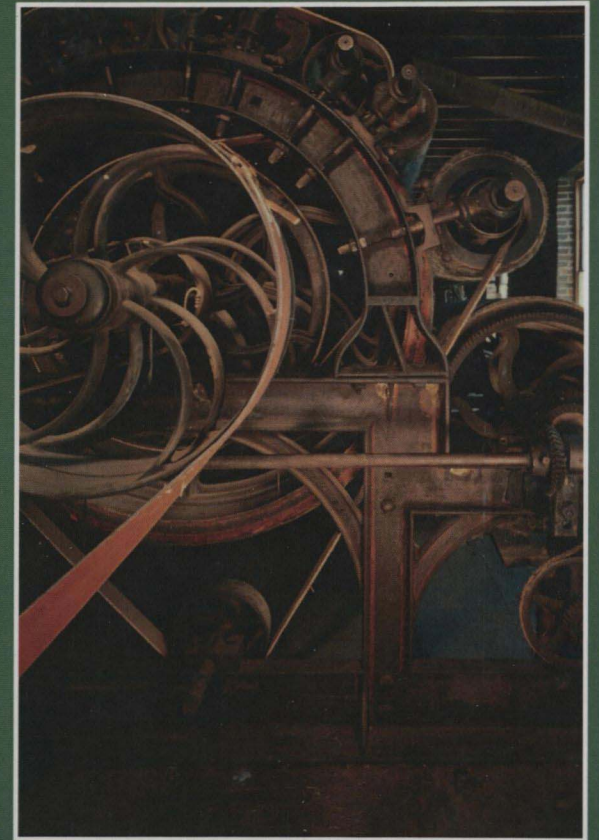
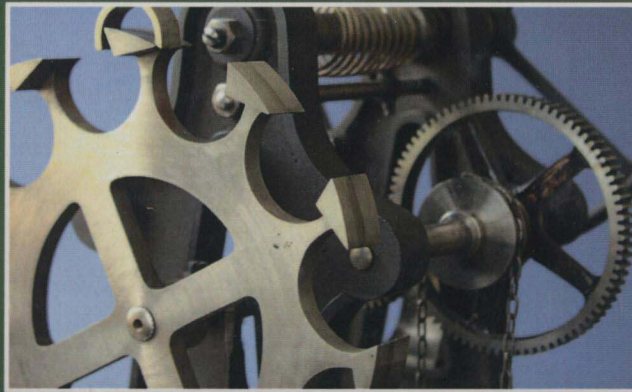
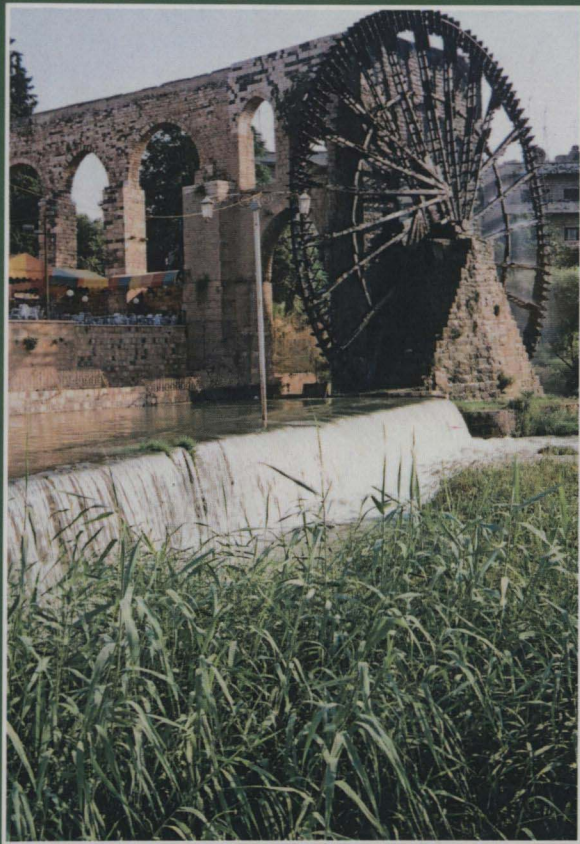


# Machines That Made History

Landmarks in Mechanical Engineering



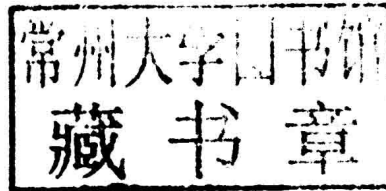
By  
Jennifer M. Black

Sponsored By The ASME History & Heritage Committee



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# Foreword

The products of mechanical engineering sustain the very fabric of modern life. Some are obvious, like the automobile; some hide behind casings, like the disc drives of computers. Sometimes they are large and visible, like the rockets that took astronauts to the moon; sometimes they are all but invisible to the general public, like the pumps that provide water to our cities or the turbines that generate our electric power. This volume provides brief introductions to 100 key landmarks in the history of mechanical engineering, devices or innovations that have shaped the field and broadly influenced modern civilization.

In 1971 the American Society of Mechanical Engineers (ASME) created its History & Heritage Committee to identify and commemorate outstanding examples of mechanical engineering and by this means to promote understanding of the history of the profession, both to its own membership and to the broader public. Shortly thereafter, the Committee initiated a “Landmarks” program, as one method to accomplish this mission. The Committee’s landmark designation process originates with nominations made by local sections of the ASME. An ASME historic mechanical engineering landmark must be a site of historic significance to the profession, or the best or earliest surviving example of an important machine or component, or an important collection of historic machines. In the ideal, it must be an outstanding example (or collection of examples) that demonstrates brilliant engineering accomplishment and beneficial consequences for society. And it must, as far as possible, be publicly accessible. The ASME’s History and Heritage Committee screens nominations to ensure these criteria are met. If approved, a formal designation ceremony usually follows, including presentation of a bronze plaque for mounting at the site. Most of the ASME landmarks in this volume can be visited, and many are in museums, although the level of accessibility may vary. A visit to a specific landmark may require a bit of internet research to pin down the details of location and public access. We hope you will seek them out, as these survivals from the past still evoke wonder and appreciation today.

As of 2013 the History and Heritage Committee has designated over 250 historic mechanical engineering landmarks. The earliest dates from around 1350, the latest from 1996. Due to the American origins of ASME, most are in the United States, but the organization’s growing global orientation has resulted in a significant number of important overseas landmarks.



Two earlier books described ASME's historic mechanical engineering landmarks. The earliest, edited by Richard S. Hartenberg, a charter member of the Committee, covered the first twenty-eight landmarks designated by the History and Heritage Committee from 1973 to 1977.<sup>1</sup> The second book was officially authored by "ASME International History and Heritage," but Carol Poh Miller prepared the bulk of the text with supporting contributions from various experts. That publication described the 135 historic mechanical engineering landmarks designated up to 1989.<sup>2</sup> Now that ASME has designated over 250 landmarks, the Committee decided that a comprehensive volume would be unwieldy and expensive, limiting its appeal. Instead we focus here on 100 selected landmarks that reflect the history of mechanical engineering, the breadth of the field, and its consequential impact on society.

Choosing those 100 proved difficult. To decide, in early 2013 members of the ASME's History and Heritage Committee reviewed the 251 then-designated landmarks and selected the "top 100," that is the 100 landmarks that they saw as the most significant in subsequent technological developments and / or in their consequences for society as a whole. A complete listing of all historic mechanical engineering landmarks (as designated to 2013) appears in an appendix of this volume and at ASME's website ([www.asme.org](http://www.asme.org)), where individual entries are often accompanied by a downloadable descriptive brochure.

With support from the ASME, two members of the History and Heritage Committee—John K. "Jack" Brown and Terry S. Reynolds—conducted a search to identify a consultant who would take the Committee's "top 100" landmarks and convert the selections into an illustrated book. They selected Jennifer M. Black, the author of the current volume. The History and Heritage Committee provided her with assistance, occasional advice, and editorial oversight—while sponsoring the publication of this volume. The end result, however, is her product.

Terry S. Reynolds, for the History and Heritage Committee

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<sup>1</sup> Richard S. Hartenberg, ed., *National Historic Mechanical Engineering Landmarks* (New York: American Society of Mechanical Engineers, 1979).

<sup>2</sup> ASME International History and Heritage, *Landmarks in Mechanical Engineering* (West Lafayette, IN: Purdue University Press, 1996).

*History and Heritage Committee—September 2013*

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# Introduction

In attempting to define the field of mechanical engineering, an engineer once quipped: “if it moves it’s mechanical.” In practice, mechanical engineering originated in antiquity. By the time of the classical civilizations (Greece, Rome, Han Dynasty China, Gupta period India) craftsmen had developed a host of complex mechanical devices, and they had made the first attempts at rationalizing their operation. In the third century BCE, Hellenistic engineer and mathematician Archimedes designed practical mechanical devices, including siege engines and, perhaps, the water-lifting device named after him (see page 3). He also sought to understand the basic principles behind the lever, pulley, and wedge. Scholars and inventors in Han Dynasty China (206 BCE—220 CE) worked with differential gears and developed complex water clocks which combined water flow and mechanical movements to increase accuracy. The Antikythera mechanism, a Hellenistic Greek machine dating from the first century BCE, may represent the pinnacle of classical mechanical engineering. Essentially an analog computer capable of indicating both past and future positions of the sun, moon, and key planets, the device had at least thirty interlocking bronze gears.

The collapse of the classical civilizations between the third and fifth centuries CE delayed the design and construction of more complex mechanical devices and hindered attempts to understand the underlying principles of machines. Important incremental advancements came during the European medieval period when mechanics and millwrights steadily expanded the use of water power and wind power, creating for the first time in human history a civilization released from complete dependence on the muscles of man and animals.

The shift in medieval Europe from animate to inanimate power sources and the consequent modification of manufacturing processes laid foundations for the First Industrial Revolution in the eighteenth century. Beginning in Great Britain, this epochal turning point in human affairs would encompass much of Western Europe and the United States by 1900. The energy-producing and labor-saving mechanical devices developed by engineers and inventors like Thomas Newcomen, James Watt, Richard Arkwright, and Eli Whitney profoundly transformed the locations, scale, and processes of manufacturing. Between 1760 and 1820 machines largely replaced hand production in the textile industry in Britain, with coal-fired steam engines powering much of the newly automated spinning and weaving machinery. In the early nineteenth century, the US textile industry harnessed water power for the same



ends. With the transition from cottage industries to mechanized production, urban manufacturing centers emerged by the late-eighteenth and early-nineteenth centuries across western Europe and in the eastern United States. As innovators developed new iron production processes to support the growing steam-engine industry, improvements in engine design led to a parallel revolution in transportation, aiding human mobility and the expansion of industry. The railroad, steam-powered boats and ships, and, later, internal-combustion-powered vehicles—all represented by landmarks in this volume—made possible the growth of cities inconceivable before 1800. The new transportation networks transformed large areas of the globe and brought an ever-expanding range of consumable goods and foodstuffs into the reach of heretofore unconnected peoples. These and other changes brought about a new “modern” era characterized by mass immigration and urbanization, economic and political shifts from the monarchical fiefdoms of the Old Regime to more capitalistic and egalitarian systems (at least in principle), and accelerated technological development.

The growth of industry eventually stimulated the emergence of a new, self-conscious group of trained craftsmen to design, construct, operate, and repair industrial machines and their components. Before the mid-nineteenth century—and even for some time after—these craftsmen variously called themselves millwrights, mechanics, mechanicians, machinists, inventors, or military engineers. Around 1750, the British engineer John Smeaton began to use the term “civil engineering” to describe all non-military engineering pursuits. Smeaton himself directed both civil and mechanical engineering projects, including lighthouses and canals (civil engineering) and water wheels and rolling mills (mechanical engineering). By 1847 a professional society, the Institution of Mechanical Engineers, emerged in Great Britain to support the efforts of mechanical engineers as distinct from other engineering specialties. Their counterparts in the US organized the American Society of Mechanical Engineers (ASME) in 1880. These men became first generation to embrace the term “mechanical engineer.” They mostly worked in machine shops that supported the textile and steam-engine industries, for the railroads, and in the new steam-powered navies of Europe and America. By the turn of the twentieth century, machines had largely replaced the work of human hands in many manufacturing industries, and mechanical engineering had grown into a globally-recognized field complete with training programs at many universities in Europe, Japan, North America, and South America.



Throughout the nineteenth and twentieth centuries, mechanical engineers strove to make machines more powerful and more efficient. They incorporated safety features that helped to prevent the accidental explosions, fuel leaks, and other hazards that once punctuated industrial life. At the same time, a succession of new energy technologies—petroleum fuels after 1860, electric power from the 1880s, and later, nuclear and geothermal sources—steadily expanded the scope and results of mechanical engineers’ work.

The ASME History and Heritage Committee selected the landmarks in this volume to illustrate the broad range of innovations encompassed in mechanical engineering’s history. The book’s thematic organization highlights changing technologies in Energy, Manufacturing, Environmental Control, Land and Sea Transportation, and Air and Space Transportation and Research, as well as in the fields of Information, Science, and Medicine. The first chapter, “Origins,” examines some early landmarks that would later shape the evolution of key areas of mechanical design, including pumping, energy production, and transportation. Later chapters outline developments that grew out of these early innovations, and they trace the changing social and economic concerns that pushed mechanical engineers to advance the efficiency, utility, capabilities, and safety of their machines. The landmarks that comprise each chapter illustrate mechanical engineering innovations in specific topical areas from the Industrial Revolution to the dawn of the Information Age.

These ASME landmarks show the broad influence of mechanical engineering innovations on societies across the globe. Innovations represented by Watt’s rotative steam engine, the machinery at the American Textile History Museum, and the Springfield Armory provided the technological underpinnings of the First Industrial Revolution, which in turn changed the very fabric of society in the eighteenth and nineteenth centuries. As capitalism took shape in the West, industrialization reorganized daily life around the steam-powered factory. It facilitated mass migrations from the fields to the growing cities, and reshaped the political and economic frameworks that ordered the various classes of society. In turn, the work of mechanical engineers assisted these processes and often resulted in the improvement or addition of “modern” conveniences to human life, especially in communication, transportation, and domestic life. Amidst these achievements, environmental and social problems often arose. For example, with industrial growth came the rise of pollutants, while the spread of mass production helped create a dependent working class vulnerable to exploitation.



In some cases, the work of mechanical engineers later moderated the complicated consequences of industrial growth. For example, the Newell Shredder, an ASME landmark, made auto recycling more economical. Here the profession contributed to correcting a problem that it had played a role in creating.

As the case of the Newell Shredder indicates, mechanical innovation often emerged because of challenges or developments posed by other areas of industry. The landmarks in this book demonstrate these interconnected relationships in mechanical engineering's history. In turn they tell a story about society's changing needs as technology developed. For example, Roebling's wire rope machine (see page 46) produced a core component required for successful operation of cable car railways, such as San Francisco's Ferries & Cliff House line (page 77), in cities across the globe. Innovations in mechanical engineering have always built upon the technologies that came before: Watt's improvements in steam power were advances on Newcomen's engine, while early devices to aid open heart surgery drew on technologies first developed in the automotive industry.

Finally, the landmarks selected for this volume exemplify highly creative solutions to social and technical problems. In manufacturing, mechanical engineers substantially mechanized production processes in fields as divergent as semiconductors and shrimp processing. During the First Industrial Revolution they found new ways to harness water, steam, and other energy sources to power the equipment needed for centralized factory production. Mechanical innovators also played key roles in the Second Industrial Revolution, creating systems of electric light and power, gasoline-powered automobiles and the mechanized assembly lines that made them affordable, and the technologies of powered flight. These engineers made public and private interior spaces more comfortable by controlling air temperatures and designing specialized ventilation systems. They devised ways to move people and goods (including refrigerated foodstuffs) in progressively more efficient ways, first across continents and oceans, and then over airways and even into space. The work of mechanical engineers has improved communications through high-speed printing, by sound recording and reproduction, and in the design of disk drives and other elements of computers. Through their work, mechanical engineers have also assisted the development of third-world countries, advanced the study of physics and the universe, and expanded the reach of modern medicine. At the heart of many developments of our modern era, one finds the work of mechanical engineers.

Albert Einstein once said: "Scientists investigate that which already is; engineers create that which has never been." The ASME Historic Mechanical Engineering Landmarks in this volume aptly illustrate this axiom.

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# Chapter 1

## Origins

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Say the name Thomas Newcomen to a group of engineers with some knowledge of the history of technology and you will bring to mind a formative moment in the history of mechanical engineering, when Newcomen's early eighteenth-century atmospheric steam engine inaugurated a new era of engineering achievements. Like Newcomen's engine, the landmarks illustrated in this section are representative examples of creativity and important early developments in mechanical technology.

Of all the motives for mechanical innovation covered in this volume, moving water has been the most constant. In the third century BCE, Greek farmers devised mechanical modes of raising water from streams to irrigate crops. Attributed to Archimedes, the principle of using a “screw” to pump water from one elevation to another would still find application in wind-powered form nearly two thousand years later in the salt industry. No screw pump attributable to Archimedes survives, but a nineteenth-century version descended from his work serves to commemorate this basic mechanical invention. By the fourteenth century, millwrights in Syria had created a sophisticated system of waterwheels to lift and distribute water to the region's residents. Called “norias,” these waterwheels would later evolve into more sophisticated prime movers—machines to drive other machinery. By 1800 efficiently distributing municipal water supplies in growing cities became a fundamental challenge for mechanical engineers. The history of Philadelphia's Fairmount Waterworks, the first such facility in the US, demonstrates engineers' struggle to identify the optimum prime mover for pumping and distributing water.

Beginning in the Roman era and accelerating in the medieval period, waterwheels and windmills began to replace muscle power in a range of mechanical applications. They helped drive nascent manufacturing operations, such as the seventeenth-century Saugus Ironworks, which used waterwheels to power its blast bellows, rollers, and hammers. Likewise, the Old Mill in Nantucket (1746) harnessed the island's powerful



winds to grind wheat into flour. Until the spread of steam power, such mills were central nodes in the geography and economies of communities across the Western world.

In 1712, Thomas Newcomen began to pump water mechanically from mines with his atmospheric engine, the first commercially successful engine to use thermal energy. Steam-powered pumping engines that descended from his design would later find application in municipal water systems throughout Europe and the United States, but the limitations of Newcomen's approach also pushed others to use steam power more efficiently. A key improvement came in the 1780s with Boulton & Watt's rotative steam engine. It transferred energy from the piston to a flywheel to provide mechanical power for a wider range of applications. Together, the advancements made by Newcomen and Boulton & Watt helped to power the First Industrial Revolution.

With the emergence of the rotative steam engine, engineers developed new applications for steam in transporting people and goods. Steam-powered locomotives found initial use in the collieries of Great Britain around 1812. In the United States, the Baltimore & Ohio Railroad (ca. 1830) was among the first to use steam locomotives for motive power. Designing, building, and maintaining these locomotives would become a major activity for mechanical engineers as the field emerged.

Despite mechanical advances in the movement of people and goods, the movement of earth still relied primarily upon beasts of burden until the 1880s, when the Fresno Scraper created a new avenue for applying mechanisms to earthmoving. Although initially horse-drawn, the scraper's design proved easily adaptable to the soon-to-emerge internal combustion engine. As part of the "Origins" of mechanical engineering, the Fresno Scraper and the other landmarks in this chapter provide formative examples of mechanical engineering excellence that would have profound effects on industry and technology in the years to come.