way, helped to point the direction of advance, but that have not possessed the total excellence that would have made them leaders of the procession.

Early in August, 1835. when our first engine was about ready to be placed on the road, Mr. Cameron, accompanied by Mr. Brandt, came to our works to inspect it. Mr. Cameron brought with him drawings of an attachment invented and patented [226] by Mr. Edgar L. Miller of the Charleston and Hamburg R. R. of South Carolina, by which a part of the weight of the tender could be thrown on the driving-wheels when an increased adhesion was required, directing us to put it on our engine, they paying the additional expense as well as for the patent right.

Anticipating this, or rather doubting the traction of the drivers, as placed back of the fire-box, being equal to the steam-power, I had devised and applied a lever arrangement, the fulcrum of which was the axle of the driving-wheels.[227] The attachment of the tender to the engine was so made that at all times when drawing a train a portion of the weight of the front of the engine was removed from the truck and thrown on the driving-wheels; this increased with the draft in ascending grades, as additional traction was required, being automatic in its action. This device was approved of and applied to our early engines, as was the Miller arrangement to the Baldwin engines, until the better distribution of weight on two pair of drivers was adopted.

[224] The chronological table of locomotives on the Philadelphia and Columbia that is perhaps most widely circulated is the one in the annual report of the railroad for 1837, reproduced in Watkins (cited in note 177 above), vol. 1, pp. 137a–137b. However, when this report is compared with others submitted by various Philadelphia and Columbia Railroad officials, a number of errors are at once apparent. The date given here for the Sellers locomotive is confirmed in a report dated October 30, 1835, reproduced in Watkins, p. 129. The U.S. Treasury's "Report on Steam Engines" (cited in note 173 above), p. 169, lists both Sellers locomotives as having been built in 1835.

[225] Letter from Charles Sellers to George Escol Sellers dated at Woodstock, July 23, 1884, copy in Paul T. Warner papers, division of transportation, Smithsonian Institution.

[226] U.S. patent of June 19, 1834.

[227] U.S. patent of May 22, 1835, by Charles Sellers and George Escol Sellers.

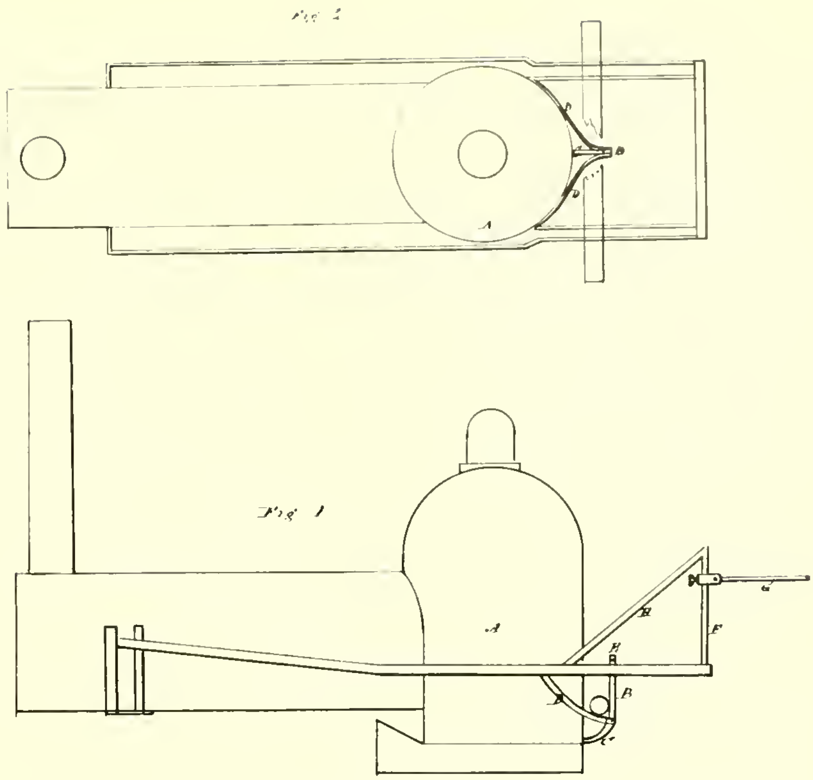

FIGURE 69.—Charles and George Escol Sellers's device for "Increasing the adhesion of the Wheels of Locomotives." A lever arrangement, terminating in the draw bar (*G*, at right in lower view) has its pivot near the axle of the driving wheels, but neither the drawing nor the specification is entirely clear. In the words of the patent specification, the load being hauled "shall tend to raise the fore end of the Locomotive in any desired degree, and thus to lessen the pressure upon the fore, and transfer the same to the behind wheels." The draw bar is adjustable up and down to change the leverage. From U.S. patent, May 22, 1835, restored drawing. National Archives photograph.

About this time we had a visit from Mr. Rogers,[228] the founder of the Rogers Locomotive Works, of Paterson, N.J. He was accompanied by Mr. Danforth[229] of the same place. Our business connection with Mr. Rogers was of long standing, having furnished him with card-clothing for cotton machinery. As he expressed a desire to visit our works, I drove him and his friend out to them. The locomotive then in the hands of the painter preparative for delivery, seemed to be the chief attraction, particularly the iron frame, outside connections, and the driving-wheels. The arrangement for securing counter-weights was commented on by Mr. Rogers, he asking why they were not cast solid with the wheel? During this visit Mr. Rogers said his friends John B. Jervis and Horatio Allen had long been urging him to try his hand at locomotive building, and that he had serious thoughts of doing so. I have related this as evidence that counterbalancing was not only under discussion but in actual course of experiment prior to Mr. Rogers commencing locomotive building.

As I was at that time residing at the works,[230] I did not return to the city with these gentlemen, but in the evening sent them with a trusty and intelligent driver, who on his return seemed to have been much amused at the conversation between Mr. Rogers and his friend; he said they both spoke in praise of the character of the workmanship on the engine; that Mr. Rogers had remarked that he had noticed a strong, broad-wheel truck that he supposed was intended to move the locomotive over the country roads to the railroad. He had also noticed that the engine was set up opposite the widest door in a substantial stone building; he had measured the doorway, and the engine across the cylinders, and found it some two feet or more wider than the opening after taking out the wooden door-frame, and the way the engine was

[228] Thomas Rogers (1792–1856). The Rogers, Ketchum & Grosvenor Machine Works of Paterson, New Jersey, made railroad car wheels and fittings at this time. See *Dictionary of American Biography*. A Rogers, Ketchum & Grosvenor advertisement was carried in nearly every issue of vol. 4 of *American Railroad Journal* (1835). The first Rogers locomotive was completed in 1837.

[229] Charles Danforth (1797–1876), inventor and builder of cotton spinning machinery, entered the locomotive business in 1852. *See Dictionary of American Biography.*

[230] "After Fred was born [February 26, 1834] and I was adding to the little house at Cardington . . . I was with Rachel, the baby and nurse boarded with Bonsall . . . ." (Memoirs, book 1, p. 39.)

FIGURE 70.—Thomas Rogers (1792–1856). From J. Leander Bishop, *A History of American Manufactures from 1608 to 1860*, 3d ed., 3 vols. (Philadelphia, 1868).

put together it would be impossible to take the cylinders off. He feared that when the Messrs. Sellers undertook to move the engine, they would find it like Robinson Crusoe's boat. William the driver said he could not help saying, "maybe the stone-mason's hammer and chisel will soon make the door right." This trivial matter must have made a lasting impression on Mr. Rogers, for twenty or more years later he asked me how we had got the engine out of the house it was set up in, adding, "I have always been curious to know."

Fifty years ago, the time I am now writing of, the mechanical engineer was no more exempt from difficulties in the introduction of anything new and untried than he has been at any subsequent period. All our arrangements had been made to deliver our first locomotive "America" from our shops to the head of the incline plane over a hilly country road of about six miles, when we received a note from the canal commissioners stating that they had become satisfied that our outside connected engine, with the spread of its cylinders, would produce so much oscillation as not only to be injurious to the engine but to the track, if the engine could be made to keep it, but this might be partially remedied by placing side bearings on the truck; that unless they were put on, the engine would not be allowed to run on the road even for a trial. Here was a serious dilemma.

Having had a full understanding with Mr. Brandt as to carrying the weight on the center-pin, and to satisfy the commissioners, having adopted outside frame and bearings for the truck axles, with separate spring to each journal, there was nothing above this outside truck-frame to which a support could be applied. Baldwin's springs over the outside wooden frames with its center-pin passing through them, resting on a cast-iron grease-box on the truck-frame, admitted the truck to turn as much as required in running the curves. The J. B. Jervis truck which we had seen on the Hudson and Mohawk had a better arrangement for turning, each axle-bearing having separate springs; the side supports were rollers or wheels having their bearings in boxes attached to the engine-frame, with flat iron plates on the wooden truck frame. I had so much confidence in the steady running with the bearing on the center-pin without side supports, that in hopes of getting permission from the commissioners to allow the trial, agreeing in case the engine was found unsteady to

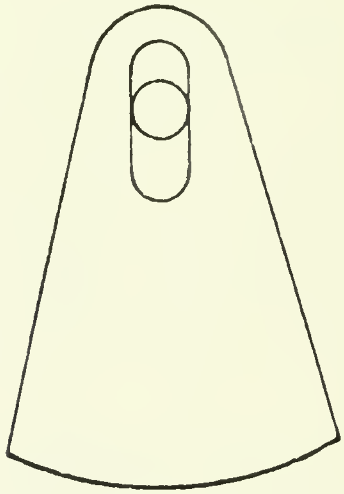

FIGURE 71.—Side support for trial of Sellers locomotive, showing slotted hole used to prove that the device was unnecessary. See text. From *American Machinist* (November 7, 1885), vol. 8.

put inside frames to the truck and supports to the iron frame, I at once went to Parkesburg to see Brandt, and, if possible, get his influence with the commissioners to allow the trial. He was greatly surprised on reading the note, and could not imagine what influence had been brought to bear; he returned with me to the city and said all he could to induce the commissioners to allow the trial. No; they had laid the subject before their engineers and several reliable mechanics; the verdict was unanimous that at any speed beyond a walk the engine would certainly jump the track.

Mr. Brandt in his characteristic way asked Mr. Cameron if he could not sit steadier on a three-leg than a four-leg chair on an uneven floor.

Mr. Cameron replied, "that is not the question; it is the oscillation caused by the alternate action of the pistons in the widespread cylinders that we fear."

I urged that the inequalities of the road would only be felt half as much with the weight carried on the center of the truck; that the weight would always be equally divided among all four wheels; that the engine would run steadier and be less liable to leave the track.

They would not yield; side supports must be applied before the engine would be allowed to go on the road. The position of the cradle carrying the center-pin socket or step where it passed under the iron frame of the engine was about 10 inches distant from it, and it was only about 5 inches wide. It would not be impossible to build on this, and to the frame so as to adopt the Jervis roller; but I was bent on having a trial without any side support, and this could not be done without connivance with Brandt.

After hours had been wasted in these discussions I suggested suspending from the frame of the engine a kind of pendulum in the shape of a segment of a wheel that would represent about 14 inches diameter, with sufficient length of its periphery, which was to rest in a grooved box secured to the cradle to allow the truck to turn the shortest curves, in fact the Jervis roller or wheel enlarged from about 2 to 14 inches diameter. Gravity would always keep it in position. This plan was approved; it could be applied without delaying the delivery of the engine, only requiring two holes to be drilled in each iron frame to secure the joint or axle, and a like number in the cradle to fasten the grooved step; these wheel segment supports were forged of wrought iron about 1 inch thick. [figure 71.]

FIGURE 72.—Matthias W. Baldwin (1795–1866). From *Memorial of Matthias W. Baldwin* (Philadelphia, 1867), frontispiece.

I have spoken of connivance with Brandt; when I told him of my intention of slotting the axle-hole so as to allow a play up and down of about 1½ inches he was much amused, but insisted on having a template sent him, that he could have an extra pair made without slotting the holes, saying he would be on the engine when first steamed up, and if the engineers and wise mechanics were right, he would have a solid pair ready to put in; the slots were hid by large washers, and to keep these sham supports firmly in place the spaces above and below the axis were filled with soft white pine.

I have no memorandum at hand of the date the engine was put on the road, but it was not later than the first of September, 1835. Supposing all difficulties in the way of a fair trial of the engine had been overcome, and while my brother was engaged in loading the engine on to the truck and removing it to the railroad, I was surprised at finding in our city office a note from Mr. Charles Chauncey, who at that time was one of the most prominent of Philadelphia counselors-at-law in patent cases, asking an immediate interview, stating that Matthias W.

Baldwin had instructed him to commence an action by injunction to prevent the running of our locomotive then being placed on the railroad, on the ground of infringement of two of his patent claims; that he, Mr. Chauncey, had declined taking the case, and that he had assured Mr. Baldwin that if we were infringing, it was without knowledge, and he had no doubt as to our making it right without recourse to law; that he had induced Mr. Baldwin to allow him to act as umpire between us; he therefore requested an immediate interview.

Our position with Mr. Chauncey was one of long-standing family intimacy and friendship. At the time of our father's death, which occurred in May, 1834, we received a letter of condolence from him, in which he said it was his wish to extend his friendship for our father to his sons, and although he was retiring from active practice at the bar, occasions might occur in our business transactions requiring legal counsel and advice; in that case he hoped we would freely call on him as a friend. From that time our intercourse was of the most friendly character, and more than once we were indebted to him for valuable counsel and advice.

When I considered our previous friendly relations with Mr. Baldwin, I was completely taken aback. His shop in Minor street was but half a block from our office, and after his removal to Lodge Alley but two blocks away; a single week had never passed without our meeting either at his shop, or at the Franklin Institute, or in our own office, where he frequently came in company with his friend, our uncle, Franklin Peale, whose position as manager of the Philadelphia museum required frequent consultations with me as chairman of the executive committee of that institution. These meetings apparently friendly, the locomotive we were building was frequently a subject of conversation. Mr. Baldwin expressed great interest in what he called the experiment of iron frames and outside connections; I do not remember his ever expressing a decided opinion of them, but as to carrying the weight on the center of the truck, he was very decided, predicting failure and a necessity of side supports. The nearest he ever came to expressing an opinion as to outside connections was that he should watch with great interest the oscillative or vibrative effect on the engine, and incidentally asking if I had ever considered the difficulty in keeping the inside bearing-journals of the driving-axles lubricated. From this I inferred that he was somewhat skeptical. I felt greatly aggrieved at Mr. Baldwin's course, for he had never made any allusion to his patent claims.

I hastened to Mr. Chauncey's office, no doubt showing some nervous excitement, for on entering, Mr. Chauncey opened the business in his mild way by assuring me that his note was dictated by friendship; that he had fully impressed Mr. Baldwin with the danger of commencing action by injunction requiring security, and in case of defeat subjecting him to damages; that on his declining to take the case against us, Mr. Baldwin had asked if he was to understand that he would act as counsel for us against him? He replied that he would act for both parties as far as lay in his power to prevent needless litigation, but if it was forced on us he should certainly give us the advantage of his advice, but he would not take an active part on either side. Mr. Baldwin had finally left with him his patent specification and claims, pointing out wherein he considered us infringing, and had consented to his writing to us.

He then handed me the specification,[231] requesting me to read it and the claims with care; after I had done so he stated that Baldwin in the first place claimed that we were infringing his combined wood and cast-iron wheel; I made a sketch and explained our continuous box rim filled with wood, with sufficient bearing on the cast-iron for the tire in case the wood should be destroyed by heat in shrinking on the tire. To his question as to how we had prevented the unequal contraction of the cast wheel that Baldwin claimed to have done by the separate or non-connected flanges on the ends of his cast-iron spokes, I replied, only proportioning the thickness of the parts, casting under considerable head with gates of ample size to feed metal as long as the casting in cooling would take it, and by leaving the casting in the sand for twenty-four or more hours with a charcoal fire on it for some twelve hours, slow cooling or annealing as far as practicable without an annealing furnace.

Mr. Chauncey's practice in patent cases and the attention he had paid to mechanics made him very prompt in expressing his opinion that there was no infringement, saying wooden felloes are not patentable; they having been in use from the time of the Egyptians, the only sustainable claim could be for a peculiar combination. He then added: "Mr. Baldwin did not seem very confident as to his claim being infringed, but he laid great stress on his claim for ground metallic joints for steam and water pipes." [232]

[231] U.S. patent of June 29, 1833.

[232] U.S. patent of September 10, 1834.

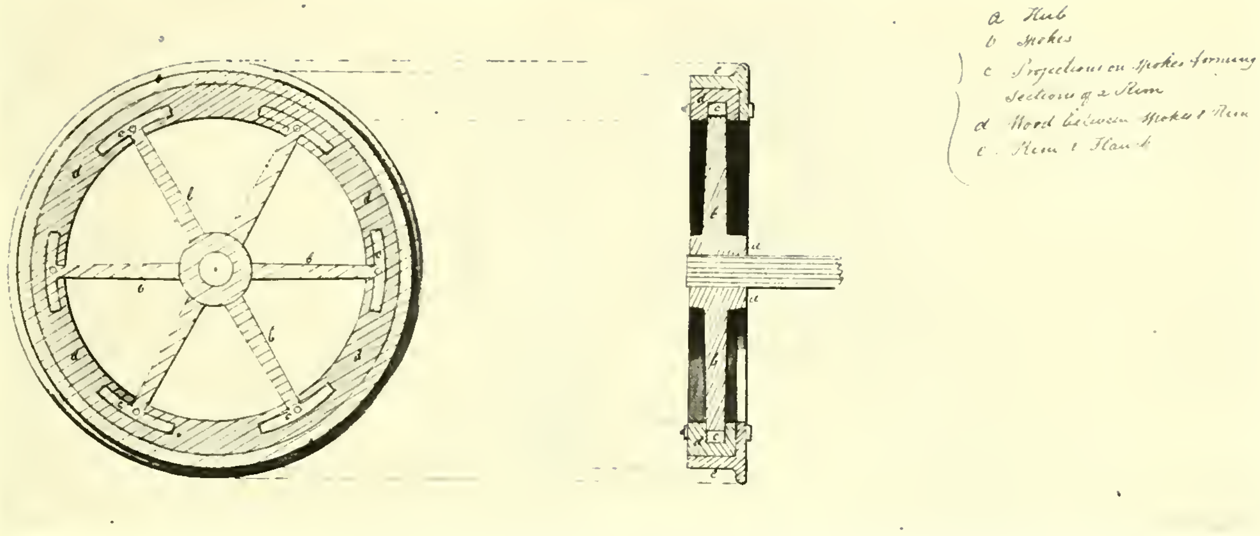

FIGURE 73.—Baldwin's locomotive wheel, showing wooden felloes (*d*) between spokes and rim. From U.S. patent, April 3, 1835, restored drawing. National Archives photograph.

To this I replied, that appears to be a claim for protection in doing good work, and that any one should make it was astounding; that in the practice of my father's shop from my earliest recollection, well-fitted metallic joints was the rule, canvass and red lead a rare exception. Mr. Chauncey asked me to reduce to writing what I had to say on that subject, and let him have it that evening; that he had an early appointment with Baldwin for the next morning, and named the hour he would see me.

In drawing this paper I referred to the custom of our shop, and our manner of making metallic steam or water-joints; that we had long known by experience that a lump or fullness could not be ground off without making a corresponding depression in the opposite; that the joints on the locomotive steam-pipes were as they came from the lathe, having been tried under direct pressure, with Venetian red finely ground in oil; that care and little practice showed where the scraper, if required, was needed; also, when it had done its work, the joints were not ground. I referred to the gunbarrel steam-pipes of the old Hawkins engine, one barrel coned into the other and drawn together with clamp-bolts that had carried steam of 800° temperature, and where these pipes, then in existence, could be seen. I also referred to Jacob Perkins' English patent of 1824, as published in Newton's journal,[233] claiming the uniting of steam-pipes by a short double-cone section drawn into the ends of the steam-pipes reamed out conically to receive them, drawn together by bolts through flanges on the steam pipes, said to have carried steam of 1,000° Fahrenheit; also, to the account of steam-heating the house of Sir J. Sloan, London, which I believe was the first published account of heating by steam-pipes, the joints of these pipes being metal to metal, as described in the Perkins patent.

At the time appointed, as I went into Mr. Chauncey's office, I met Mr. Baldwin coming out; his passing-greeting was hurried and excited; what had passed between him and Mr. Chauncey I never knew, nor did I inquire, for Mr. Chauncey said to me, "You put your engine on the road; you will never hear more of these patent claims." This episode did not produce any estrangement; after-meetings were always pleasant; neither of us ever reverted to it.

As I have before stated, this our first locomotive was put on the State road early in September, 1835, my elder brother Charles and Mr. Brandt handling the throttle on its first trip to Columbia and back with a freight train; after this, my brother made other trips with the runner having charge.

[233] British patent 4732, December 10, 1822.

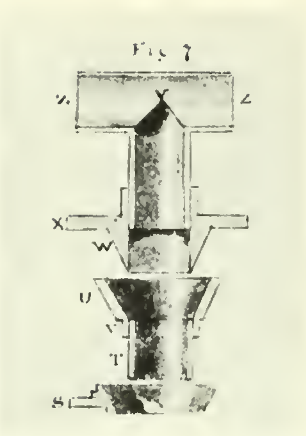

FIGURE 74.—Baldwin's conical steam joint. Compression pipe joint as shown in U.S. patent, September 10, 1834. National Archives photograph.

When satisfied that all was ready for a public exhibition, a round-trip to Lancaster was made, accompanied by the canal commissioners, the civil engineers of the road, and a number of invited guests, Mr. Brandt being on the foot-board with my brother. During the trip to Lancaster the commissioners and engineers took turns in riding on the engine. Among the invited guests were Dr. R. M. Patterson, director of the U.S. Mint, Adam Eckfeldt, chief coiner, our uncle, Franklin Peale, then assayer, melter and refiner, afterwards chief coiner and inventor of the steam-coining press on which the first steam coinage was struck, March 23, 1836, Mr. Thomas Chauncey and a number of others. M. W. Baldwin was the only invited guest that did not accompany us.

William Norris, though a rival builder, was sincere in his congratulations, and made himself the life of the party. At our dinner at Lancaster he spoke with enthusiasm of the success and unexpected steadiness with outside connections, saying that from it he dated a new era in locomotive building; he could clearly see the time would come for increasing the number of driving-wheels, heavier engines, with a better distribution of weight on the road, making available and using more effectively the steam-power of the engine with less injury to the roadway; he called on the commissioners for their opinion of our engine.

Mr. Jas. Cameron replied that they had been very reluctant in consenting that an outside-connected engine should be built; that they had given way to Messrs. Sellers backed as they were by John Brandt in whom he had great confidence; that he must confess to being very agreeably disappointed, as all who had seen the performance could bear witness to the great steadiness of the engine on the road; he had ridden on all their engines, and this was certainly the steadiest; then turning to me he said: "You now see the wisdom of our insisting on the outside supports from the truck frame. Where would we have been left if the engine had been allowed to rock on its center-pin with every stroke of the pistons?"

When about taking the cars for the return trip, I crawled all around the engine; then standing on a level track, directing Mr. Cameron's attention to the side supports, I took hold of one and raised it clear of its bed groove.

"What," asked Mr. Cameron, "is the axle broken? We must have a new one put in before we start; I feared they were too light to bear the thrust."

Going to the other side, and taking hold of the other one I found it jambed, and was obliged to jar it with a hammer before I could raise it. "What," asked Mr. Cameron, "is this one also broken?"

I directed the pins to be taken out to show the slots. As this was being done Brandt came to my assistance, with the duplicates he had made in hand; showing them to Mr. Cameron with the ones that had been slotted, he said, "With your positive order I could not let the engine go on trial without having these in case they were required."

"Ah! Johnnie, Johnnie," said Mr. C., "you are a sad man, I see you believe in the old Scotch adage that the proof of the pudding is in chewing the string. I think this time you have chewed it pretty fine. I was going to say take off the things, but on second thought they had better be left on as a safeguard in case of rocking too far on a sudden lurch." The other engine went out without any side supports.

On our way back to Philadelphia my brother came from the engine into the car, and asked the commissioners how they liked the performance of the engine; the answer was, that it was perfectly satisfactory, and if we would call at their office, an order on the treasurer would be ready for us. We had no written contract; the understanding was if the engine performed satisfactorily we were to be paid $5,000. When I called I was handed a draft for $5,500, Mr. Cameron explaining that the $500 had been added for the lever attachment to throw part of the weight of the forward end of the engine on the drivers instead of applying the Miller attachment. [62]

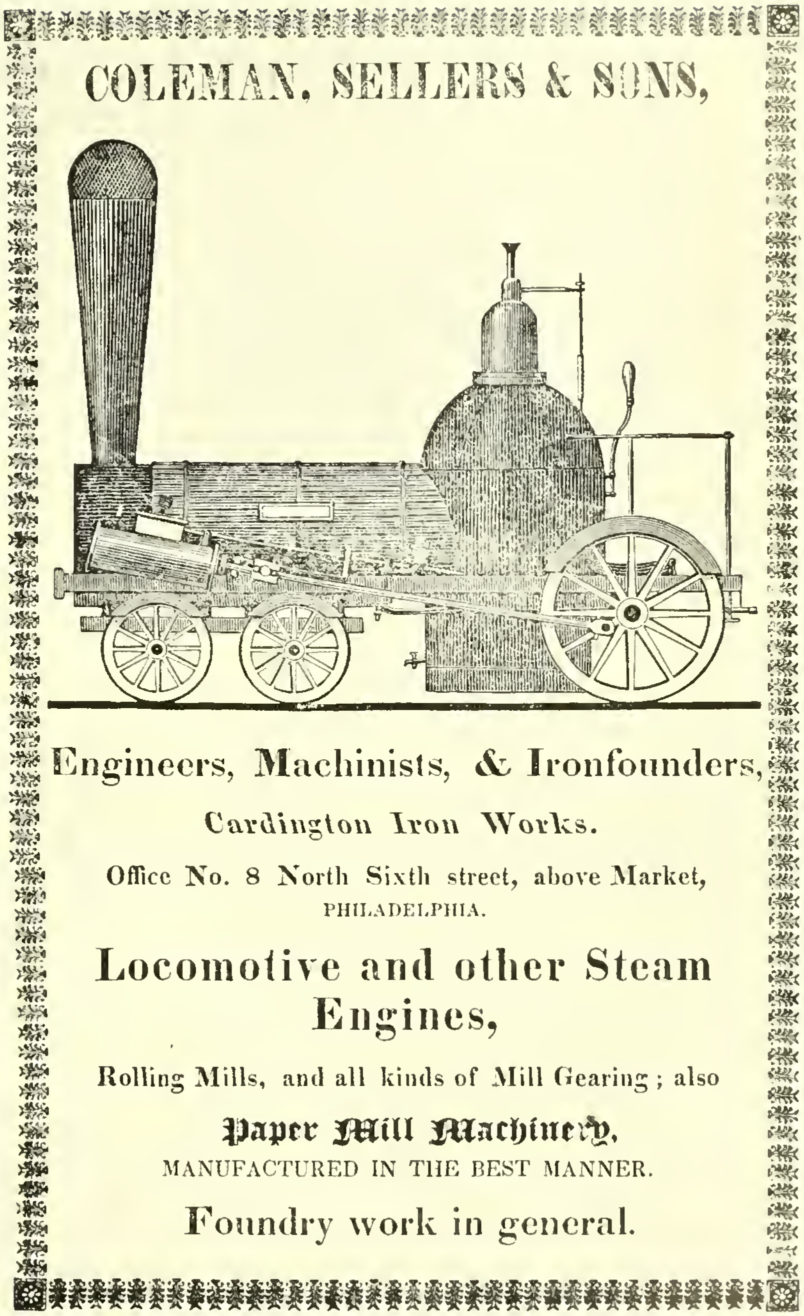

FIGURE 75.—Advertisement in *A. M'Elroy's Philadelphia Directory for 1839*, showing the Sellers locomotive as described by George Escol Sellers in the present chapter. Library of Congress photograph.

25. Phineas Davis and the *Arabian*

Another of Sellers's friends who had an important influence upon the design of early railroad locomotives was Phineas Davis. In 1831 Davis built the *York*, a locomotive with vertical boiler and vertical steam cylinder, with which he won a competition staged by the Baltimore and Ohio Railroad. Shortly afterward he accepted a position as manager of that railroad's Mount Clare shops. His successful career with the Baltimore and Ohio Railroad was cut short in 1835, when, at the age of 35, he was killed in the derailment of one of his locomotives.[234]

It is interesting to learn here how Davis's thinking may have been influenced by a visit to the Peale Museum, where he found a steam traction engine model built many years earlier by Oliver Evans, and by talking with Matthias Baldwin, who had not yet become involved with locomotive building but who had just completed his vertical stationary steam engine to drive the shop machinery of the firm of Baldwin and Mason.

At the Chicago National Railway Exposition [of 1883] there was exhibited, by the Baltimore and Ohio Railroad Company, an old relic of the most interesting character, the old locomotive "Arabian," an engine that went into service on that road in June, 1834, and has been well preserved, and was still doing good service in the yards of the Mount Clare workshops after a lifetime lacking but one year of a half century; undoubtedly the oldest effective locomotive in the world. I remember this engine on its first trial on the tracks at the machine shops, and as exhibited it is the same engine;[235] the only change I noticed was dispensing with the fan blowers that urged the fire and substituting the draft made by the exhaust steam.[236]

Seeing this old relic brought vividly to mind my first acquaintance with Phineas Davis, its designer and constructor, and incidents that occurred at the time of our first meeting, that I have no doubt had an influence in directing his mind in the bent that produced his first small 2½-ton engine built at York, Pa., and afterwards the "Arabian" built in the shops of the Baltimore and Ohio Railroad Company.

Peter Cooper's little engine, that was tried on the Baltimore and Ohio Railroad in 1830, has the credit of drawing the first passenger cars in America. If my recollection is not entirely at fault, it only made a few trips from Baltimore to the Relay House,[237]

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234 The sketch on Davis in *Dictionary of American Biography* refers to further biographical information.

235 The latest positive date that I have seen for existence of the *Arabian* is 1850, in the *24th Annual Report . . . of the Baltimore and Ohio* Rail Road *Company* (1850), table G, opposite p. 54. Before the 1893 exhibition certainly, and perhaps before the 1883 exhibition, the identity of the various grasshopper locomotives had been thrown into utter confusion by the renaming and "restoring" done for one of the exhibitions. On the other hand, I have seen no specific account of the *Arabian's* loss or scrapping. It was known as "No. 1" in 1860. See Lawrence W. Sagle, *A Picture History of B & O Motive Power* (New York: Simmons-Boardman, 1952).

236 The fan blowers, intended to promote the burning of anthracite coal, were patented by Phineas Davis on July 29, 1834. Two "fan wheels" (conventional forward-curving blade centrifugal blower fans) were directly driven by a "steam wheel," built "in the same manner nearly as the wind wheels," all mounted on a common shaft. The steam wheel was turned by exhaust steam. See figure 77, on page 183.

237 The Peter Cooper locomotive experiments were made in 1830 on the line to Ellicott's Mills. See J. Snowden Bell,

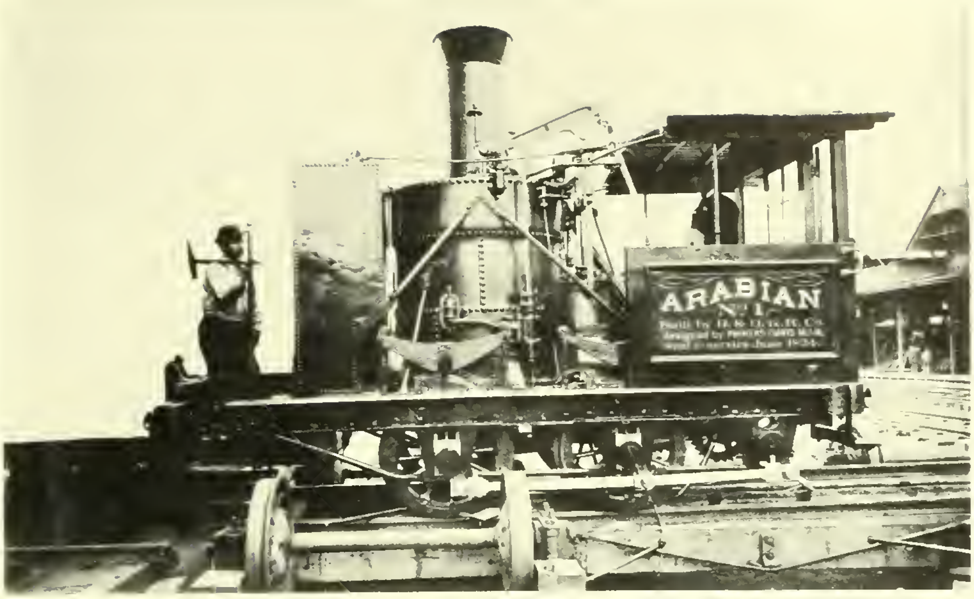

FIGURE 76.—*Arabian*, as displayed at the Chicago Exposition of Railway Appliances, 1883. Photo courtesy of Baltimore & Ohio Railroad.

and was followed by two attempts by Reeder, of Baltimore, neither of which was successful; then came Davis's little engine that took the place of horses, but was found too light for the increasing traffic even for the short distance to the Relay House and Ellicott's Mills, and Davis, who had become foreman of the shops or master mechanic of the road, designed the "Arabian," taking a bold leap for the time from a 2½-ton engine to one of 13 tons,[238] and that for a strap-bar rail on wooden stringers.

When George King, of York, Pa., a paper maker, would come to us for paper moulds (it was the time of hand-made paper), he always had something to say about Phineas Davis, a young man of York, whom he considered a prodigy in mechanics; he could turn his hand to anything; he could reface paper moulds with wire cloth, form the letters and devices in wire for water marks and sew them on the moulds as well as the most experienced hand; he told us of a patent lever watch that Davis had made, and so small that he could cover it with a levy, the old Spanish coin, the ⅛ of a dollar, in Philadelphia called eleven penny-bit or levy for short, and in New York a shilling. The next time Mr. King came to the city he brought the watch to show us; as I recollect it, it was about the size of our 20-cent piece. It was a beautiful piece of workmanship considering the tools Davis had at his command. Mr. King represented that he [Davis] had never had an opportunity of seeing how work was done outside of the watch repairers, blacksmith and gunsmith shops of York, that he was very anxious to see how work was done on a larger scale.

My father sent an invitation to him to pay us a visit, saying that my brother and myself would show him what we could among the shops. The little watch was left with me, and remained in my possession for some weeks until Phineas made his appearance. His stay was only a few days, but no time was lost, for a more eager one to see all that was to be seen I never met.

I cannot, with certainty, fix the date of this visit. It was either 1828 or 1829. Mason & Baldwin had just put in operation a small novel and ingeniously constructed vertical steam-engine in their works for manufacturing bookbinders' tools and calico-printing

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The Early Motive Power of the Baltimore and Ohio Railroad (New York, 1912), pp. 5–8.

[238] The *Arabian* was the third locomotive to be built by Davis after the *York*. The weight of the *Arabian* was given in an annual report as 7½ tons. See BELL (cited in preceding footnote), pp. 17–19.

cylinders.[239] This was particularly attractive to Davis, and Mr. Baldwin had much to say as to the importance of vertical cylinders not being subject to the wear of the piston and cylinder as in the horizontal engines, even going so far as to predict that, at no distant time, a horizontal steam engine would not be known, and as for water pumping engines, that are always subject more or less to sand and grit, the wearing was so serious on the lower side of horizontal cylinder that, although Mr. Frederick Graff had so arranged the cylinders of the great pumping engines at Fairmount dam, which supplied Philadelphia with water, that they could be taken out and rebored or replaced by new ones without disturbing the rest of the machinery, they would have to give way to vertical pumps. This evidently made a strong impression on young Davis. It must not be forgotten that this was before the time of efficient tools, and that the little cylinder of Baldwin's vertical engine was bored by hand by bits set in a wooden boring block.

From Mason & Baldwin's shop I took Davis to the Philadelphia Museum, which at that time was under the management of my uncle, Franklin Peale, with his brother Titian R. Peale as naturalist. I introduced Davis to the latter, whom we found in the taxidermic room busy among animal and bird skins, mounting specimens; this I thought would interest him, but I was mistaken, for as we passed through the little workshop of my Uncle Franklin, his eye had caught sight of a model steam-engine on wheels. This stood on a shelf nearly hidden by a heterogeneous mass of gimcracks piled over it, essays at perpetual motion, model churns, plows and such like, that had found their way to the museum and were not considered as worth being put on exhibition.

It was soon evident that Davis' mind was not on the work of the naturalist, for he began asking questions as to the steam-engine on wheels that he had only caught a glimpse of as he passed through the anteroom. My uncle took him back into the shop, and while removing some trumpery, to get a better view of the model, my Uncle Franklin came in and was much amused at Davis' eagerness and the questions he asked about it. He explained the model, and gave its history as being the joint work of his father, Charles Willson Peale, and Oliver Evans to produce a traction engine for agricultural purposes. I do not recollect that any date was named; I somehow got the impression that it was about the time that Oliver Evans moved the dredging scow from the works to the Schuylkill river by steam-power; this was in the year 1804. I cannot look back to a time that I did not know this model, for when a small boy I had been allowed to play with it and push it about on the floor of my grandfather's *play-shop*, as he called his, at his place near Germantown, and on one occasion I had seen it steamed up and running around in an irregular circle on a flat piece of ground, with a great propensity to turn on its side on meeting any trifling obstruction or enough steam given to accelerate its speed beyond a slow walk and to burn the fingers of the one attempting to right it. This was my experience on that occasion; it was very top-heavy.

Davis was so much interested that he asked permission to remove it to the work bench, finding it in better condition than expected; the remainder of the day into the night, was spent in overhauling it, and the next morning, in the presence of a crowd, that soon collected, it was started from the back steps of Independence Hall (the old State House), and made the trip the length of the square to Walnut street and return to the place of starting; on the back trip it ran into the side gutter and twice turned on its side.

I have no reason to doubt my uncle's statement that the miniature working model was the joint work of his father and Oliver Evans, and I cannot be far wrong in fixing its date as not later than 1805. In fact, since I commenced writing this article little circumstances as related to me by my grandfather in connection with the removal of the dredge boat from the works to the Schuylkill, its launching and its trip down the Schuylkill to the Delaware and up it to the foot of Market street on that river front, propelled by little paddle-wheels driven by the small steam-engine on board, convince me that the working model dates back to near that date, which was 1804. Previous to the death of my uncles I learned from them that at the time of the last removal of the Philadelphia Museum the model was in the store-room and in good preservation, and the supposition is that it was destroyed at the time that collection was burned. My hopes were that my Uncle Franklin, as a mechanic, had taken possession of and preserved it.

I believe that the conversation with Baldwin, on the value of vertical cylinders, and the day with the Evans and Peale working model gave the bent to Davis' mind

[239] This engine, preserved in the U.S. National Museum, was partially described by Franklin Peale in his obituary of Matthias Baldwin in *Proceedings of the American Philosophical Society* (December 1866), vol. 10, pp. 279–288. A complete account of the engine in its original state has not yet been found.

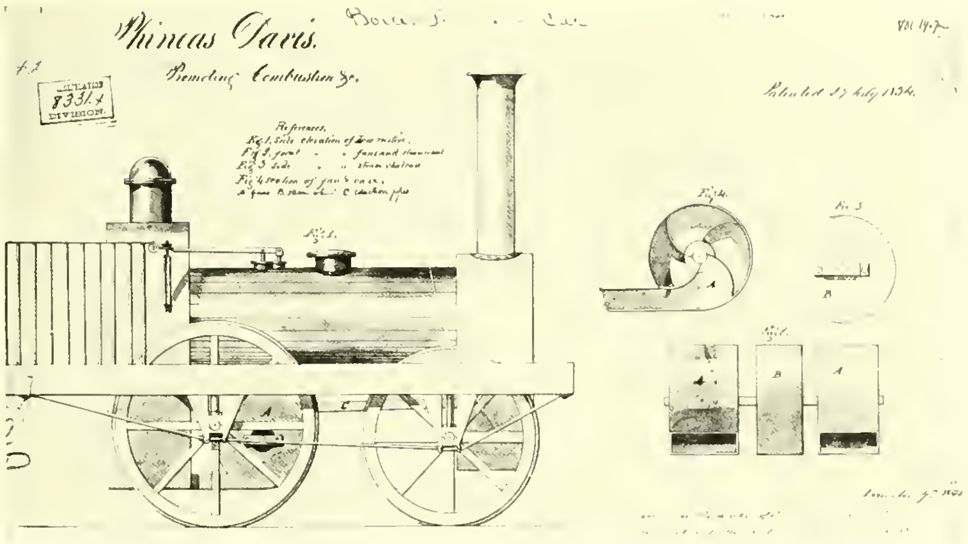

FIGURE 77.—Phineas Davis's device for "promoting combustion &c" in the burning of anthracite coal. Two "fan wheels or vanes revolving within drums [A] in a manner well known to machinists . . ." were turned by a "steam wheel" [B] built "in the same manner nearly as the wind wheels." From U.S. patent, July 29, 1834, restored drawing. National Archives photograph.

that he worked out so successfully in his "Arabian," as to make it the type of the engines that for several years effectively did the work on the Washington branch as well as the main line of the Baltimore and Ohio Railroad.[240] It is to be hoped the company will so dispose of the "Arabian" that it shall be perpetually preserved.

I cannot give a detailed description of the working model, but so much that its general character can be understood. The boiler was a wrought iron mercury bottle, say about 4 inches diameter and 12 inches long; holes were cut in the ends and through them 1½-inch inside diameter copper tube brazed to the heads, so that when placed horizontal, as it was in the model, it represented a single-flue cylinder boiler. The steam-engine was a single vertical cylinder, which was placed on a frame extending from one end of the boiler, its piston-rod connected directly to a lever beam, which had its long end journaled to a pair of straddle legs secured by rock joints to the top of the boiler; there were no guides to piston-rods, parallel bars being used instead, the connecting-rod working from the short end of the lever beam gave a longer sweep to the crank than the length of the piston stroke.[241] The crank was central on a shaft hung on the frame that carried the steam cylinder, a fly-wheel on each end of the shaft; to the arms of these fly-wheels were deeply grooved stud pulleys, from each of which chain belts ran to corresponding pulleys of a greater diameter on the axle of the carrying or driving wheels at or near the other end of the boiler; about the center of this driving axle was a single pulley from which a chain belt ran to one on the front axle, so that all the wheels were connected and the entire weight of the engine made available for traction, with the exception of what was carried on a pair of narrow-tread and narrow-tired guide wheels; they were hung on a lever arrangement so that the driver, with his foot on a treadle, could increase or decrease the pressure on the road. These guide wheels were governed by the driver through a pinion working in a segment of a tooth wheel; on the

[240] The Peter Cooper locomotive also had a vertical steam cylinder.

[241] This is a description of the Evans straight-line linkage. However, I have not found a positive attribution of it to Evans before the widely circulated engraved plate of the "Columbian" engine of about 1813.

model a screw clamp was arranged to secure the guide wheels in position as set. This was done in the case I have referred to when running in an irregular circle; the steam valves were revolving stop-cock plugs driven by bevel gearing from the crank shaft. The throttle valve was an ordinary brass stop-cock, no water feed pump; a funnel and stop-cock on top of the boiler to fill it, a stop-cock in the bottom to empty it.

The boiler was first filled with hot water to heat it, this was then drawn off and it was again filled with boiling water to a taper screw plug representing a gauge cock. To generate the steam a highly heated round iron rod, nearly filling the copper flue, was thrust into it . . . .

I have referred to having seen the "Arabian," on its first trial. The intimacy with Davis had been kept up from the time of his first visit to Philadelphia, and before he commenced building the "Arabian" he showed me his drawings. I chanced to be passing through Baltimore and stopped over to see Mr. Davis, and found him at the shops steaming up the "Arabian" for its first trial on the road, and I then rode with him on its open platform, for it was before the day of cabs. He spent the evening with me in Baltimore, and I have a very distinct recollection of many of the reasons he gave for having adopted the style of engine.

In the first place he had a light strap railroad to deal with, with many short curves; he must have weight to give adhesion; he must turn the curves without danger of running off, and with the least possible friction; to accomplish this the bearing on the road must be short; three-foot wheels, close together, met this; to carry the weight central, the upright boiler became a necessity. Trucks, if they had been conceived of, had not been successfully tried within his knowledge. Six tons at that time was the utmost admissible weight on four driving wheels; he was more than doubling this, and was afraid to take direct hold of the driving axle by crank; that no counterbalancing could prevent injurious hammering on the light rails. He believed this was greatly neutralized by the independent crank-shaft; the strain being within the machine, he did not think it would be injuriously transmitted through the cog-wheels. He considered the independent crank-shaft much safer than a carrying axle cranked; the outside connection of one pair of wheels to the other could be counterbalanced.

He did not calculate on fast running. That he said was further along. The problem he had to solve was an effective engine on light rails and short curves; the time would come when both these would be remedied. He certainly did produce the first effective engine on the Baltimore and Ohio Railroad, more than answering his own expectations. It for years drew the passenger trains on both the main road and the Washington branch, and was the model from which many others were built, and successfully lifted the company out of a state of great depression.

No one can overestimate the value of the preservation of early efforts in all branches of mechanical and civil engineering, relics, as landmarks in progress. I cannot better close this paper than by a quotation from a letter recently received from a well-known engineer, W. W. Evans, on the subject of preservation of models; he says: "No one knows the value of models of useful inventions until many years after they are made. John Stevens' first screw propeller, with its engine and boiler as it stands in the Stevens Institute, at Hoboken,[242] is to me a most interesting and invaluable model, and so would be the little locomotive made by Peter Cooper, if it had been preserved, as I understand that it actually did more when tried in proportion to weight and dimensions than did the celebrated 'Rocket' of Stephenson, which engine, now standing in the Patent Office in England,[243] I go to see everytime I go to England, and also to see another engine standing by it called 'Puffing Billy,' which engine preceded the 'Rocket,' in time, eighteen years. I take people to see it so they can judge of the improvements we have made in seventy-three years, as 'Puffing Billy' was built in 1812. Its axles have square ends, and the driving wheels are fastened on with wooden wedges; the frame is made of wood, and it is trued up only at such spots where an attachment was to be made; it is a 'rummey' looking affair, but it is very interesting to see it and then turn to the very splendid machines of the present day." [63]

I have heard Mr. B. H. Latrobe say that the "Arabian" never met with but one serious accident, and that caused the death of its designer and constructor. It was but a few days after our last evening together that the sad accident occurred. Mr. Davis was treating the workmen of the Mount Clare shops,

[242] Now in the U.S. National Museum.

[243] Now in the Science Museum, London.

with their families, to a trip to Washington and return. The road was then only opened as far as Bladensburg, from there to Washington in coaches. The trip was made, they dined in Washington, and on the return, when within fourteen miles of Baltimore, the engine left the track, turned on its side, killing Mr. Davis who was sitting on the platform; no one else was hurt. I believe the cause of the engine leaving the track was never discovered. By this one accident the world lost a mechanic who had proved himself to have been in advance of the age, and whose name should be remembered among the original men of the time, and a man who, had he lived, would not have been left behind in the race. It is to be hoped that the "Arabian" will be perpetually preserved as an undying monument to his memory.

26. Seth Boyden's Locomotives

Seth Boyden (1788–1870) was one of the most versatile inventors in America. Making significant contributions in several diverse fields, he had already applied his talents to the production of patent leather and malleable cast iron when, in 1837, he turned to the building of locomotives.

He built only three locomotives, the first two being the *Essex* and *Orange* for the Morris and Essex Railroad, which later became the Delaware, Lackawanna and Western. The third locomotive is accounted for in this chapter. Boyden's locomotives had an exceptionally long stroke, bearing a ratio to cylinder diameter of 3 to 1, in order to take advantage of the expansion of steam after an early cut off.

Bishop [244] relates that after building his three locomotives Boyden turned to the development of a stationary steam engine with variable cut off. While he did not patent a governor-connected cut-off valve gear, he was an early contender in the race that was won eventually by George Corliss of Providence.

MY EARLIEST RECOLLECTION of Mr. Boyden was about the time he was introducing his patent leather.[245] At that time he came to Philadelphia to see a leather-splitting machine that my father had invented, and had in daily use.[246] I do not know when their acquaintance and intimacy commenced, but I do know that it lasted until my father's death, which occurred in 1834. I recollect that my father frequently spoke of Mr. Boyden as a sound mechanic; a man of original thought, a most prolific inventor.

The leather-splitting machine that I refer to was for equalizing the thickness of calf or kip skin for machine cards, without torturing and twisting it out of shape as was the case when drawn against the edge of the splitting knife by being wound on a small roller. This my father accomplished by a solid cylinder or roller made of marble, having a circumference greater than the longest leather to be equalized. The wet leather, in strips a little wider than required for the card to allow of trimming, was secured to the cylinder by points in a groove set sufficiently below its surface to pass under the splitting knife without interfering; as

[244] J. LEANDER BISHOP, *History of American Manufactures from 1608 to 1860*, 3 vols., 3d. ed. (Philadelphia, 1868), vol. 2, pp. 546–548. Boyden's valve-gear, a modification of the ordinary slide-valve, is illustrated in GUSTAVUS WEISSENBORN, *American Engineering* (New York, 1861), pl. 42.

[245] This was about 1819, when Sellers was 11 and Boyden was 20 years older. See *Dictionary of American Biography*.

[246] Boyden's father, also named Seth Boyden, had patented his leather-splitting machine in 1809 (figure 79), and the younger Boyden had brought an improved machine to Newark, New Jersey, when he moved there about 1813 from Foxborough, Massachusetts.

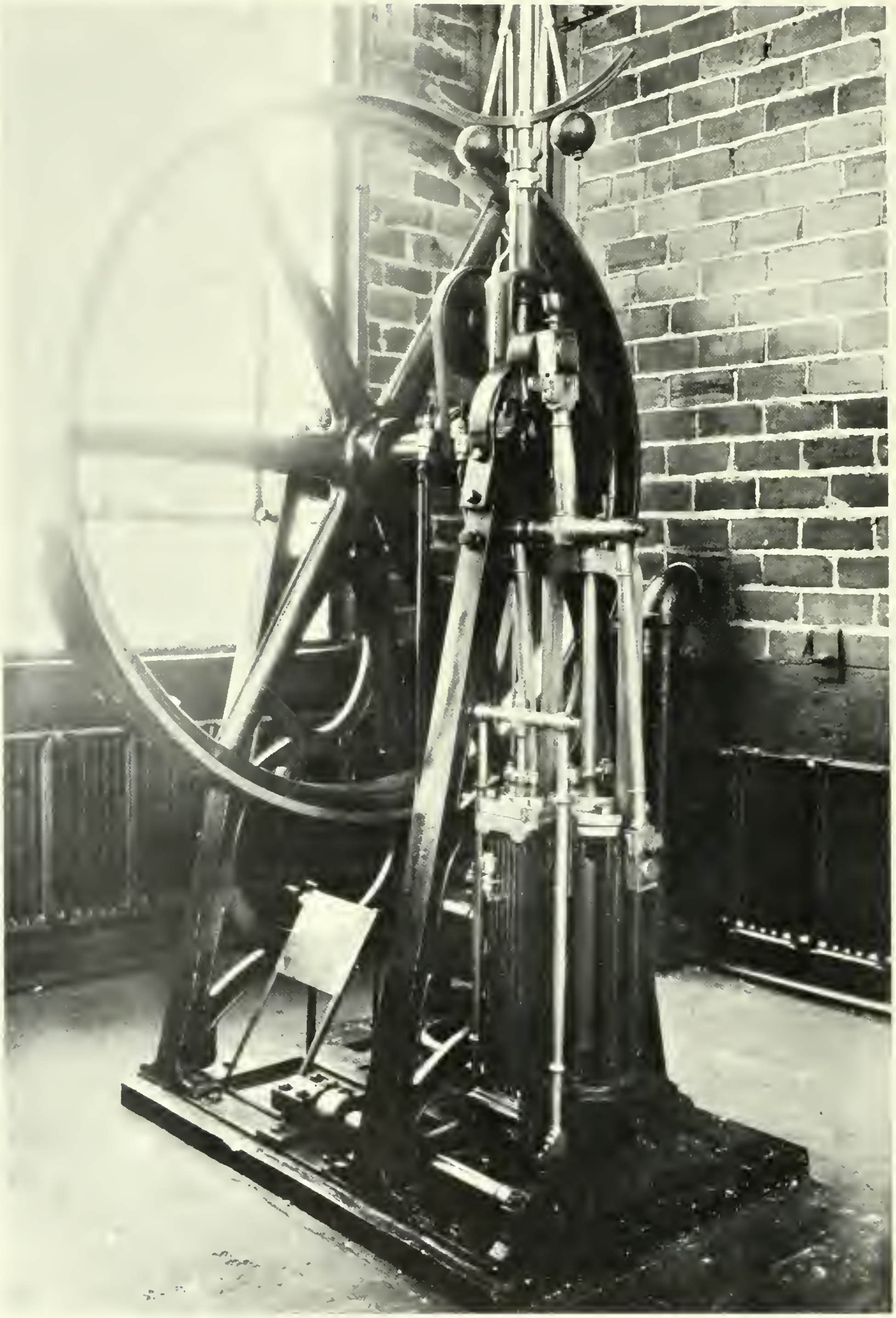

FIGURE 78.—Baldwin's stationary steam engine, 1829, shown after retirement, about 1920. The governor drive, originally consisting of friction wheels, had been modified and the flywheel had been replaced. The engine is now in the U.S. National Museum. Photograph courtesy of Association of American Railroads.

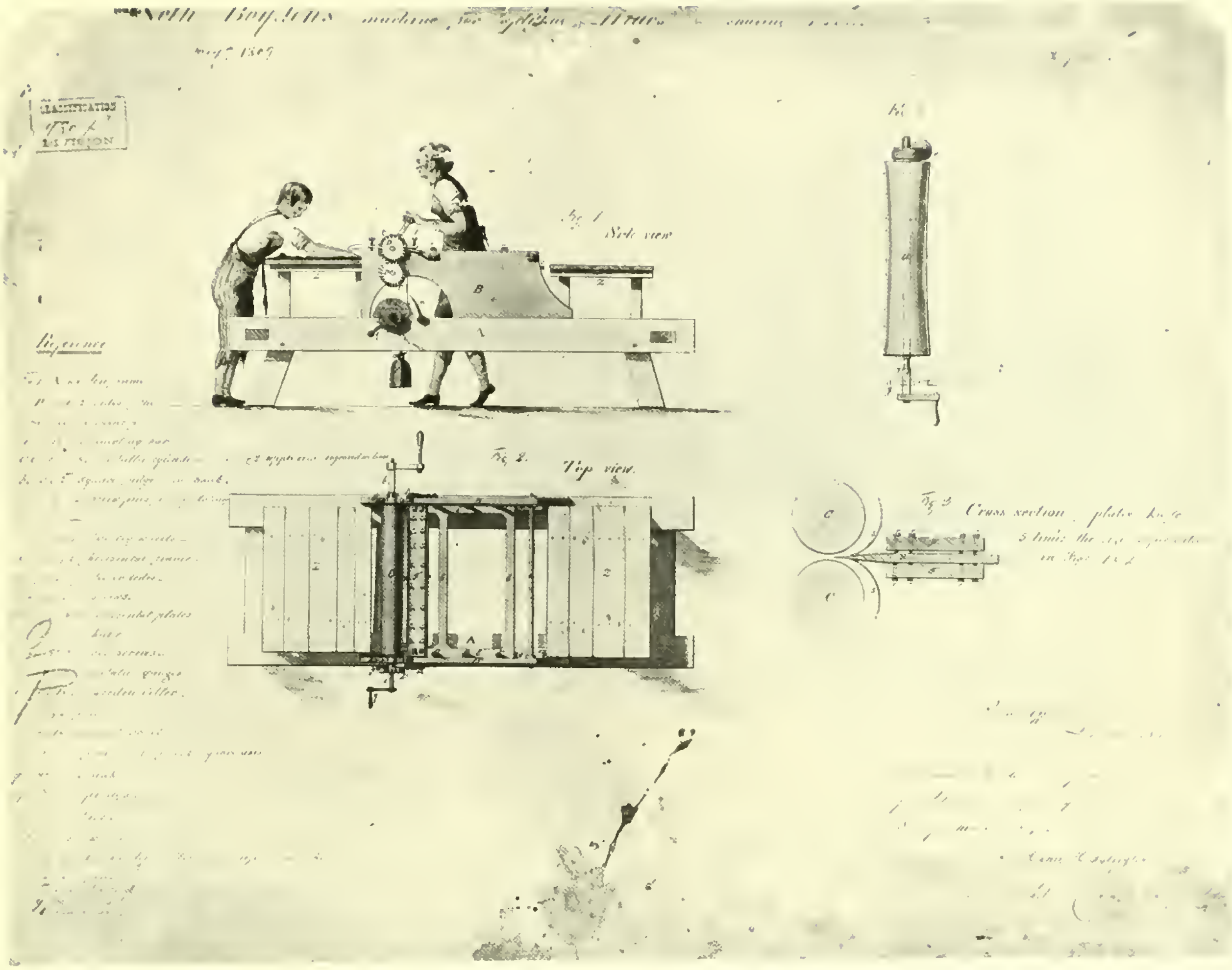

FIGURE 79.—Leather-splitting machine of Seth Boyden the elder, father of the Seth Boyden of this chapter. From U.S. patent, January 7, 1809, restored drawing. National Archives photograph.

the marble cylinder was turned under the knife, the wet leather pressed to it immediately in front of the knife by the ordinary spring straight-edge would hug to the cylinder, and pass through perfectly straight; a considerable portion of the shavings or splits, were valuable for boot stiffeners and other uses, that previously were lost by the usual currier's shaving. With this Mr. Boyden was much pleased, for he believed it would be practicable to get two sheets out of the common kip skin thick enough for japanning. It was not many months before he sent specimens The whole size of the skins less the skirtings, had been split into three, all beautifully japanned and highly finished.

The idea of japanning [varnishing] leather was not original with Mr. Boyden, for at the time of small clothes and fair top boots, it was as common to see the exquisites of the day claying their boot tops, as it was to have an immaculate black polish to the feet and legs, until there came from London patent white or buff-japanned leather for boot tops on which a damp sponge and soft dry cloth took the place of the clay cleaning. Mr. Boyden's invention, or rather discovery, was in the japan that would give the intense black hardness with high polish and sufficient elasticity at so low a temperature of the ovens as not to injure the leather. Years later he explained this fully

FIGURE 80.—Seth Boyden (1788–1870) From J. Leander Bishop, *A History of American Manufactures from* 1608 *to* 1860, 3d ed., 3 vols. (Philadelphia, 1868).

to me, and showed the memoranda of the immense number of experiments he had made before he had succeeded.

This leather-splitting machine I never saw, but his letters to my father at the time explained his substituting a moving table for the cylinder, various experiments as to the mode of holding the leather firmly to it, and to the edge of a quickly vibrating splitting knife.

Mr. Boyden is well known as the father of malleable iron castings, of which he made an entire success, and afterwards his great invention of manufacturing felt hat bodies by machinery, over which patent there was a long and bitter contest against a powerful combination. He resorted to the novel expedient of exhibiting his machine at work in the presence of judge and jury, and finally sustained his rights.

I have made this digression to show the versatility of Mr. Boyden as an inventor. I have heard him say the hardest work of an inventor was to discover what was wanted; that once established all was easy, or, as he expressed it, "plain sailing."

To return to the locomotive "Essex," and its mates. Previous to his entering into the contract to build the two engines above referred to he came to Philadelphia, bringing with him a movable card model of his proposed valve gear, in which he took the motion from the crosshead. He laid great stress on the importance of quick opening and closing of steam ports, so adjustable as to take the greatest advantage of using the steam expansively. I do not recollect the details of his arrangement. It was in a measure anticipating the present link motion. This model was so made that by moving the piston the position of the valve was shown. Baldwin at that time was confined to engine cylinders of from 10½ to 12 inches diameter and 16-inch stroke. My brother and myself were using 10-inch cylinders by 18-inch stroke. Boyden proposed using 8-inch diameter cylinder by 30-inch stroke with his adjustable cut-off, and he insisted on it that we were all wrong in the short stroke. He had made drawings to use Baldwin's half-crank to get width of fire-box. He had been to Messrs. Vail & Son, Morristown, N.J., to inquire about tires, and some heavy iron work, and had learned from them that the half crank was patented, and at the same time that we had outside attachment engines successfully running on the Pennsylvania State road; this brought him to Philadelphia.

He stated to me that before calling on us he had seen Mr. Baldwin, had tried to interest him in long-stroke engines, with his valve arrangement, and that Mr. Baldwin had declined to sell the right to use his half-cranks on the engines he [Boyden] had agreed to build for the Morris and Essex Railroad. He had many questions to ask about steadiness of the outside connected engines on the road. We at that time had two on the State road, one of which had been in daily service over a year. One of his questions was as to patents covering any portion of our engines, saying he would rather abandon building, and demonstrating the value of his hobby—expansive steam in long-stroke cylinders. I took him to our shops, showed him two engines then on the floor,[247] that but little was being done on, as we were driven to our full capacity on the contracts we had taken to build the steam engines, rolling mills, milling machines, ingot moulds, and melting and refining furnaces for the branch mints at Charlotte, N.C., and Dahlonega, Ga.; also remodeling the melting and refining departments of the mints at Philadelphia and New Orleans.

[247] The author seems to refer to two locomotives, in addition to the two already completed. No further information on these later locomotives has been found.

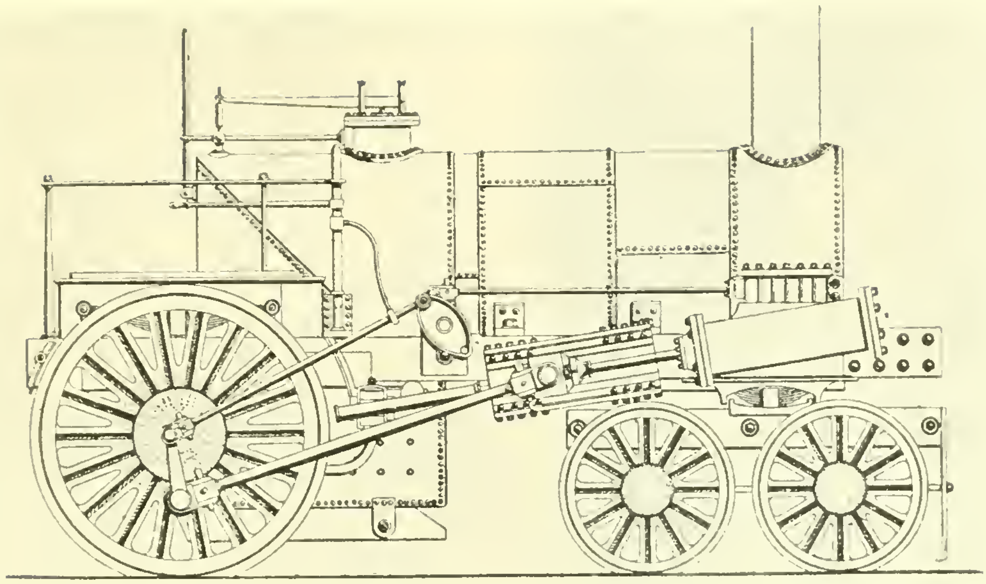

FIGURE 81.—*Orange*, 1837, built by Seth Boyden for the Morris & Essex Railroad. From Angus Sinclair, *Development of the Locomotive Engine* (New York, 1907).

I could not take the time to go with Mr. Boyden to the shops of the State road. I gave him a letter to John Brandt, who took him over the road on the platform of one of our outside connected engines. On his return he expressed himself as perfectly satisfied as to safety and steadiness of running. He had much to say as to the advantage he should gain in adhesion by placing his driving-wheel axle close to the fire-box. I do not know what took place between him and Brandt, but I was surprised at his saying, he had decided on 8-by-24-inch cylinders, and he laughingly said, that 6 inches over us and 10 inches over Baldwin was probably as much as it was safe to venture, but he believed the time would come, when the economy of fuel would demand it; that three feet stroke even if gearing had to be used, would be adopted: such was his faith in cut-offs and expansive use of steam, and when he had worked out a problem to his own satisfaction in his mind, there was no changing him. All the three engines he built had cylinders 8 inches by 24 inches stroke.

The third engine he built was not taken by the railroad that the two first were built for, and he took it to Cuba. The last time I saw Mr. Boyden was shortly after his return from Cuba. He then spoke hopefully of the success of what had taken him there. He had invented and used for a long time a system of furnaces for burning wet tan, the heat of one chamber drying the tan in the adjoining one, the escaping gases from which were ignited in a combustion chamber common to all the separate tan chambers. There were no grates, the tan being burned from the top. Mr. Boyden had, through a Mr. Hollibird, of Cincinnati, essayed to introduce his system of furnaces for burning and generating steam by the wet bagasse, as it came from the rolls of the sugar mill (the same as he had burned wet tan) in Louisiana. Mr. H. had only made it practically successful; hence his experiments in Cuba were under his own management.

If Mr. Boyden was now living he would be the last man to claim outside-connected engines as his system. As I have stated in a previous paper,[248] I never claimed it as an invention, but the battle for the practical introduction in our American system of locomotives devolved mainly on me, all of which Mr. Boyden was fully aware of, and having ridden on an engine that had been in successful use for over two years before his first engine was turned out, he was perfectly safe in assuring the experts "that it would not jump the track; if it did, the sooner the better." [64]

[248] Chapters 22 and 24 of the present work

27. George Escol Sellers Takes Leave of His Friends

Although this paper was only the 11th of the 40-odd published papers of George Escol Sellers, it makes an appropriate closing chapter because it ranges widely in time and geographical location, epitomizing the author's thorough, first-hand knowledge of more than 60 years of engineering in America.

The sharply etched vignette of an evening in the city of Washington during the Civil War gives the reader a glimpse of as distinguished a group of men as he is likely to encounter anywhere or at any time—Joseph Henry, omnierudite first Secretary of the Smithsonian Institution; Joseph Saxton; Stephen H. Long, explorer and engineer; Alexander Dallas Bache, guiding light of the Coast Survey; and John A. B. Dahlgren, of naval ordnance fame.

At the same time that the Pennsylvania works were progressing, Major Stephen H. Long, afterwards Colonel in the U.S. Army, and who, in his old age, succeeded Col. John J. Abert as head of the topographical department, was making the surveys and location of the Baltimore & Ohio Railroad, which work he continued until some time in 1830; I believe that during the last year Major George W. Whistler was associated with him, and he continued the work for a year or more after Col. Long left it. Col. Long was a New Englander, born in Hopkinton, New Hampshire, in 1784. He lived to the age of 80, dying in Alton, Ill., in 1864. His whole life was one of great usefulness. In the year 1829, while engaged on the Baltimore & Ohio, he published his "Railroad Manual" that became the text-book in the hands of all young engineers, it being the first work of the kind published in America. It was through him during the last year of his work on the Baltimore & Ohio, that I became acquainted with his assistant, Benjamin H. Latrobe, which acquaintance ripened into a life long friendship.

My acquaintance with Colonel Long dates back to the time he was a frequent visitor at my father's house previous to his expedition to the Rocky Mountains.[249]

About the time of his leaving the Baltimore & Ohio Railroad he took great interest in the question of locomotive power, and made a design and working drawings for a locomotive. He induced William Norris, then a merchant of Baltimore, to go into the business of locomotive building, and what was so long and favorably known as the Norris Locomotive Works, of Philadelphia, was established in 1832,[250] and the first engine built was from Col. Long's designs, and could not be called an entire success, but the second or third engine was eminently so. It was a six wheel engine, two drivers, and a four wheel truck. The drivers were in front of the fire-box and carried a large portion of the weight of the engine. It climbed the incline plane at Peters Island, on the old State road with a loaded tender and as many people as could hang on to it.

On one occasion, after Mr. Norris' return from Vienna,[251] where he had been building locomotives

[249] The expedition during which Long's Peak was named, occurred in 1819–1820. See *Dictionary of American Biography*.

[250] The firm was organized in 1832 as the American Steam Carriage Company, with Long as president and Norris as secretary. Norris bought out Long's interest in 1834 or 1835.

[251] William Norris returned from Vienna in 1848, went to Panama to work on the eastern division of the Panama Railroad, and returned again to the United States in 1855.

for the Austrian Government, in speaking of this first engine as the "Long" engine, and the vast strides that had been made in locomotives since it was built, he appealed to me to vouch as one who was present at its first trial for the truth of what he was about to state.

The trial was on the Columbia Railroad. I will use his own words as nearly as I can recollect them: "Gentlemen, I can, on my honor, assure you that we ran four miles and a-half in seven hours and a quarter, and running all the time at that." The engine was not so bad as he made it appear. It was deficient in its steaming, and primed badly. The great trouble came from not allowing play on the rails between the flanges of the wheels, between the cast iron chairs which were rigidly secured to stone blocks. The light T rails would spring so as to allow the tire to rest on the rail, but in passing the chairs the flanges would jam, often so much as to raise the face of the wheels from the rail, and the entire four and a-half miles were run by the almost constant use of the pinch bar. After this fault was corrected, and the priming partially prevented by the use of a wove wire diaphragm, the engine did pretty fair service.

From 1837 to 1844 Col. Long was chief engineer of the Western & Atlantic Railroad, of Georgia. It was when on this work that he displayed not only great engineering skill, but mechanical ingenuity in accomplishing a work with the limited means that were available. He crossed great ravines on trestle-work; in some cases series of bents or trestles one above the other, narrowing from the base to the road track, every timber so arranged as to be taken out and replaced in case of decay or any defect without interfering with the traffic on the road. Short spans were successfully crossed on his simple and cheap lattice bridges.[252] After he was recalled from his work in Georgia, he, for many years, had charge of snag removal and improvements of the Mississippi and Ohio rivers. He designed and had built the efficient snag boats, substantially as used at the present time.[253] He was then located at Louisville, Ky., and during that time my intercourse with him was frequent and of a most pleasing character. His leisure was employed on an elaborate series of experiments with models of wooden railroad bridges. It was a wooden inverted suspension arch, in one of these, I have been told, that set Remington off on his wooden suspension bridge, that for a time attracted considerable attention.

Figure 82.—Stephen Harriman Long (1784–1864). Portrait by Charles Willson Peale, 1819. Photo courtesy of Independence National Historical Park Collection.

It was about the second year of the civil war that business called me to Washington. Learning Col. Long had succeeded Col. Abert,[254] and was then the

[252] The Long truss, patented March 6, 1830. A specification and a restored patent drawing are in the National Archives.

[253] He shared with Henry M. Shreve and others the credit for the snag boat. See Louis C. Hunter, *Steamboats on the Western Rivers* (Cambridge, Mass.: Harvard University Press, 1949), pp. 193–195.

[254] A sketch of John J. Abert (1788–1863) appears in the first supplementary volume of *Dictionary of American Biography.*

FIGURE 83.—Joseph Saxton (1799–1873). From original photograph in National Academy of Sciences Library.

head of the Topographical Department. I called on him at his office. It had been over two years since we had met, and I was shocked at his evident failure and rapid aging during that short period. He said he was overwhelmed with work, but it was not that which was wearing him out; he had his duty to perform and was doing it to the best of his ability. He said many years of his life had been spent in the South. He had warm friendship for some of those then engaged in "this fratricidal war," and it was the horror of the thought of that, and not the work that was killing him. He felt he was not fit for the place he was filling, and would gladly retire and relinquish it to some younger man.

Night was coming on; it was after the hour for closing his office. I waited for him and together we walked from the department towards Willard's Hotel. He talked of old times, and gave a graphic description of the experiments which led to his efficient snag boats. We dined together, and then went to the house of Prof. A. D. Bache, then at the head of the Coast Survey, where we met Prof. Henry, Commodore Dahlgren and Joseph Saxton, my old schoolmate and friend. It was a most enjoyable evening, and I never saw Col. Long more animated than he was, when Prof. Bache read a letter just received from Commander Farragut on the great value of the work of the Coast Survey, which had enabled him to so place his gun boats under the banks and out of sight and range of the guns of the forts for protection of the harbor of New Orleans; that by calulation they could so handle the guns and mortars as to drop almost every shell within the forts. It was a most interesting sight to see Col. Long and Commodore Dahlgren, with maps, scale and compass locating these gun boats.

This was the last time I enjoyed the company of either Long or Dahlgren. The letters that for years I had been receiving from the Colonel dropped off. This I attributed to the heavy duties during the war, as head of the engineering department of the army. Some time in September 1864, scarce two years after the pleasant evening at Prof. Bache's, I saw a notice of the death of Col. Long at Alton, Ill., on the 4th of September of that year. No doubt his life was shortened by the cares and anxieties of the first years of the war. I have always considered him the leading engineer of his time, and I am not alone in that, for B. H. Latrobe referred to him as the father of the engineers of his day . . . . [65]

Appendix

Sources of Sellers' Text

The bracketed numbers in the following list correspond to those at end of quoted sections in the text. In this list "Volume" numbers refer to *American Machinist*; "Book" numbers refer to the George E. Sellers memoirs in Peale-Sellers papers at American Philosophical Society Library.

In Part I

[1], Vol. 9, May 29, 1886, pp. 4–5.
[2], Vol. 9, July 3, 1886, pp. 2–3.
[3], Vol. 7, October 11, 1884, p. 6.
[4], Book 20, pp. 1–3, 12.
[5], Vol. 7, October 11, 1884, p. 6.
[6], Book 20, p. 6.
[7], Vol. 7, October 11, 1884, pp. 6–7.
[8], Vol. 7, October 25, 1884, pp. 2–3.
[9], Vol. 7, November 1, 1884, p. 6.
[10], Book 20, p. 5.
[11], Vol. 7, November 1, 1884, p. 6.
[12], Book 4, pp. 1–5.
[13], Vol. 7, June 7, 1884, pp. 2–3.
[14], Vol. 7, June 14, 1884, pp. 1–2.
[15], Vol. 7, July 12, 1884, pp. 3–4.
[16], Book 4, pp. 31–34.
[17], Book 4, pp. 63–64.
[18], Book 4, pp. 37–50, 61–62.
[19], Vol. 7, August 9, 1884, p. 6.
[20], Vol. 7, August 23, 1884, p. 2.
[21], Vol. 7, August 9, 1884, p. 6.
[22], Vol. 7, August 23, 1884, p. 2.
[23], Vol. 16, May 4, 1893, pp. 2–3.
[24], Vol. 16, May 18, 1893, pp. 4–5.
[25], Vol. 16, June 8, 1893, p. 2.
[26], Book 4, pp. 54–55.
[27], Vol. 16, June 8, 1893, p. 2.
[28], Vol. 10, January 15, 1887, p. 1
[29], Vol. 16, June 8, 1893, p. 2.
[30], Vol. 10, January 15, 1887, p. 1.
[31], Vol. 16, June 8, 1893, pp. 2–3.
[32], Vol. 14, July 23, 1891, pp. 3–4.

In Part II

[33], Vol. 9, August 7, 1886, pp. 1–2.
[34], Vol. 9, August 14, 1886, pp. 2–3.
[35], Vol. 9, September 4, 1886, p. 2.
[36], Vol. 10, January 15, 1887, pp. 1–2.
[37], Vol. 10, February 12, 1887, pp. 2–3.
[38], Book 1, pp. 61–65.
[39], Book 1, pp. 13–16.
[40], Vol. 10, February 12, 1887, p. 3.
[41], Vol. 10, April 16, 1887, p. 4.
[42], Book 4, p. 37.
[43], Vol. 10, April 16, 1887, p. 4.
[44], Vol. 10, April 30, 1887, p. 4.
[45], Vol. 10, April 30, 1887, pp. 4–5.
[46], Vol. 10, May 28, 1887, pp. 2–3.
[47], Vol. 10, August 27, 1887, p. 2.
[48], Vol. 10, August 27, 1887, pp. 2–4.
[49], Book 4, pp. 13–14.
[50], Vol. 10, February 12, 1887, p. 3.
[51], Book 4, pp. 14–18.
[52], Vol. 7, December 13, 1884, p. 3.
[53], Vol. 9, September 4, 1886, pp. 2–3.
[54], Vol. 9, September 11, 1886, pp. 2–3.

In Part III

[55], Vol. 7, December 20, 1884, p. 2.
[56], Vol. 8, March 14, 1885, p. 5.
[57], Vol. 8, August 22, 1885, pp. 1–2.
[58], Vol. 8, April 11, 1885, pp. 1–2.
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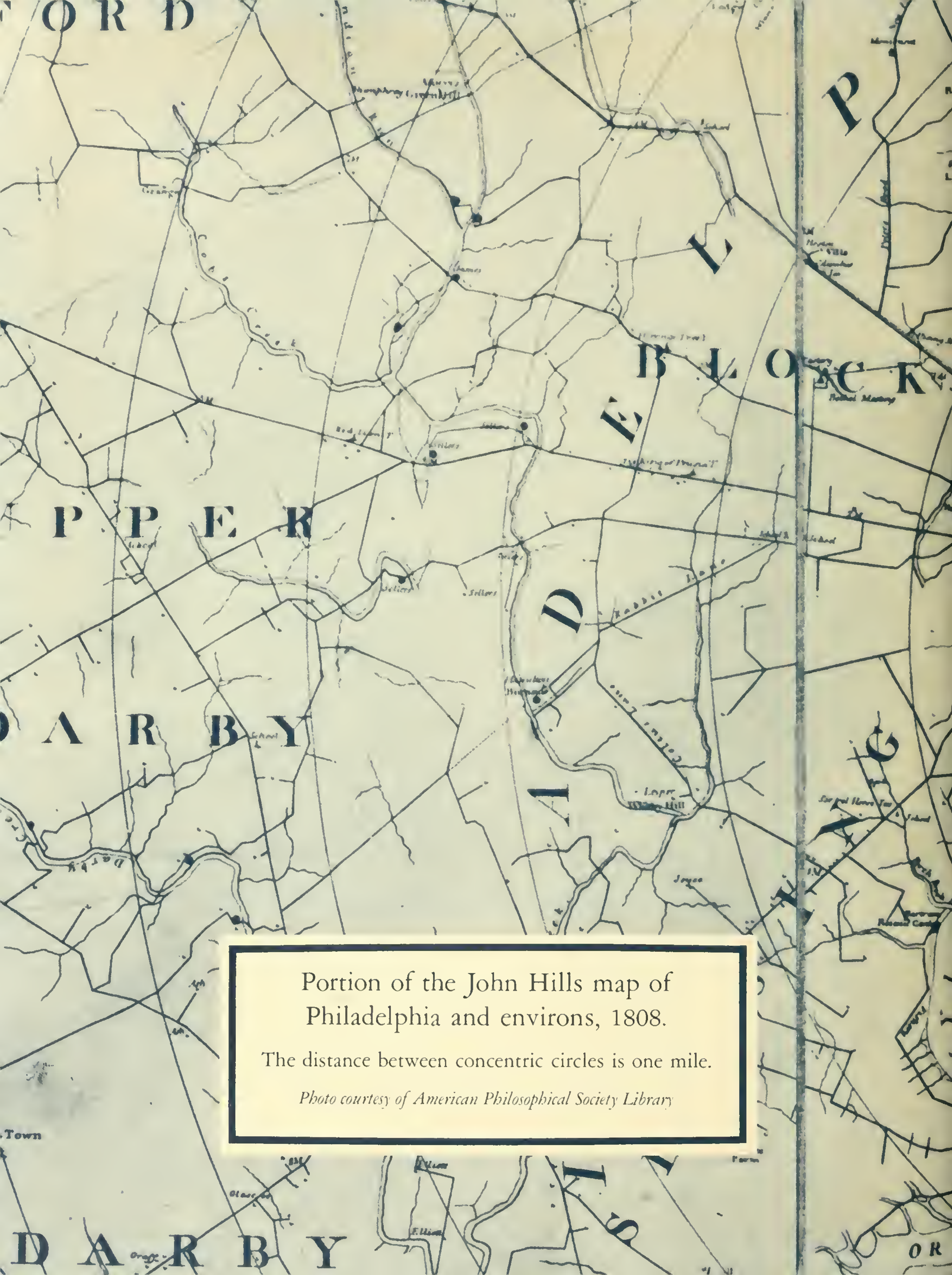

Portion of the John Hills map of Philadelphia and environs, 1808.

The distance between concentric circles is one mile.

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NORTHERN
EY
Kensington
Hamilton
Bush Hill
Spring Garden
RIVER
Southwark
Ship
Camden
Gloucester Point Road
Whitehall