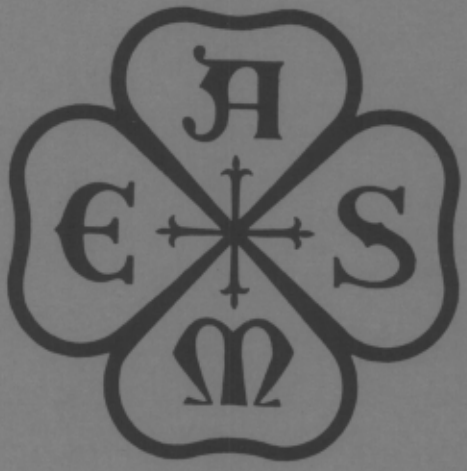
The 102-inch Boyden Hydraulic Turbines

at

Harmony Mill No. 3, Cohoes, New York



The American Society
of
Mechanical Engineers

Printed in honor of the occasion of its designation as
a National Historic Mechanical Engineering Landmark
American Society of Mechanical Engineers,
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HISTORICAL SIGNIFICANCE OF THE 102-INCH BOYDEN HYDRAULIC TURBINES

The two water turbines (Figure 1) which are being dedicated today as National Historic Mechanical Engineering Landmarks were probably the largest and nearly the most powerful water turbines ever built in the United States to supply direct mechanical power to a manufacturing plant. These turbines have been recognized as Landmarks not only by virtue of their size but also because their installation sometime between 1871 and 1873 makes them among the oldest surviving mill water turbines.

The machines are entirely intact and in excellent condition and represent a typical nineteenth-century application of water power. The fact that the turbines are still in place at the site where they were originally installed, and can be easily inspected, makes them unusual among surviving water power machinery.

The Landmark water turbines are of the Boyden type, which was the first turbine to be manufactured in quantity in the United States. Compared to its immediate predecessors, such as the Scotch turbine, it was a more sophisticated design and consequently was more efficient. This gives the Boyden turbine a particularly special place in the development of water power in this country.

Water power was the source of energy for the beginnings of industrialization in the United States and in other countries as well. In America one of the early industrial centers was in the geographical region at the junction of the Hudson and Mohawk Rivers, partly because of the substantial power provided by the 104-foot difference in level between these two rivers which exists at Cohoes. The growth and prosperity of Cohoes, and even the layout of the streets in the city, were closely tied to this water power. The Landmark turbines, are, therefore, of special significance to Cohoes, representing an example of the turbines that were originally used to power its textile mills and its industrial plants.

The turbines probably remained in operation until 1915 at which time Harmony Mill No. 3, and the other mills of Cohoes, converted to electric drive. The electric power was supplied from the newly opened hydroelectric generating station of the Cohoes Company, the owners of the water power canal system and the purveyors of hydraulic power to the various mills in Cohoes. The electric generating station drew water from the Upper Level Canal of the Cohoes Company. This station is still in use and is now owned and operated by the Niagara-Mohawk Power Corporation.

THE BOYDEN TURBINE

The Boyden turbine was derived from the Fourneyron turbine (1827) which was introduced into the United States about 1843 by Elwood Morris of Pennsylvania (2). In about 1844 U. A. Boyden (see biographical sketch in later section) greatly improved the performance of the Fourneyron turbine by providing a conical approach passage for the incoming water. In addition the water was more efficiently utilized by providing guide vanes in the outlet passages and by adding a submerged diffuser, and a diverging exit passage, which converted part of the kinetic energy of the discharging water into pressure and hence increased the effective head across the turbine (Figure 2).

The Boyden turbine is of the outward flow type in which the water is supplied to the inside of the runner and flows outward. This tends to have a detrimental effect on the efficiency of the machine because its passages are diverging and the flow, in consequence, tends to become separated with a resulting loss of energy in eddy formation. The machine also is expensive to manufacture, difficult to maintain, and the speed cannot be governed closely.

Because of its limitations, the Boyden turbine was superseded by the inward flow turbine, in which the direction of water flow is opposite to the direction in the Boyden machine. The inward flow turbine was first patented in the United States by S. B. Howd in 1838 (1, p. 61) but the design was greatly improved in 1849 by J. B. Francis (1) so that this type has since become associated

with his name. The Francis turbine, and its variants, is now the most widely used turbine in situations involving medium heads and large flow rates.

One of the surprising things about the Cohoes turbines is the fact that they are Boyden turbines rather than Francis turbines, as might be anticipated in view of their date of installation (1871 to 1873) (4) by which time their limitations were probably well known to turbine users. However, this is not the only instance of the comparatively late use of outward flow turbines since Fourneyron turbines were used in the original Niagara Falls hydro-electric installation in 1895.

DESCRIPTION OF THE LANDMARK BOYDEN TURBINES

The two Landmark turbines are located in the basement at the south end of Harmony Mill No. 3 in Cohoes, New York. They were built by the Holyoke Machine Company and installed between 1871 and 1873 (4).

The machines are arranged with their shafts vertical and were supplied with water from level number 2 of the Cohoes Company power canal system. The water was discharged from the turbines into a pit in which the turbines are located, and this water was carried away in the canal of level number 3 of the power system to supply other mills.

Power was taken from the turbines through bevel gearing and a common horizontal shaft. This shaft drove pulleys which, through belts, transmitted the power to each of the five floors of the mill. The main pulley and line shaft system is no longer in existence.

The north end of Number 3 Mill, which was built between 1866 and 1868, originally contained three Boyden turbines which were used to drive the machinery in that portion of the building (figure 3). These were smaller than the Landmark turbines, possibly because at the date of their installation the necessary technology had not been developed to permit the construction of larger machines. The smaller turbines are no longer in existence having been sold for scrap at an unknown date.

The specifications of the Landmark turbines are as follows:

Type: Boyden outward flow

Size: 102-inch diameter runner

Horsepower: 800

Speed: unknown

Head: 20 feet (estimated)

Manufacturer: Holyoke Machine Company, Holyoke, Massachusetts

Date: 1873-1896 (exact date is uncertain)

THE PLAQUE

The plaque denoting that the Boyden turbines located in the Harmony Mills have been designated as National Mechanical Engineering Landmarks bears the following words:

102 INCH BOYDEN HYDRAULIC TURBINES

CIRCA 1872

Among the largest of their time built by the

Holyoke Machine Company for the Harmony Mills,

Cohoes, New York

BIOGRAPHICAL SKETCH OF U.A. BOYDEN AND J.B. FRANCIS

The Boyden turbine was invented by Uriah Atherton Boyden, an early American hydraulic engineer whose portrait is shown in Figure 4. Boyden was born at Foxboro, Massachusetts, on February 17, 1804. He was involved in various aspects of mechanical and civil engineering, eventually becoming associated with the Amoskeag Manufacturing Company for whom he designed a hydraulic power system at Manchester, New Hampshire. In 1844 he designed an improved version of the Fourneyron turbine, which now bears his name, for the mills of the Appleton Company at Lowell, Massachusetts. At about this time he is reputed to have invented the hook gage which is used for measuring the head at a weir and hence the volumetric rate of flow across the weir (1, p. 18). About 1850 Boyden moved to Boston and devoted the greater part of the remainder of his life to scientific investigation. In 1874 he deposited $1,000 with the Franklin Institute of Philadelphia to be awarded to any resident of North America who should determine by experiment whether light and other physical rays are transmitted at the same velocity. This prize has never been awarded. He died in Boston, Massachusetts, on October 17, 1879 (5).

The design procedures used by Boyden for his turbine were undoubtedly quite simple with a strong content of empiricism but were placed on a rational basis by James Bicheno Francis (1, p. 44), a distinguished nineteenth-century American Hydraulic engineer, and inventor of the Francis turbine which was the successor of the Boyden turbine.

James B. Francis was born at Southleigh, Oxfordshire, England, on May 18, 1815. At the age of 14 he became assistant to his father who was superintendent of a railroad and harbor company in Wales. In 1833, at the age of 18, he emigrated to the United States and was immediately employed as an assistant engineer on the construction of the Stonington and Providence Railway. In 1834 he entered the employment of the Locks and Canals Company in Lowell, Massachusetts, becoming Chief Engineer in 1837. He remained with

the Locks and Canals Company for 48 years, that is, for most of the remainder of his professional life. From the time of his retirement until his death on September 18, 1892, he was Consulting Engineer to the Locks and Canals Company (6, 7, 8).

James B. Francis can be regarded as the originator of the scientific method of testing hydraulic machinery. The design rules that he devised for the Boyden turbine were based on the results of a series of systematic tests that he carried out at Lowell under the auspices of the Locks and Canals Company. The results of the tests were published in 1855 in Lowell Hydraulic Experiments (1) and have been a model for all subsequent hydraulic turbine testing and represent an outstanding American contribution to hydraulic engineering.

Francis was a founder member of the American Society of Civil Engineers and was elected President of the Society in 1880. A portrait of Francis probably made in about 1887 is shown in Figure 5.

ACKNOWLEDGEMENTS

The Hudson-Mohawk section of the American Society of Mechanical Engineers would like to acknowledge the assistance of the following in connection with the dedication: Cohoes Industrial Terminal, Inc. and, in particular, Mr. W. J. Magee, Executive Vice President, for permitting the 102-inch Boyden Hydraulic Turbines to be dedicated as National Mechanical Engineering Landmarks; the General Electric Company and, in particular, Mr. H.R. Hill, Vice President and General Manager of the Steam Turbine-Generator Products Division for providing financial assistance for the production of this brochure; Mr. R. M. Vogel, Curator of Mechanical and Civil Engineering, Smithsonian Institution, Washington, D.C., for supplying valuable advice and information, and some of the illustrations that appear in this brochure; Professor Edwin Layton, Case Western Reserve University, for assistance in locating a portrait of U.A. Boyden; Mrs. Susan Harris who typed and retyped numerous drafts of this brochure.

The Hudson-Mohawk Section would like to especially acknowledge the efforts of Professor E.F.C. Somerscales of Rensselaer Polytechnic Institute for his work in researching the background for this Landmark award and authoring the brochure. Professor Somerscales is Chairman of the Section's History and Heritage Committee.

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5. Boyden, Uriah Atherton, National Cyclopedia of American Biography, Vol. 11, p. 88, New York: White, 1909.

6. James Bichino Francis, Past President and Honorary Member, Proceedings ASCE, 19, 74-88 (1893).

7. James B. Francis, Engineering News, 17, 14 (1887).

8. James B. Francis, Engineering News, 28, 266 (1892).

CAPTIONS

Figure 1. The Landmark Boyden water turbines viewed from the northwest (photograph by Jim Shaugnessy).

Figure 2. Boyden type turbine manufactured by the Holyoke Machine Company. This is not one of the Landmark turbines but is an illustration of a similar machine taken from the company catalog of 1876.

Figure 3. Arrangement of the turbines and line shafting in the north end of Harmony Mill No. 3. A similar arrangement was probably used with the two Landmark turbines in the south end of the building (from Leigh, E., The Science of Modern Cotton Spinning, 2nd edition. Manchester, England: Palmer & Howe, 1873).

Figure 4. Uriah Atherton Boyden from a Daguerreotype taken about 1845 (courtesy Smithsonian Institution, Washington, D.C.).

Figure 5. James Bicheno Francis about 1887 (from a photograph in the Proceedings of the American Society of Civil Engineers, Volume 19, p. 74, 1893).

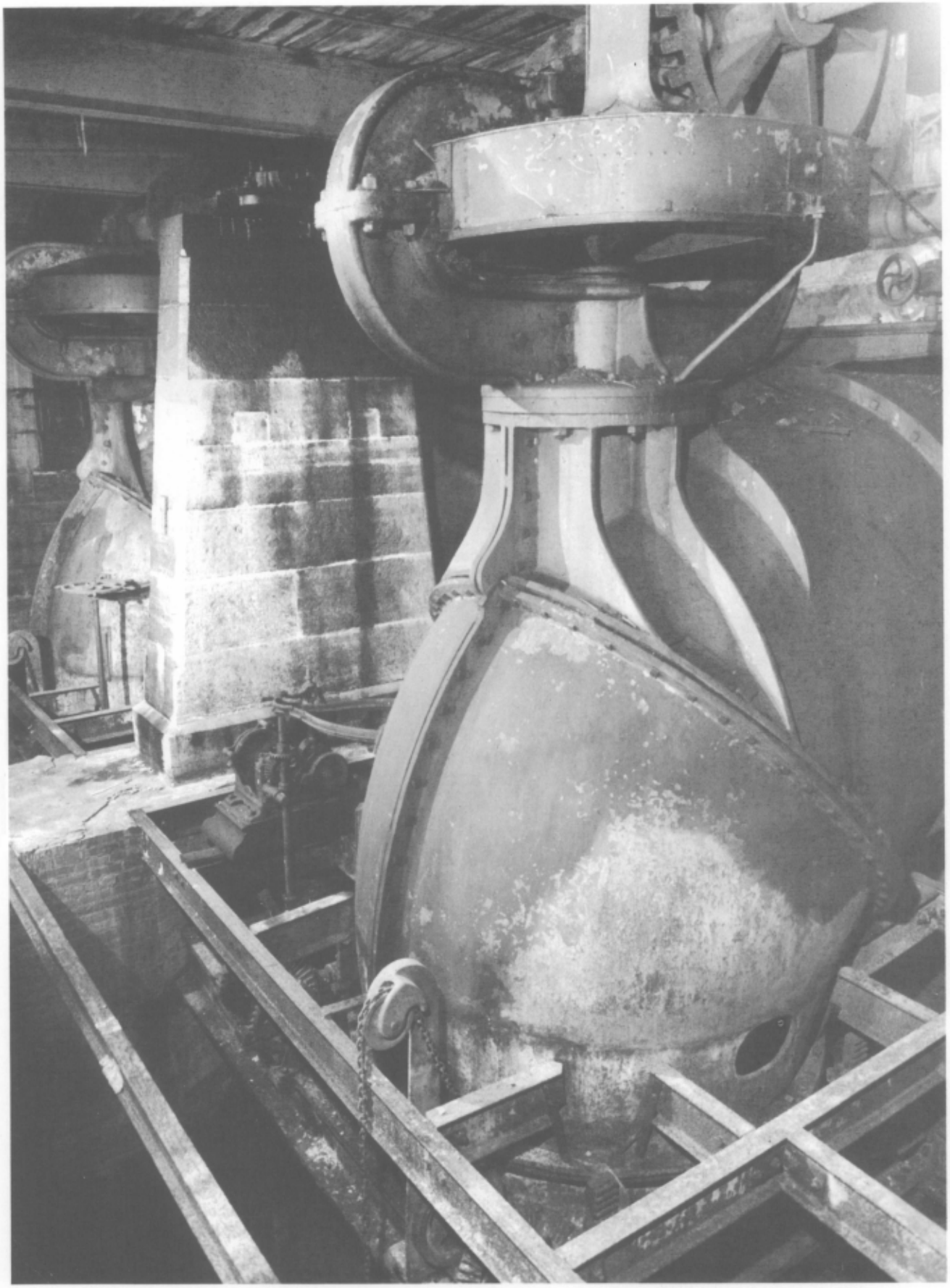
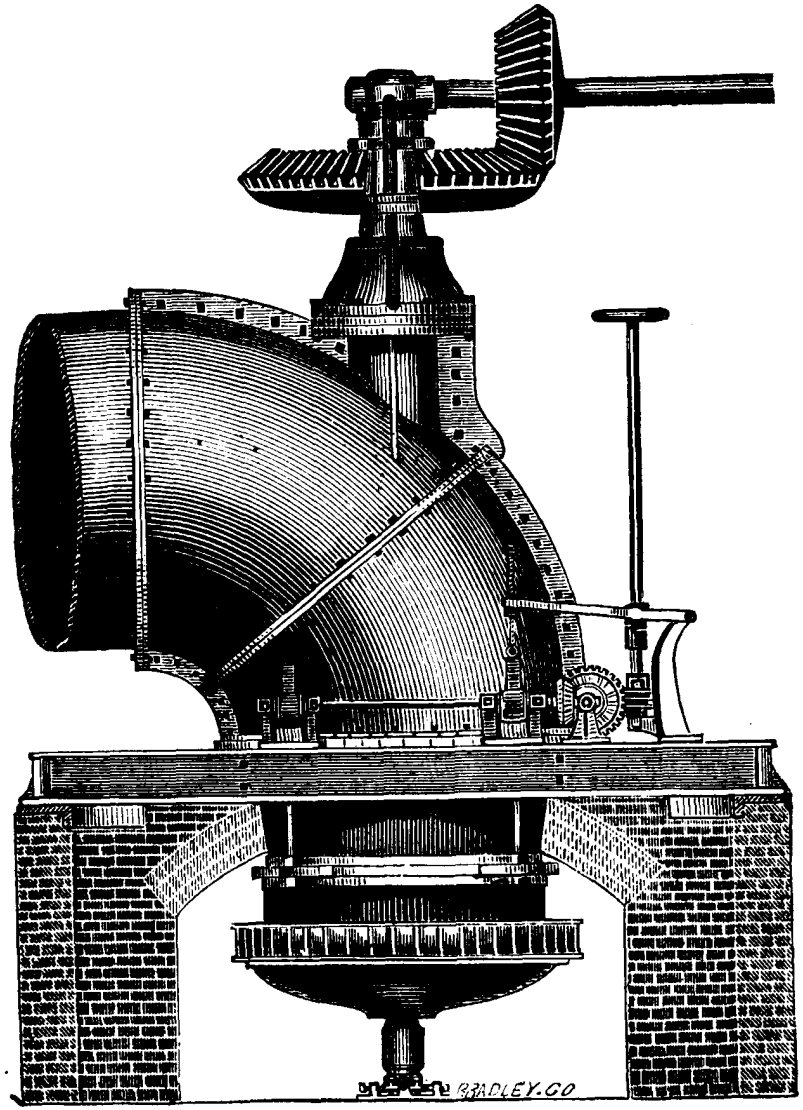


Figure 1.



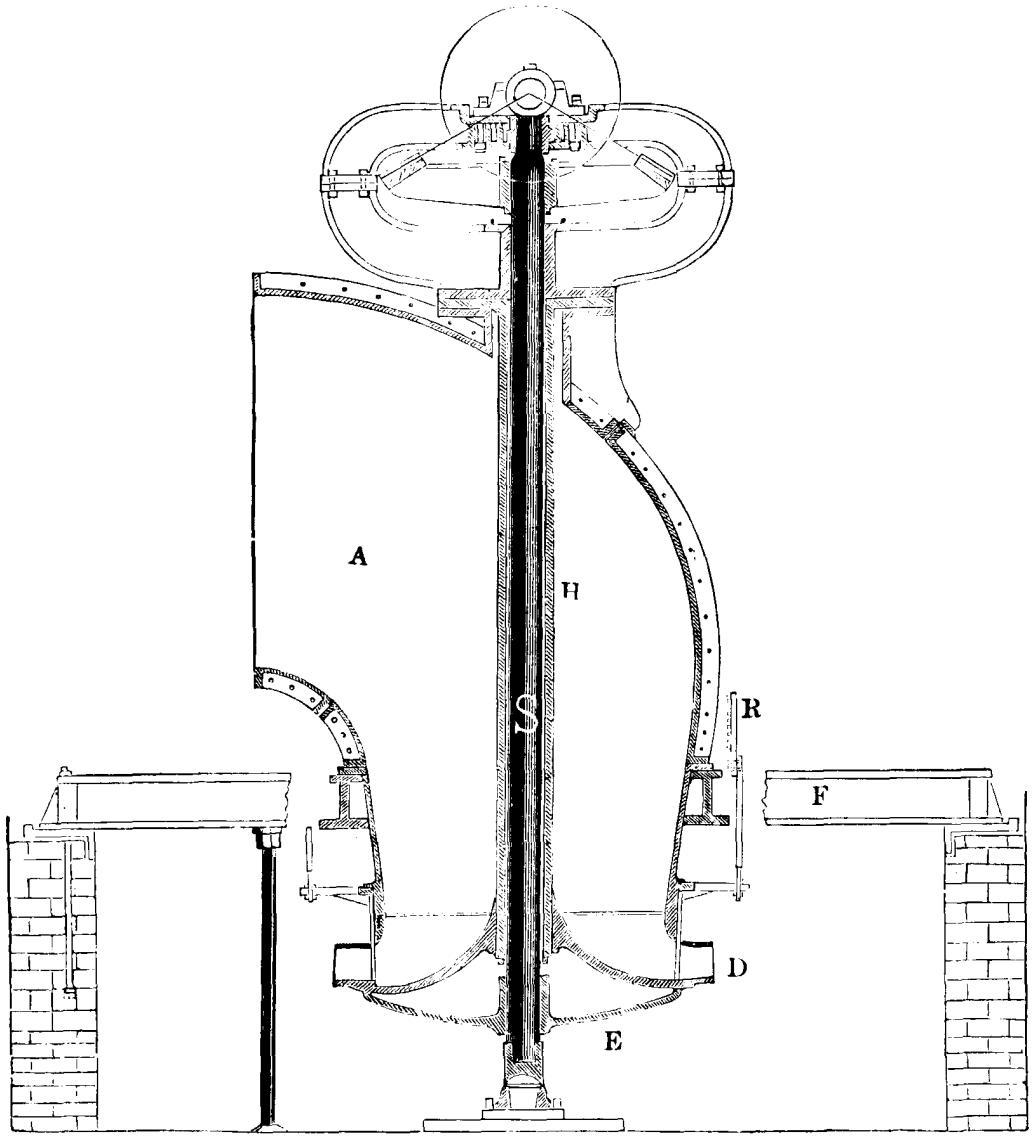


Figure 2.

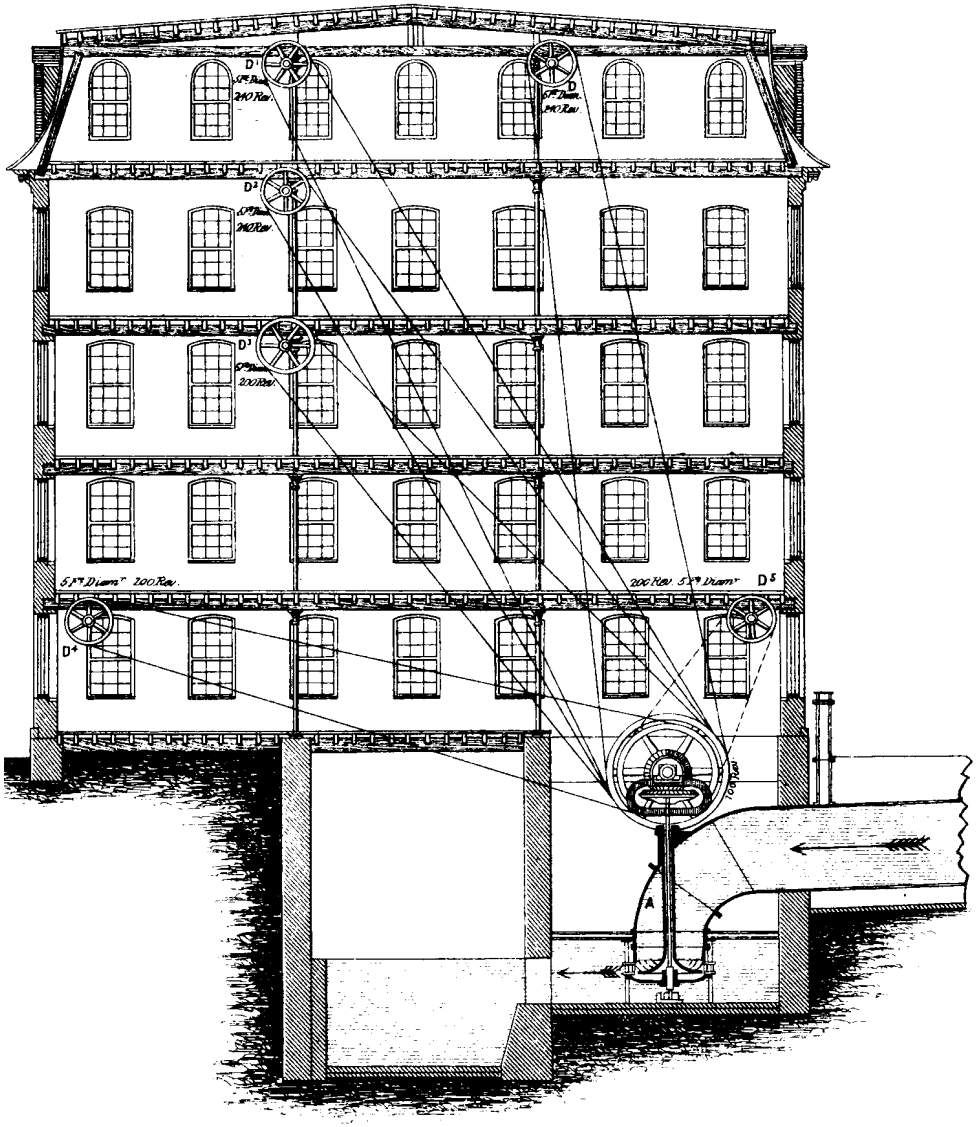
HARMONY MILL, Nº 3, COHOES, N.Y.

a

SCALE OF FEET.

50 Feet 40 30 20 10 5 0

SECTION OF MILL SHOWING TURBINES AND BELTING.



PART PLAN OF MILL AND TURBINES.

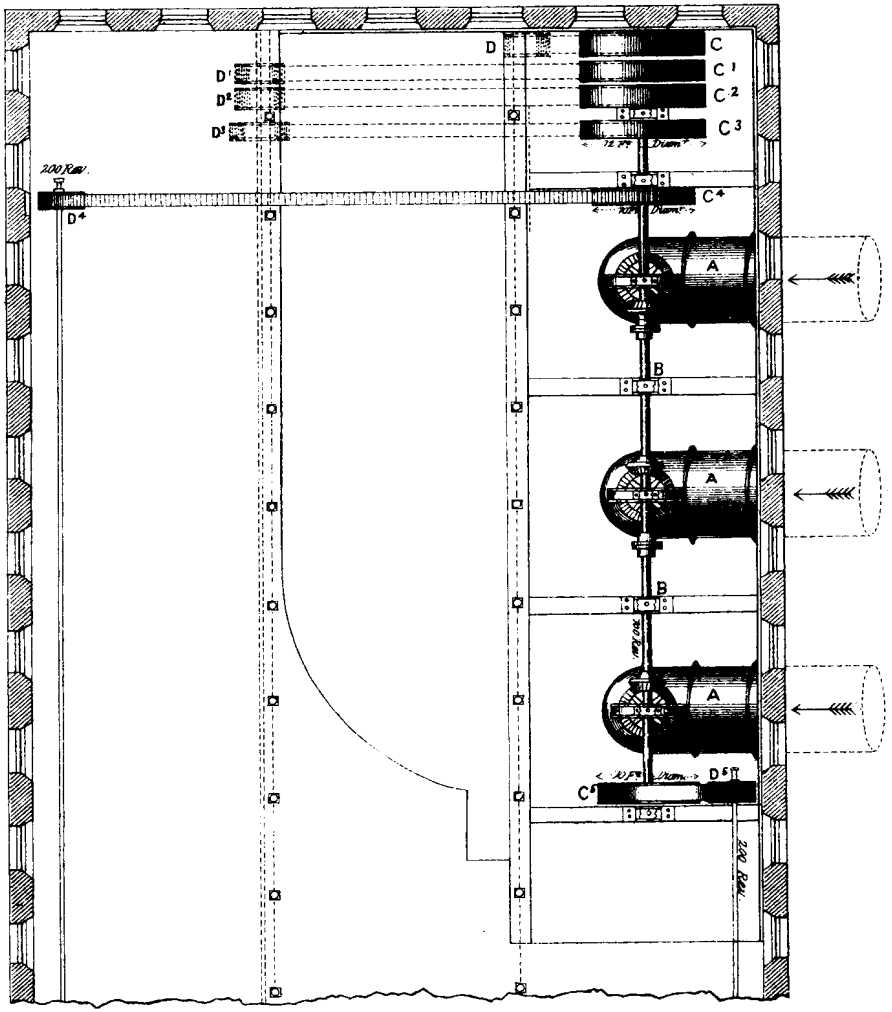


Figure 3.

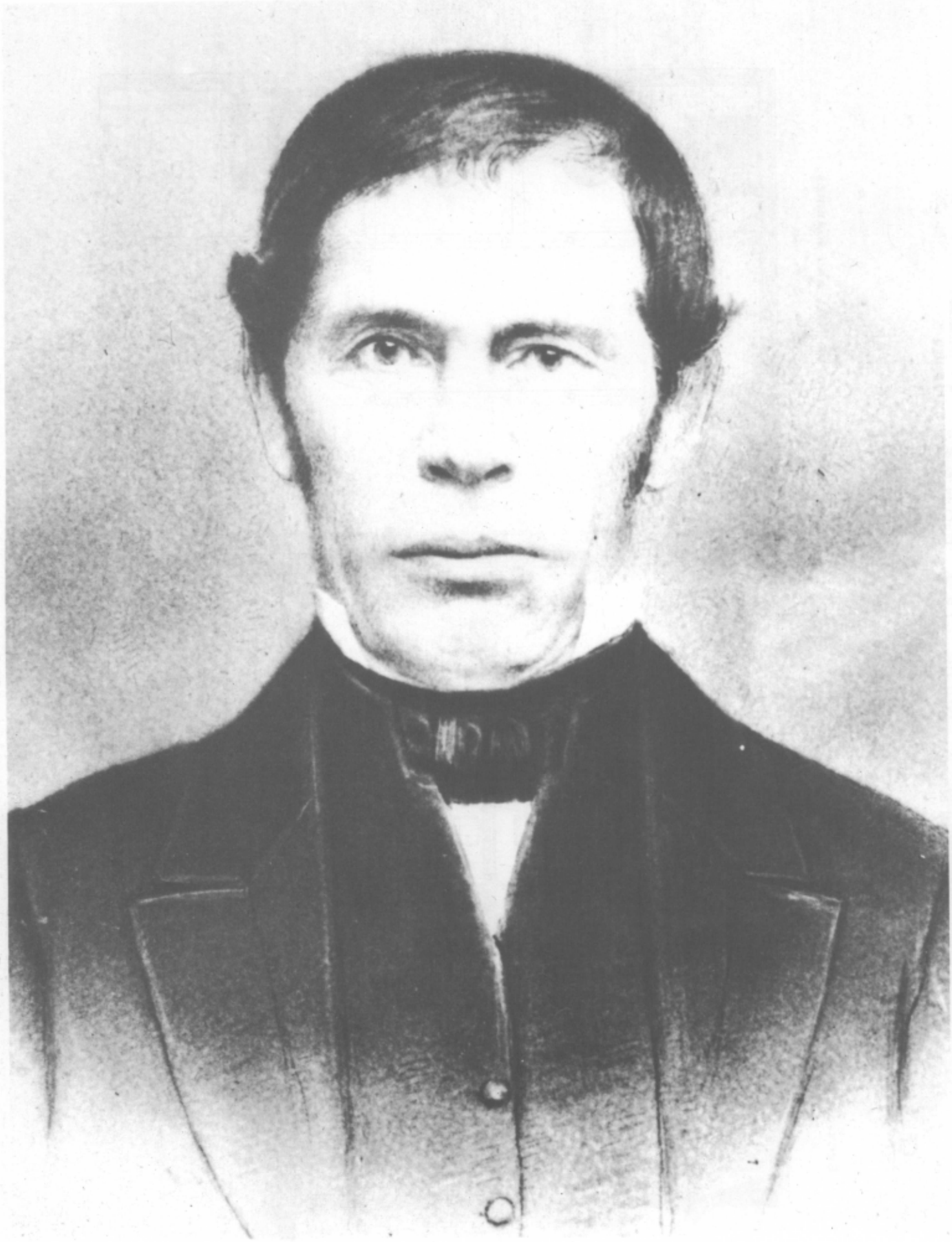


Figure 4.

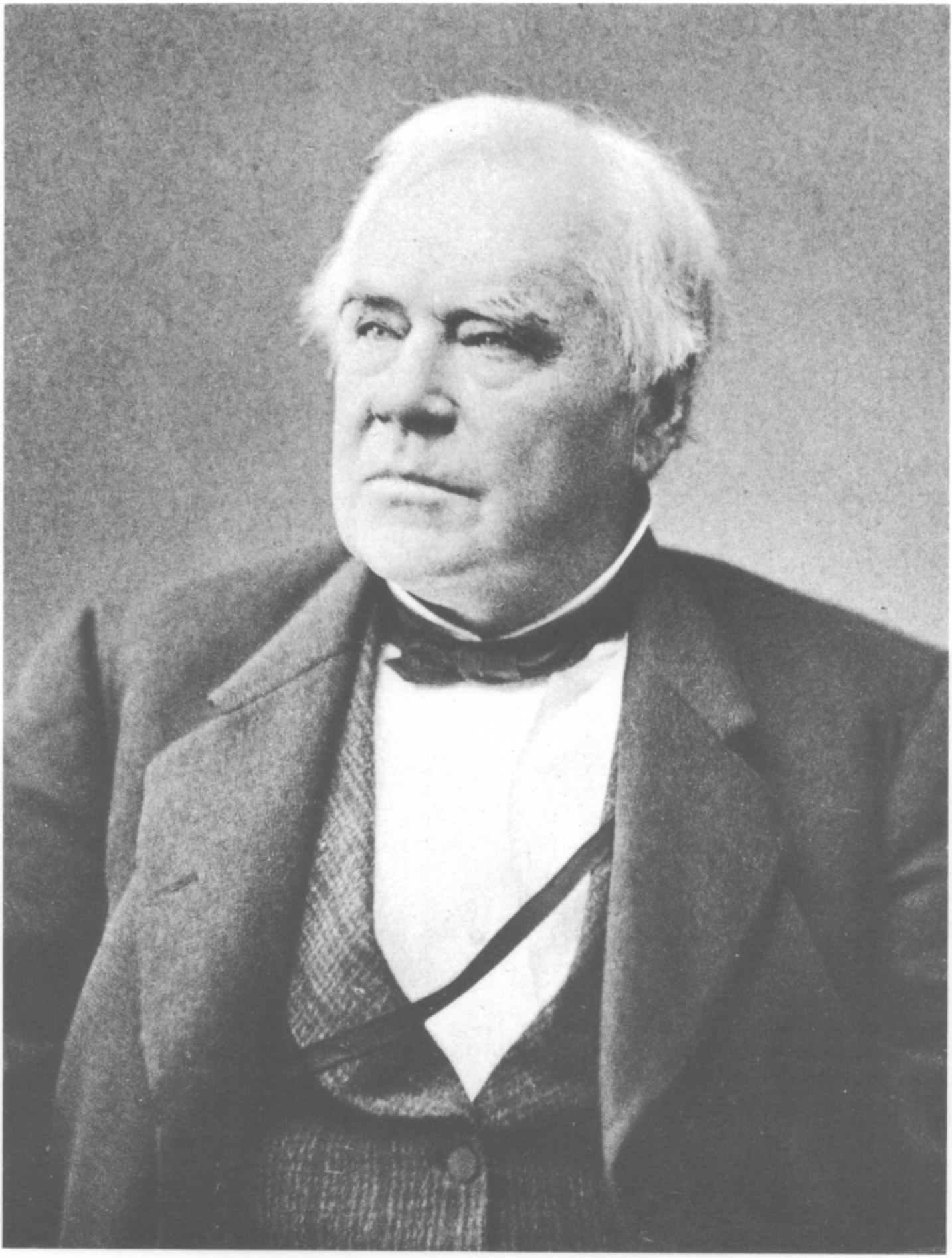


Figure 5.