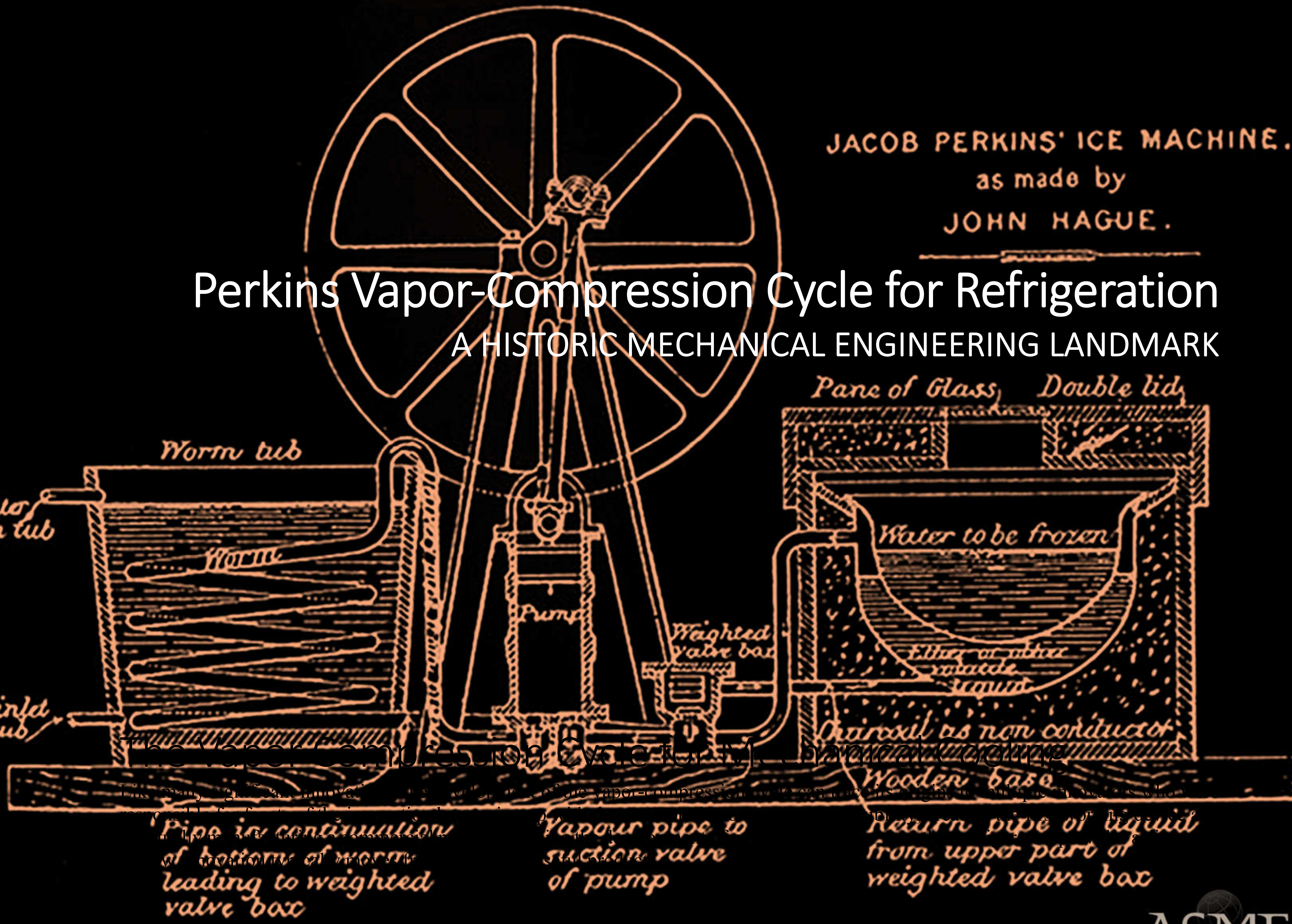
Perkins Vapor-Compression Cycle for Refrigeration

A HISTORIC MECHANICAL ENGINEERING LANDMARK



ASME
SETTING THE STANDARD

Published by the History and Heritage Committee of the American Society of Mechanical Engineers

Perkins Vapor-Compression Cycle for Refrigeration

A Historic Mechanical Engineering Landmark

Refrigeration and air conditioning are often regarded as among the most significant innovations of all time.[1,2,3] Both rely upon the vapor-compression cycle, first demonstrated by Jacob Perkins. While ice has been used since pre-historic times to help preserve food from spoilage, it has obvious limitations. Only the coming of mechanical vapor-compression refrigeration made it practical to store and transport foods that require cooler temperatures than that provided by ice. The same vapor-compression technology has provided us with the ability to maintain homes and other living spaces at comfortable temperatures. In addition, numerous other applications rely upon the same technology, such as processes for the manufacture of paper, drugs, soap, glue, shoe polish, perfume, celluloid, and photographic materials.[4]

History of the Vapor-Compression Cycle for Cooling

Early humans undoubtedly noticed the cooling effect of water evaporating off their skin on a hot day. When a liquid evaporates, its molecules shift from the liquid phase to the vapor phase. It takes energy for this to occur. Thus, when the molecules evaporate from a surface, they take the heat required for the phase shift with them, causing a cooling effect on the surface left behind.

The first documented public demonstration of artificial refrigeration occurred in Edinburgh in 1756, when Scottish professor, chemist, and physician **William Cullen** used a pump to create a partial vacuum over a container of diethyl ether. As he reduced the pressure, the ether boiled, absorbing heat from the surroundings. This created a small amount of ice.[5] However, no practical use of the phenomena was explored.

American inventor, engineer, and businessman **Oliver Evans** noted that drawing a vacuum on water reduces its boiling point and cools it. In the appendix to his book *The Abortion of the Young Steam Engineer's Guide*, he observed that a vacuum would have the same effect upon ether, and the resulting cooling should be sufficient to produce ice. Evans then described an apparatus to accomplish this continuously, using a vacuum pump. His theoretical device included an ether chamber placed in a vessel of water, an air pump to discharge the vapor into a condenser, and a pipe from this to return the liquid back to the ether chamber. He pointed out how the compression stroke of the vacuum pump could be used to re-liquify the vapor, and in so doing he identified all of the major components of a vapor-compression

---

1 "10 Greatest Inventions That Changed the World," by editorial staff. Retrieved at: http://www.scienceve.com/10-greatest-inventions-changed-world/, October 30, 2019.

2 Amanda Erickson, "History's Greatest Invention: The Refrigerator," *Washington Post*, December 4, 2015; reviewing the book *Chilled* by Thomas Jackson.

3 "Landmark Revolutionary Inventions in Mechanical Engineering," from *A Brief History of Mechanical Engineering* (n.p, Switzerland: Springer, 2018), 40-43, which includes refrigeration and air conditioning as one of the most significant mechanical engineering inventions.

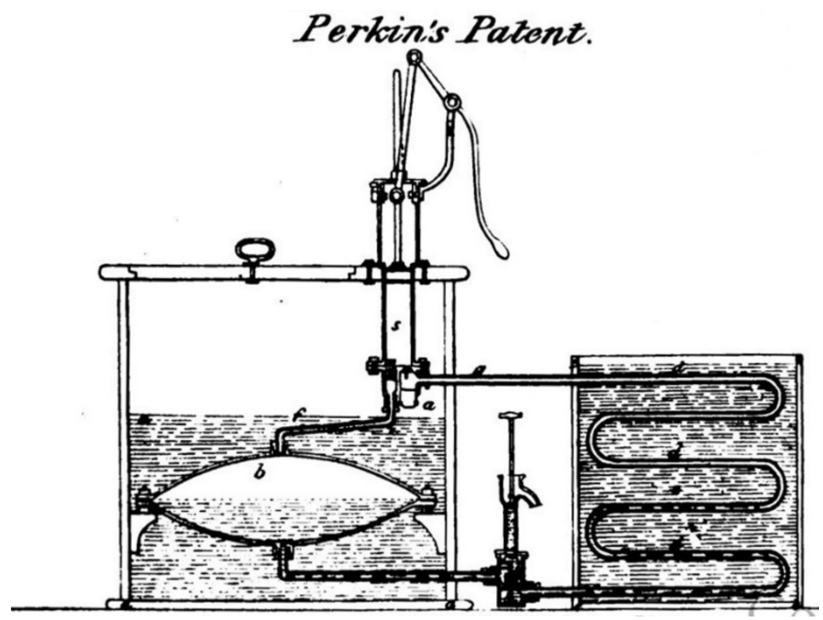
4 Barbara Krasner-Khait, "The Impact of Refrigeration," *History Magazine*, Feb./Mar. 2000, retrieved on-line February 6, 2020.

5 William Cullen, "Of the Cold Produced by Evaporating Fluids and of Some Other Means of Producing Cold," in *Essays and Observations Physical and Literary Read Before a Society in Edinburgh and Published by Them*, vol. 2 (Edinburgh: Philosophical Society of Edinburgh, 1756), 145-156.

refrigerator, including the cooling coil and condenser.[6] Evans noted that the device could: "... undergo the same operation; and so on *ad infinitum*." Although he likely provided the first coherent description of a vapor-compression refrigerator, there is no evidence that Evans ever produced such a device.

Later in his career, Evans collaborated extensively with fellow American mechanical engineer and inventor **Jacob Perkins**.[7] Almost certainly, Perkins learned of the possibility of vapor-compression refrigeration from Oliver Evans and his writings.

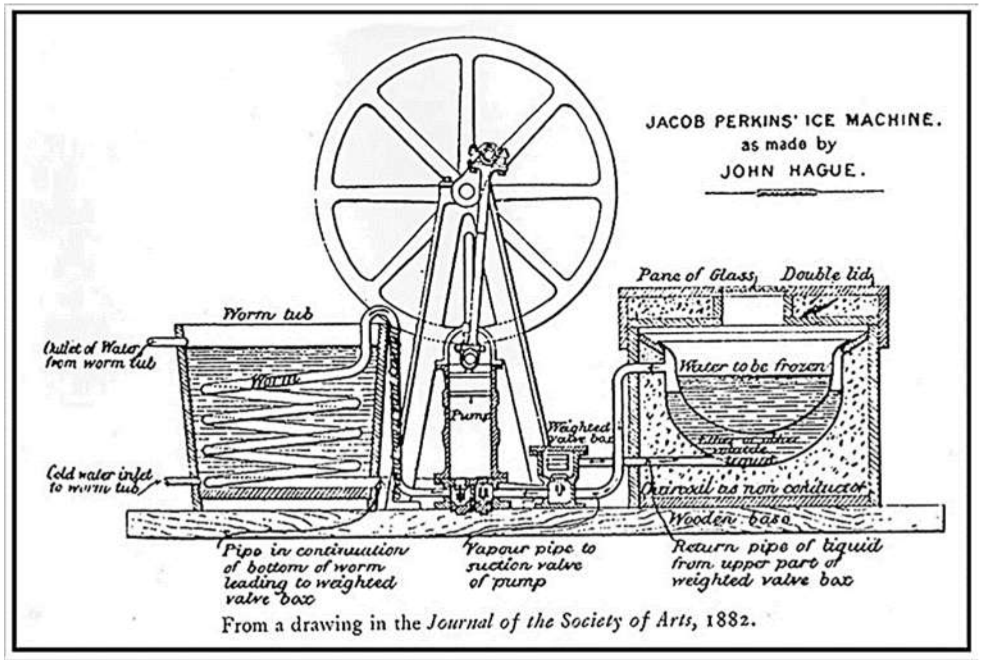
Jacob Perkins moved to England in 1819 to pursue his principal pursuit at the time, an engraving business for currency designed to prevent forgery. Perkins lived in England for the rest of his life, during which he continued to develop steam engines and other devices. While in England, he also designed and had built a device which used a vapor-compression refrigeration cycle and obtained a patent for it, assigned on August 14, 1834, and entitled, *"Apparatus and means for producing ice, and in cooling fluids."* It was the first working device that used a vapor-compression refrigeration system. It was a closed-cycle device and it could operate continuously.[8]



Right: Drawing from Jacob Perkin's patent entitled, "Apparatus and means for producing ice, and in cooling liquids."

[6] Evans, Oliver, *The Abortion of the Young Steam Engineer's Guide* (Philadelphia, Penn.: Fry & Kammerer, 1805), appendix.
[7] Greville and Dorothy Bath, *Jacob Perkins: His Inventions, His Times, & His Contemporaries* (Philadelphia, Penn.: The Historical Society of Pennsylvania, 1943), 64–65.
[8] Aubrey F. Burstall, *A History of Mechanical Engineering* (Cambridge, Mass.: MIT Press, 1965), 277.

John Hague, an engineer and associate of Perkins, fabricated the device described in Perkins' patent. A drawing of the resulting machine by Frederick Bramwell, which appeared in the *Journal of the Society of Arts* in 1882, and later in the *Scientific American* in early 1883,[9] is shown below.



Drawing by Frederick Bramwell of Jacob Perkins' *ice machine*, built in 1834 by John Hague.

Bramwell's Society of Arts article provided his recollections of assisting Hague in building Jacob Perkins' *ice machine.* Writing almost fifty years after building the device, Bramwell stated: "The apparatus was a small one, carried on a wooden base…some five feet long by two feet or two feet six inches wide. At one end there was a jacketed copper pan, the interior of which held the water to be frozen, while in the jacket was the volatile liquid and its vapor. The pan was inclosed (sic) in a wooden box, containing powdered charcoal as a non-conductor. From the top of the jacket a pipe was led away to the suction valve of an air pump, fixed in the middle of the wooden base, at the end opposite to that where the jacketed pan was. The worm tub was supplied with water, from an inlet at the bottom, and the escape was by an overflow at the top. A pipe, in continuation of the lower end of the worm, was connected to the under side of a valve box, in which was a valve loaded to about fifteen pounds to the inch, so that the vapor in the worm was subjected to this pressure, as well as to the

[9] Frederick Bramwell, "One of the First Ice Machines," *Scientific American* (January 20, 1883), 34, as first reported in the *Journal of the Society of Arts*, 1882. In the article, Bramwell describes building the device under the direction of engineer John Hague along with T.R. Crampton.

cooling influence of the water, and by these means was brought back to a liquid condition. From the upper side of the valve box a pipe proceeded to the bottom of the jacketed pan, to convey the liquid to it, thus completing the circuit.”

While the device demonstrated that ice could be continuously produced from a vapor-compression machine, Perkins did not develop any commercial application. Commercialization of the vapor-compression cycle for producing ice would await the efforts of American engineer **Alexander Twining**, whose first “elementary trials” were “made as far back as the year 1848,” and **James Harrison**, an Australian printer and newspaperman, who built a mechanical ice-making machine in 1851.[10]

The 1870s saw the beginnings of rapid commercialization of vapor compression refrigeration with a system developed by **Carl Paul Gottfried Linde** (von Linde), a German engineering professor and scientist, using ammonia (NH_3) as a refrigerant. Systems using sulfur dioxide (SO_2) were also introduced by the Swiss **Raoul Pierre Pictet** as well as methyl chloride (CH_3Cl) by the French chemist **Camille Vincent**. Both Linde and Pictet developed methods of liquefying gases, including oxygen and nitrogen.

Early ice-making and refrigeration devices were typically powered by steam engines, or by line-shafts activated by hydro sources. As a result, vapor-compression machines were almost entirely used, at first, in large commercial/industrial settings. The emergence of small electric motors after 1900 made it practical to produce much smaller refrigeration devices for home and domestic use. Initially home units were costly, with the mechanical parts installed in the basement or a room adjacent to the *cold box* in the kitchen. In 1918, Frigidaire introduced one of the first-contained units.[11] This was soon followed by General Electric’s *Monitor-Top* refrigerator, which came to market in 1927.[12] The introduction of chlorofluorocarbon (CFC) refrigerants, such as Freon in the late 1920s, provided a safer alternative to ammonia and was perhaps the final step toward making vapor-compression refrigeration commonplace in household and commercial settings.

Vapor-compression air-conditioning for residential and commercial applications followed a somewhat similar path, although it was not as quickly adapted.

10 Brian Roberts, “James Harrison, Refrigeration Pioneer,” http://www.hevac-heritage.org/built_environment/pioneers_revisited/harrison.pdf, retrieved February 6, 2020.

11 Reuben Bechtold and Alfred Mellowes introduced a self-contained refrigerator with a compressor on the bottom of the cabinet. Mellowes produced this refrigerator commercially using the name Guardian Frigerator. The enterprise was eventually acquired by William C. Durant, who renamed the concern Frigidaire.

12 *Wikipedia, the Free Encyclopedia,* s. v. “Refrigerator,” (assessed December 5, 2019), https://en.wikipedia.org/wiki/Refrigerator.

Oliver Evans[13]

Oliver Evans (died–April 15, 1819) was an American inventor, engineer, and businessman. He was born in rural Newport, Delaware, in 1755 and later worked commercially in Philadelphia.

Evans received little formal education and in his mid-teens was apprenticed to a wheelwright. Going into business with his brothers, he worked for over a decade designing, building, and perfecting an automated mill with devices such as bucket chains and conveyor belts. In doing so Evans designed perhaps the first sophisticated continuous manufacturing process that required no human labor. This novel concept would prove critical to the Industrial Revolution and the development of mass production.

Later Evans turned his attention to steam power and built the first high-pressure steam engine in the United States in 1801, developing his design independently of Richard Trevithick, who built the first in the world a year earlier. Evans was a driving force in the development and adoption of high-pressure steam engines in the United States. Evans dreamed of building a steam-powered wagon and would eventually construct and run one in 1805. Known as the Oruktor Amphibolos, it was the first “automobile” in the country and the world's first amphibious vehicle, although it was too primitive to be a commercial success as either.

Evans was a visionary who produced designs and ideas far ahead of their time. In 1805 he was the first to describe vapor-compression refrigeration and propose a design for a refrigerator, but it would be three decades until his colleague Jacob Perkins constructed a working example. Similarly, he drew up designs for a solar boiler, machine gun, steam-carriage gearshift, dough-kneading machine, perpetual baking oven, marine salvage process, quadruple-effect evaporator, and urban gas lighting, all ideas and designs which would not be made reality until some time after his death. Evans had influential backers and political allies, but he lacked social graces and was disliked by many of his peers. Disappointed and then angry at the perceived lack of recognition for his contributions, Evans became combative and bitter in later years, which further damaged his reputation and left him isolated. Despite the importance of his work, his contributions were frequently overlooked (or attributed to others after his death) so he never became a household name alongside the other steam pioneers of his era.

[13] Adapted from *Wikipedia, The Free Encyclopedia,* s. v. “Oliver Evans,” (retrieved October 4, 2019), *https*://en.wikipedia.org/wiki/Oliver_Evans#Refrigeration,

Jacob Perkins[14]

Jacob Perkins was an American mechanical engineer, inventor, and physicist. He held many patents, among which were several (from 1834 and 1835) for mechanical refrigeration.

Perkins was born in Newburyport, Massachusetts, in 1766, and went to school there until he was twelve, at which time he apprenticed to a goldsmith in Newburyport. When the goldsmith died three years later, Perkins continued the business and added the manufacture of shoe buckles.

His metalworking abilities were recognized early. At the age of twenty-one, Perkins was tasked by the Massachusetts mint with making a die for producing copper coins. He received the first of his numerous patents in 1795, for a device that cut and headed nails. Other innovations included machinery for boring out cannons and a bathometer to measure the depth of the sea.

Perkins later established a printing business with engraver Gideon Fairman. Their business printed school books and legal currency for a Boston Bank. In 1819 Perkins relocated to England to compete for a £20,000 reward for creating ‘unforgable notes.’ He was part of a group that included Gideon Fairman, Asa Spencer, and British engraver-publisher Charles Heath. They eventually won the competition and went on to print currency for banks, as well as postage stamps.

Before leaving the United States, Perkins, in conjunction with Oliver Evans of Philadelphia, had worked on innovations in steam power, including an experimental high-pressure steam engine that proved impractical due to the technology available at the time. However, Perkins was somewhat more successful in using high-pressure steam for firing projectiles via his steam gun. Demonstrated in the mid-1820s, his gun could be adapted to fire lead musket balls in rapid succession—building a early form of ‘machine gun,’ as such armaments later became known.

Perkins also conducted experiments on the compressibility of water and the liquefaction of gases, which facilitated his work on the vapor-compression cycle, leading arguably to his most successful invention: his “Apparatus and means for producing ice, and in cooling fluids.”[15] His August 14, 1834, patent by that name described a device that is now referred to as a refrigerator. It employed the vapor-compression cycle initially conceived by Oliver Evans, an American inventor. The vapor-compression cycle used by Perkins was later employed for air-conditioning and, with variations, in heat pumps.

Jacob Perkins married Hannah Greenleaf of Newbury on November 11, 1790. They had nine children. He died in 1849, while residing in London, England.

[14] Adapted from *Wikipedia, The Free Encyclopedia,* s.v. “Jacob Perkins,” (retrieved October 4, 2019), https://www.historyofrefrigeration.com/refrigeration-invention/jacob-perkins/.

[15] Patented in England in 1834, Number 6662.

HISTORIC MECHANICAL ENGINEERING LANDMARK

VAPOR-COMPRESSION REFRIGERATION AND COOLING

1805, 1834

THE CLOSED, VAPOR-COMPRESSION CYCLE FOR COOLING WAS CONCEIVED BY OLIVER EVANS IN 1805, WHO DESCRIBED THE CYCLE BUT NEVER CONSTRUCTED A WORKING DEVICE. IN 1834 JACOB PERKINS, AN ASSOCIATE OF EVANS, FILED A PATENT IN ENGLAND FOR A CONTINUOUS VAPOR-COMPRESSION MACHINE THAT COULD COOL WATER AND SOLIDIFY IT INTO ICE CONTINUOUSLY. THE PERKINS VAPOR-COMPRESSION MACHINE WAS CONSTRUCTED AND DEMONSTRATED IN 1835 BY JOHN HAGUE. THIS SUCCESSFUL DEVICE IS THE PROTOTYPE OF VAPOR-COMPRESSION DEVICES FOR REFRIGERATION, AIR-CONDITIONING, AND HEAT PUMPS.

IT TOOK THE EFFORTS OF MANY OTHERS, INCLUDING AMERICAN SCIENTIST AND INVENTOR ALEXANDER TWINING AND AUSTRALIAN JAMES HARRISON, BEFORE MECHANICAL VAPOR-COMPRESSION SYSTEMS FOR ICE-MAKING WERE COMMERCIALLY SUCCESSFUL.

THE WIDE USE OF THE VAPOR-COMPRESSION CYCLE IN THE PRESERVATION OF FOOD, IN COOLING AND HEATING LIVING SPACES, AND NUMEROUS OTHER COOLING AND HEATING APPLICATIONS MAKES IT ONE OF THE WORLD’S MOST SIGNIFICANT MECHANICAL INNOVATIONS.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS—2020

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 http://www.asme.org

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, 273 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.

ASME
SETTING THE STANDARD

ASME OFFICERS

Bryan A. Erler, P.E., President
Thomas Costabile, P.E., Executive Director/CEO

ASME HISTORY AND HERITAGE COMMITTEE

Herman H. Viegas, P.E. (Ret.), Chair
Terry S. Reynolds, Vice Chair
Lee S. Langston, Secretary
Thomas H. Fehring, P.E., Immediate Past Chair
Marco Ceccarelli
Richard I. Pawliger, P.E. (Ret.)
Robert T. Simmons, P.E. (Ret.), Past President

Corresponding Members

John K. Brown
Scott Davidson, P.E. (Ret.)
Michael Iden
Francis C. Moon
Martin C. Ross
Virginia Ross
Steven Walton
Robert O. Woods, P.E. (Ret.)

Emeritus Members

J. Lawrence Lee, P.E. (Ret.)
Robert Vogel

ASME STAFF

Mel Torre, Manager, Corporate Communications
Wil Haywood, Communications Specialist