SETTING THE STANDARD

Batavia, Illinois, Windmill Collection

A Mechanical Engineering Landmark

Overview

This collection of early mass-produced self-governing windmills is located in Batavia, Illinois, their site of first manufacture. From the 1860s until the 1950s, Batavia, Illinois, was home to six companies manufacturing windmills that greatly accelerated America's ability to settle "the West."

Windmills of various designs have been known for many centuries throughout the world, principally for lifting water and grinding grains. Immigrants brought Dutch-style and other windmill designs to the New World as early as 1621. These designs were complete buildings built on-site, requiring the care and maintenance of a full time miller. In colonial New England, given its hilly topography and relatively wet climate, water-powered mills were common. Hence, there were few needs for an enhanced windmill in the Northeast.

However, by the mid-19th century, western expansion fueled the need for an improved means to pump water in flatter, drier, and more remote regions. Daniel Halladay and other mechanically inclined inventors sought to fill this need. Several of them set up factories in Batavia as it was a good location for both the manufacture and distribution of their new designs.

This collection of restored windmills in Batavia, Illinois, is where six manufacturing companies competed with each other and many other windmill makers. Here in 1863, the U.S. Wind Engine & Pump (U.S.W.E.) Company, built the nation's first mass-production windmill factory. Connecticut machinist Daniel Halladay, a principal with U.S.W.E. had invented the self-regulating wind engine in 1854. Halladay's patent revolutionized the industry, inspiring the development of many windmill companies. While at U.S.W.E. in 1883, engineer Thomas Perry developed optimum metal-bladed windmills, using his unique wind resistance test machine. Batavia windmills were critical to the rapid growth of the arid American West.

Bringing 'em Home

Assembling this collection of self-regulating windmills was begun in 1994. Windmills and components that had been manufactured in Batavia were acquired from around the country under the theme of "Bringing 'em Home." Batavia resident Bob Popeck is the leader of the Molinologists of Batavia, aka "the MoB," a group of enthusiasts that maintains and coordinates windmill repairs. There is a Windmill Maintenance Fund, first established with a bequest from resident Arlene Nick, that is administered by the City of Batavia.

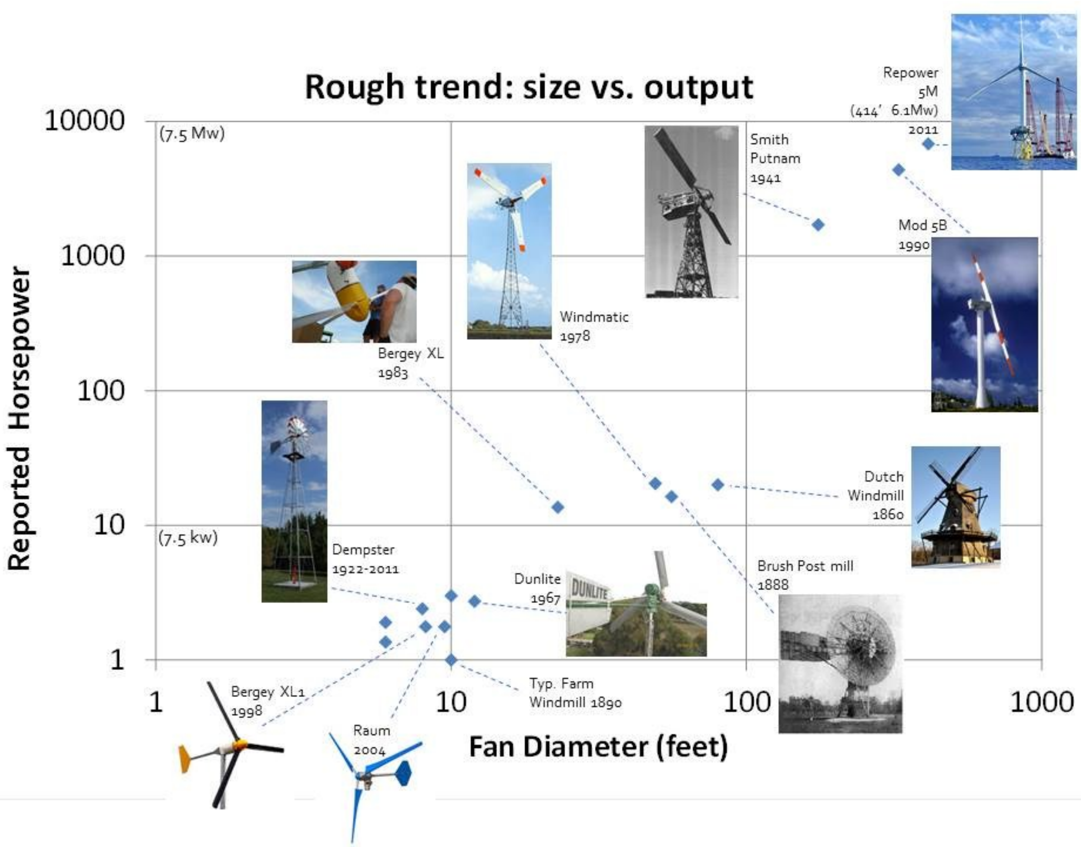
The authentic windmill reconstructions are examples from the three largest local manufacturers and one of the three smaller local manufacturers. They are maintained in excellent condition. Nine of seventeen windmills are in the immediate vicinity of the Batavia Government Center near the Fox River, formerly the original Appleton Manufacturing Company building. Access is good because of the public display at the Center along the Batavia River Walk. The Batavia Depot Museum and Gustafson Research Center contain windmill memorabilia and are a block distant from the display of windmills along the Fox River.

Energy in the Wind

Although North American farm windmills were developed in the mid-19th century, their physics weren't fully understood for several decades. Around 1920 three physicists (Briton F.W. Lanchester, Russian N.Y. Zhukowsky, and German A. Betz) determined that a theoretical maximum energy could be extracted from the wind: 59.3 percent. In reality the wheel does not reach this value (now known as Betz's limit), and because of aerodynamic efficiency and friction in all its components, a farm windmill on average can convert and use between 7% to 27% of the wind's energy. (A good rule of thumb is 15%.) How quickly the converted work can be applied to a useful task is known as power, indicated in watts (or horsepower, hp).

Besides power, another important performance issue for windmills is how much torque they provide. Starting torque is the performance indicator that governs whether the mill can start its water pump from a dead-stop. Such torque is where American farm windmills outdid other designs. Their many-bladed wheels present rather solid obstacles to the wind. Although this sacrifices some of their efficiency, this solidity results in four to twenty times more starting-torque than any other possible wind wheel shape. Wheel and blade designs were gradually optimized to provide pumping in winds as slight as 5 to 7 mph. Even today, no other wind wheel design has been found to pump water better for agricultural use.

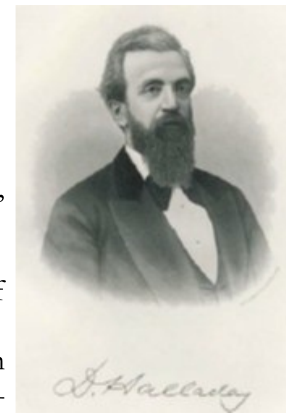
To illustrate the evolution of windmill output, various reported horsepower of windmills, small and large, are shown below.



Typical Mechanical Specifications

The diameters of the windmill wheels displayed in Batavia range from eight to fourteen feet. The windmills are displayed on relatively short towers (compared to "real" installations) in order to provide visitors improved visibility of the gearing. The pumping powers of these windmills were commonly specified in catalogues of the day. A typical 8 foot diameter wheel of the late 1800s would have produced roughly 250 watts (or 1/3 hp) in a moderate (15 mph) breeze. In this example, the windmill could lift 450 gallons per hour from a depth of 40 feet. Later, two independent reports were published in 1901 by E. C. Murphy at the U.S. Geological Survey, which significantly contradicted some of this optimistic sales literature.

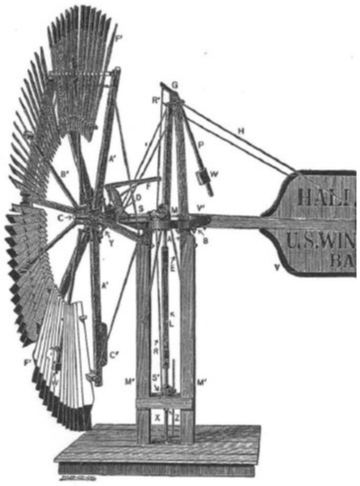
New England Roots



Daniel Halladay, the father of the American windmill industry, was born in Vermont on November 24, 1826. At the age of 19 he was apprenticed as a machinist in Massachusetts, and at 21 was in charge of machinery for the government armory at Harper's Ferry, Virginia. In 1851 Halladay was chosen to represent Ericsson's Caloric Engine at the World's Fair, held in London.

When Halladay returned, he purchased an interest in the machine shops at Ellington, Connecticut, and there developed his first self-governing wind engine. Self-governing meant it would turn its four variable-pitch blades away from a strong wind, rather than spinning so fast that centrifugal acceleration would destroy it. His patent, No. 11629, was awarded in August 1854.

The ingenious mechanical design of the wind-engine system of gears and linkages made efficient use of centrifugal and gravitational forces in controlling the windmill blades' resistance to air flow by automatically adjusting blade orientation to the wind to provide nearly constant wheel speed in variable air velocities. His original Standard design had only 4 sails, or wooden fins, and looked more like a box fan than the stereotypical Western windmill. With crude research, he evolved to designs with many



The Improved Halladay Standard Pumping Wind Mill.

After an original design with four wide blades, Halladay's designs evolved to many slender blades.

slender slats, which provided better performance. In an early revision, the Halladay Standard linkage enabled sections of the wheel blades to rotate, lessening the effective blade area in higher wind speeds. Due to manufacturing and materials limitations, the blades and vane (tail) were originally of wooden construction. The Halladay Standard Windmill was awarded the First Prize at Expositions in Philadelphia in 1876 and Paris in 1878.

A Midwest Market

Halladay and his partner John Burnham found sales in the northeast U.S. were not as brisk as desired, so they moved sales to Illinois. For the first time in the history of wind power thousands of customers could order a windmill, complete with delivery and installation by a team of professionals. Windmills could also be purchased from catalogues, dealers, or traveling salesmen who often carried a miniature working sample. The mills could also be assembled and erected by the buyer. Wind engines were about to be mass-produced and, because of their simple, inexpensive design, millions would be sold. The construction of wind engines made settling the American West possible, and they still provide free, efficient pumping to rural locations worldwide.

Sales in the Midwest (and dry plains beyond) were better than in New England; however, shipping costs from the factory back east remained high. As windmill demand from the Northeast dwindled further, Halladay's partner, John Burnham, convinced Halladay to relocate the factory westward. Batavia resident, engineer and investor John Van Nortwick (then with the Chicago Burlington & Quincy railroad) was added as a partner and the U.S. Wind Engine & Pump Company was created in 1857 in Batavia with just a few employees.

Expansion and Competition

Batavia was a more central location to satisfy the increasing demand of the burgeoning American West, and also a better location because of the ongoing Civil War. From here, U.S.W.E. sold the Halladay Standard windmills by the thousands to farmers and ranchers on the plains and prairies of North America and farther west, as well as around the world. At its peak in the 1880s, U.S.W.E. employed over 200 people in its windmill factory. This brochure's cover (upper photograph) shows one of their original buildings in Batavia.

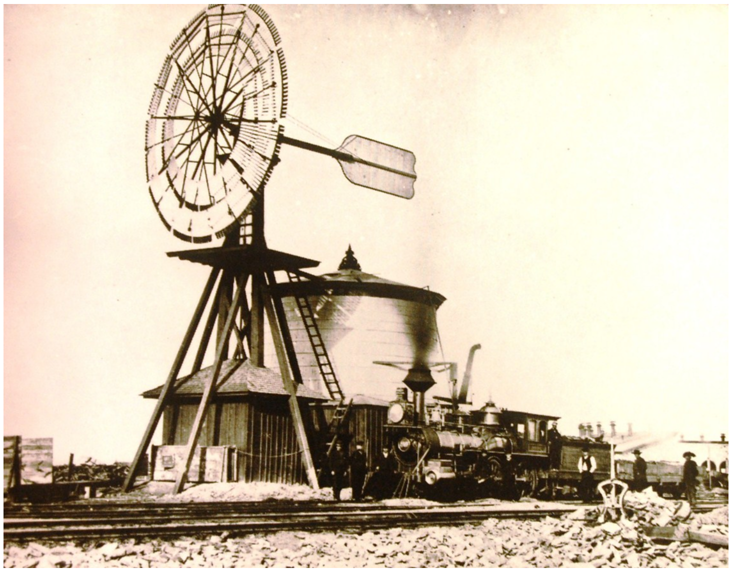
At its peak, the U.S. Wind Engine & Pump Company employed over 200.

As with modern industry, success begets spinoffs and competitors, and Batavia was not unique in this aspect. It came to be known as the "Windmill City" and the "Windmill Capital of the World" in the old times. This was due to the number of windmill manufacturing companies that eventually operated there and the numbers of farm-style windmills these companies sold throughout the United States and around the world. Six windmill manufacturing companies operated in Batavia:

- U.S. Wind Engine & Pump Company
- Challenge Wind Mill & Feed Mill Company
- Appleton Manufacturing Company
- Batavia Wind Mill Company
- Snow Manufacturing Company
- Danforth Windmill Company

Based on the rapid expansion of competitive windmill manufacturers in Batavia, Halladay and Burnham helped start the industrial "green" revolution in this country and beyond.

Batavia (and other) windmills were a significant factor in the western expansion of the United States because this technology was used to pump water for livestock, plants, and people. With windmills, settlements were not confined to the immediate presence of a river or lake. Upon digging a well, water could be readily pumped from underground. Perhaps more importantly, full westward expansion would prove dependent on a faster transportation mode for people, supplies, and raw materials across long distances. Steam locomotives could provide this speed and power, but needed to refill their water tanks more often than their fuel bins. On the first transcontinental railroad, water towers were needed about every 20 miles—and those towers needed a wind-driven pumping system. As in the 21st century, water was of prime importance in the West. Steam could only be made from water; the windmills made possible the widespread availability of otherwise scarce water.



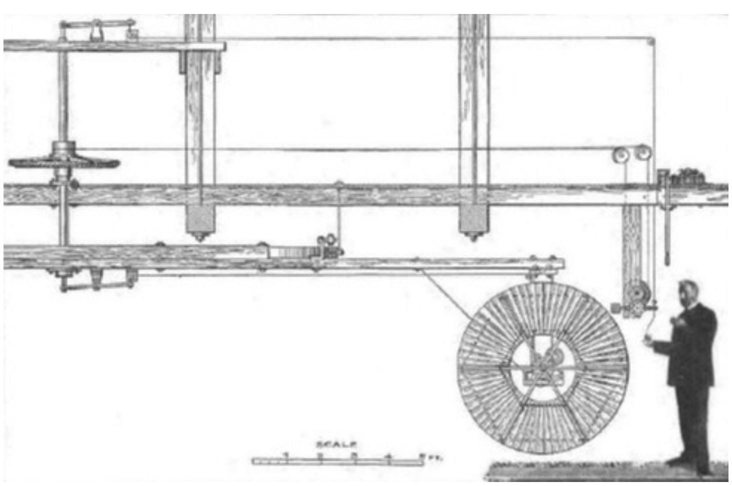
Steam locomotives depended on a plentiful supply of water. Water refills were needed roughly every 20 miles, more often than fuel.

The Industry Matures

Halladay's wheel was sectioned, so each segment could pivot relative to the wind (somewhat like the spars of an umbrella). It governed itself, thereby taking itself in and out of sail, but it was mechanically complicated. A solid wheel would obviously be simpler, and later competitive designs used different mechanisms to turn the solid wheel away from strong winds.

Refinements were to follow. Thomas Perry, a U.S.W.E. engineer, performed some of the first extensive aerodynamic "wind tunnel" testing anywhere. To study the efficiency of his revolutionary metal-bladed design conceived in 1882, Perry constructed a huge steam-powered centrifuge in which he mounted 61 different wheel and blade combinations and conducted 5,000 separate tests.

The figure at bottom provides a scaled side view of his testing apparatus. An unproven fan design was mounted on the end of a 16-foot revolving arm that he called "the



While at U.S.W.E. in 1882, Thomas Perry performed over 5,000 sophisticated performance tests using a rotating-arm equivalent of a wind tunnel.

sweep." In a controlled and closed room, continuous revolution of the large arm caused the fan to spin. A dynamometer measured speed and wind power harnessed by the fan, with corrections for variations in the data for factors like humidity and temperature.

Perry's tests explored not only the material but the curvature and angle of the blades. The experiments were performed in the U.S.W.E. "back shop" which is still standing in downtown Batavia today, but it has been repurposed. His best design featured slightly curved, thin steel blades that turned in the slightest breeze. "It was necessary for Perry to determine just the right proportion of back-gearing to give the pump plunger the proper speed. And this was found to be about three revolutions of the wheel to one stroke of the pump."

Although Perry perfected the final galvanized steel configuration at U.S.W.E., he could not convince conservative management to use his findings. So after 14 months he and LaVerne Noyes severed ties with U.S.W.E. and founded the Aermotor Company in Chicago. The metal windmill revolutionized the industry by outperforming its wooden-bladed contemporaries. Its design was so successful that it remained virtually unchanged for the next 100 years. The Aermotor later became popular worldwide–even today the company produces windmills from San Angelo, Texas.

Perry's original research reports remained private and in the hands of U.S.W.E. for many years thereafter. Finally, in 1899 the company was persuaded that the public could share in his work, which he entitled "Experiments with Windmills" and published with the U.S. Government Printing Office.

Marketing Innovations

At least one Batavia windmill company also saw the marketing potential of an aftermarket in windmill insurance. This cropped up around the turn of the 20th century. In about 1910, Appleton Manufacturing Co. began offering five years of protection against anything but neglect for $5.00. The option was prominently advertised in farm trade publications.

Once established, the windmill companies also produced and marketed other farm equipment and recreation products. For example, Challenge Company eventually offered lamps, door stoppers, rowing machines, shuffleboard sets, benches and lawn swings.

Intellectual Property

Individuals and companies in Batavia sought to protect their new ideas, and thus applied for many U.S. patents. It may never be known exactly how many new windmill developments came about in Batavia, but *A Guide to United States Patents for Windmills and Wind Engines 1793–1950*, compiled by T. Lindsay Baker and edited by A. Clyde Eide, provides a rough idea. A search therein led to 108 potential patents having a Batavia connection. After detailed review of the patent documents themselves, at least 59 patents were awarded in connection with Batavia-made windmills.

Due to mergers, bankruptcies, temporary partnerships, and buyouts, it is a difficult task to connect each of the patents to a particular company. However, the authors estimate a breakdown in this manner:

U.S. Wind Engine & Pump	27 patents
Challenge	21 patents
Appleton/Goodhue	7 patents
Snow Manufacturing	4 patents

Also, because some engineers and inventors worked for more than one company over time, not every invention from some engineers can be said to have a Batavia connection. For example, Thomas Perry had 24 windmill-related patents, but at most two or three seem to be connected with his Batavia work (the balance being with Aermotor in Chicago). Estimates of the most prolific U.S.W.E. inventors were John H. Miller (13 patents), William Burnham (6), James Burnham (3), Daniel Halladay (6), William S. Marshall (5), and Thomas Perry (2). William D. Nichols seems to have 10 patents — mostly related to his time as either a stockholder or employee with the Challenge Mill Company, although his designs were also used by Batavia Manufacturing Company, Elgin Wind Power & Pump Company (successor to a partnership), and likely for a brief time by his son. Also at Challenge, Thomas Snow Sr. had six patents (and signed as witness on many others) and John August Lund had six patents on perhaps their most successful design, the Challenge 27.

Modern manufacturing concepts, such as design-for-assembly, can even be seen in these ideas from long ago. A cast hub designed with integral pins to hold the fan bars to the radial arms on a U.S. Solid Wheel (by U.S.W.E.) was shown in Patent 391,401 awarded to W. H. Burnham and J. H. Miller on October 23, 1888. The specification states that, "when the angle-iron is bolted to an arm, the fan-bars will be firmly held in place without any other fastening." In 1931, John Lund (Challenge) invented an anchor ring (Patent 1,788,116) and his patent states, "It is expensive to provide key ways and keys for securing the sleeve bearings to the shaft. To avoid the cost, time and labor involved in constructing key ways, I provide indentations which may be easily and cheaply formed in one end of the bearing."

Another seemingly 21st-century concept is design-for-maintainability. John H. Miller saw this need in 1893, with a pitman bearing (Patent 490,296) that was used on the U.S.W.E. "Gem" model. He noted that the reciprocating motion in lifting the pumping rod became jarring to the machine when the bearing fit deteriorated. His remedy was two graphite sleeve bearings that could be removed via a bolt, and then the owner could reduce the graphite thimbles' diameter if they "cut a slit (preferably using a saw for that purpose)," and when reinstalling, "tighten it to compensate for any wear in the joints."

The Rise, Decline, and Perseverance of American Farm Windmills

Starting with the invention of the Halladay self-regulating windmill in 1854, a broad industry was created which eventually led to manufacturers worldwide. The affordability of these new devices was largely due to mass-manufacturing and durability improvements driven by competition amongst the makers. By 1890 there were over 100 windmill companies in America. Rural electrification precipitated a decline in windmill usage, and the reallocation of metal and labor for World War II further depressed the industry.

Appleton Mfg. Co. exited the windmill business in the 1930s. Batavia Metal Products Company bought out both U.S. Wind Engine & Pump and the Challenge Company between 1938 and 1945. During the war, brass shell casings were made in Batavia. After the war, the combined U.S.–Challenge Company remained in business until approximately 1951. Despite the end of windmill manufacturing in Batavia, American farm windmills are still being produced in the United States and elsewhere. It is still an economically viable method to get underground water to the surface in a remote location.

"Reconstructed Windmills"

In this designation, reconstructed means the entire windmill, including the wood or metal wheels, the windmill engines, and other cast iron and metal parts were all originally manufactured in Batavia then shipped to either a dealer or private owner. Towers were also manufactured in Batavia, but were not always included in a sale.

Local windmill champions Bob and Francine Popeck have a further comment about the collection: "With regard to the windmills that are on display in Batavia, we were able to obtain most of the mills, to the best of our knowledge, with all of their original cast iron and other metal parts, which were then painted or repaired before installation in Batavia, where they were originally manufactured. Occasionally we recast a part in the event of something missing or too broken. These few windmills are referred to as 'restored.' In the case of windmills with wood wheels, the original wood blades have been replaced with new material as the original wood had disintegrated over the 100+ years since they were made."

The former Appleton factory now serves as the Batavia Municipal Center.

Industrial Archaeology

The Appleton factory building, with U.S.W.E. Model E in foreground, are preserved as shown above. The building is now the Batavia Municipal Center. From there, the Challenge factory building is located directly across the Fox River.

The former Challenge factory is across the river from the Municipal Center.

Acknowledgments

The preparers of this brochure acknowledge with gratitude the people who have made this Landmark possible. They include especially the late AMSE member Gerald J. Moyar who shepherded the project in his last year with us; William Shust who, while ASME Fox Valley Section Chairman, initiated the project and did early research; Tim Moyar, who was responsible for nomination document production, editing, photography, and graphics; Jay Geller, former ASME Section Chair, who advised and contributed to the research effort; as well as Chad Rohlfs, of the Department of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign, for helping locate early *Scientific American* documents.

ASME Fox Valley could not have undertaken and completed this project without the knowledgeable and generous participation of Batavia residents and windmill enthusiasts Bob and Francine Popeck. They provided many references and documents, access to the City of Batavia storage areas, and effective advice and editing throughout. We also acknowledge with thanks the help of Stacey L. Peterson and George H. Scheetz, Batavia Public Library, and Carla Hill, Museum Director at the Batavia Depot Museum. Finally Dr. T. Lindsay Baker professor and noted windmill authority, provided very helpful correspondence and materials from his books and back issues of the *Windmillers' Gazette*.

Other Windmill Collections

Other larger collections of reconstructed early windmills are found at sites such as the American Wind Power Center in Lubbock, Texas, the Mid-America Windmill Museum in Kendallville, Indiana, and the Shattuck, Oklahoma outdoor museum. The former Kregel Windmill Company, operated from 1903 to 1991, remains fully intact in Nebraska City, Nebraska, and is open to the public by appointment.

References/Bibliography

Baker, T. Lindsay. *American Windmills: An Album of Historic Photographs*. Norman: University of Oklahoma Press, 2007.

Baker, T. Lindsay. *A Field Guide to American Windmills*. Norman: University of Oklahoma Press, 1985.

Baker, T. Lindsay, and A. Clyde Eide. *A Guide to United States Patents for Windmills and Wind Engines, 1793–1950*. Watford, Herts, England: International Molinological Society, 2004.

Fraenkel, Peter. *Water Lifting Devices*. Rome: Food and Agriculture Organization of the United Nations, 1986.

"Improved Governor for Wind Mills." *Scientific American*, October 7, 1854.

Murphy, E.C., *The Windmill, Its Efficiency and Economic Use, Parts 1 and 2,* U.S. Geological Survey, 1901.

Perry, Thomas O., "Experiments With Windmills." Washington: Government Printing Office, 1899.

Peterson, Stacey L., and George H. Scheetz (eds.). *Windmill City: A Guide to the Historic Windmills of Batavia, Illinois*. Batavia: Batavia Public Library, 2008.

The Windmillers' Gazette (various issues), T. Lindsay Baker, Editor, P.O. Box 507, Rio Vista, TX 76093.

The History and Heritage Program of ASME

Since the invention of the wheel, mechanical innovation has critically influenced the development of civilization and industry as well as public welfare, safety and comfort. Through its History and Heritage program, the American Society of Mechanical Engineers (ASME) encourages public understanding of mechanical engineering, fosters the preservation of this heritage and helps engineers become more involved in all aspects of history.

In 1971 ASME formed a History and Heritage Committee composed of mechanical engineers and historians of technology. This Committee is charged with examining, recording and acknowledging mechanical engineering achievements of particular significance. For further information, please visit www.asme.org.

Mechanical Engineering Heritage Collection

SELF-GOVERNING WINDMILLS
1863-1951

These windmills, manufactured by U. S. Wind Engine and Pump, Challenge, Appleton, Batavia Wind Mill, and Aermotor include many of the early self-regulating types. First developed by Daniel Halladay in 1854, self-regulation mechanisms automatically adjusted the wheel or blade angle to maintain near-constant speed and power in varying winds without an operator's constant attention.

These windmills were designed for easy assembly, operation, and maintenance using only simple hand tools. Primarily used to pump water on remote farms throughout most of North America, windmills also filled railroad water towers, powered feed and saw mills, and drove other agricultural machines. Six companies mass-produced windmills in Batavia, Illinois, between 1863 and 1951.

American Society of Mechanical Engineers 2013

Text of Landmark Plaque

Landmark Designations

There are many aspects of ASME's History and Heritage activities, one of which is the landmarks program. Since the History and Heritage Program began, 253 artifacts have been designated throughout the world as historic mechanical engineering landmarks, heritage collections or heritage sites. Each represents a progressive step in the evolution of mechanical engineering and its significance to society in general.

The Landmarks Program illuminates our technological heritage and encourages the preservation of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers. It also provides reminders of where we have been and where we are going along the divergent paths of discovery.

ASME helps the global engineering community develop solutions to real world challenges. ASME, founded in 1880, is a not-for-profit professional organization that enables collaboration, knowledge sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education and professional development programs provide a foundation for advancing technical knowledge and a safer world.

Brochure Co-author

ASME Staff

Roger Torda, Manager, Communications Projects & Initiatives
Wil Haywood, Communications Coordinator