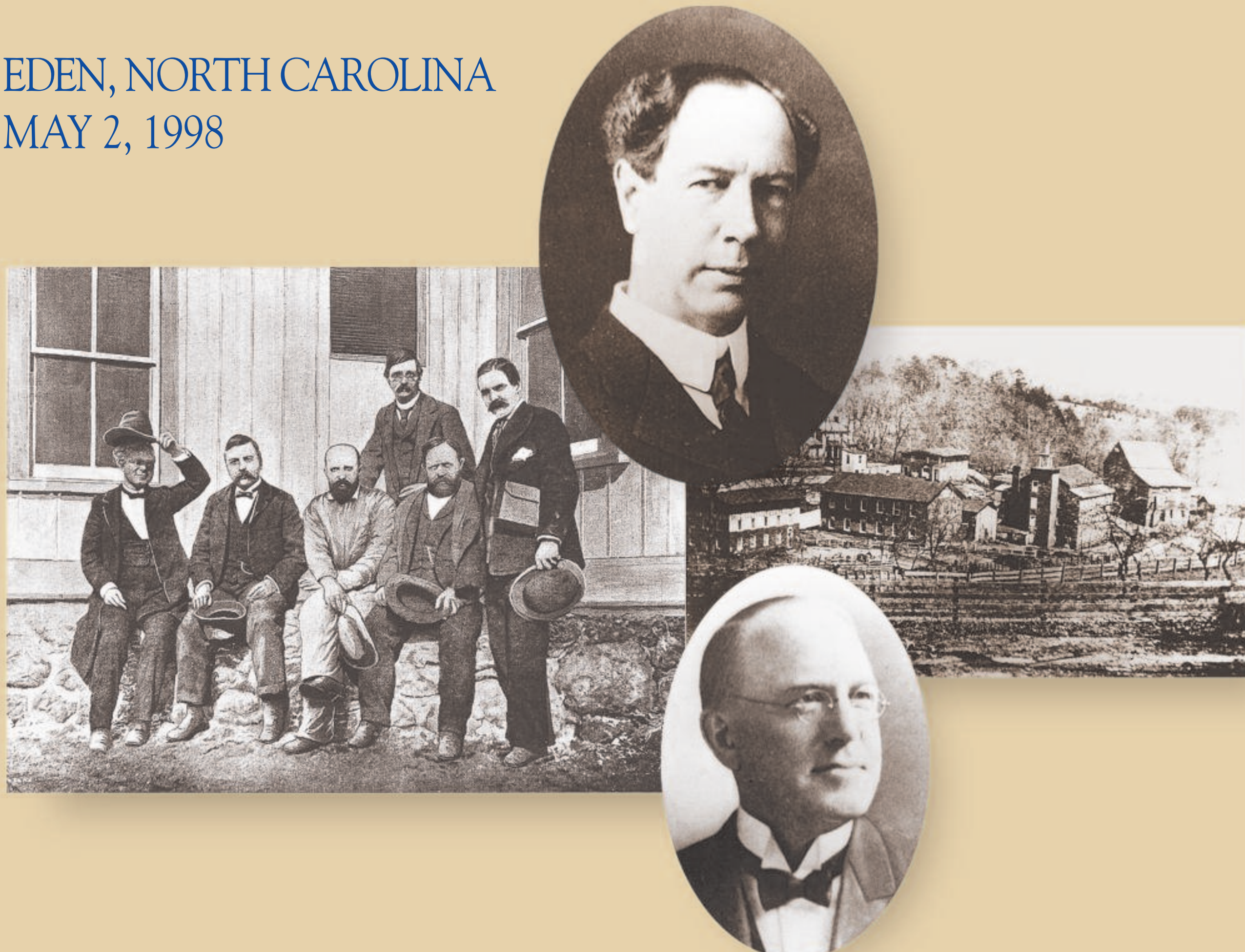
A NATIONAL HISTORIC
CHEMICAL LANDMARK

DISCOVERY OF THE COMMERCIAL PROCESSES FOR MAKING CALCIUM CARBIDE AND ACETYLENE

EDEN, NORTH CAROLINA
MAY 2, 1998



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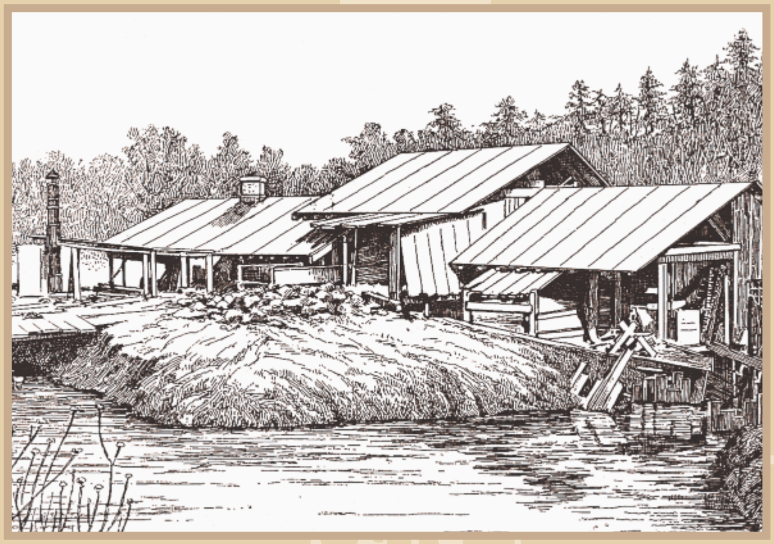

Willson Aluminum Company plant, Spray, N.C., 1896

This booklet commemorates the designation of the site of the discovery of the commercial processes for making calcium carbide and acetylene as a National Historic Chemical Landmark. The designation was conferred by the American Chemical Society, a nonprofit scientific and educational organization of more than 155,000 chemists and chemical engineers.

A plaque marking the designation was presented to Spray Cotton Mills, owner of the site in Eden, North Carolina, on May 2, 1998, 106 years to the day after the discovery of the process. The inscription reads:

"At this site on May 2, 1892, while searching for an economical process to make aluminum, Canadian inventor Thomas L. Willson (1860–1915) accidentally discovered the electric-arc process for preparing calcium carbide, which reacts with water to form acetylene. The first commercial calcium carbide plant, built by local entrepreneur James Turner Morehead (1840–1908), operated here between 1894 and 1896. From this beginning, calcium carbide and acetylene manufacturing spread around the world. Acetylene, used first for lighting homes, railways, mines, and marine buoys and then for oxyacetylene welding, became one of the foundations of the synthetic organic chemicals industry."

The original one-acre site of the Willson Aluminum Company plant where the discovery was made is now partially covered by the Spray Cotton Mill, which was built in 1896 after the Willson plant burned. Nothing remains of the Willson plant except the waterwheel, which generated power for the cotton mill until the 1970s.

Out of the discoveries at Spray, numerous companies sprang up around the world, the oldest and best known being Union Carbide Corporation, originally Union Carbide Company, which was incorporated a century ago on April 1, 1898.

On the cover: (Clockwise)
Thomas L. Willson; Spray, N.C., October 1886; James Turner Morehead; technical experts at Spray, March 1896:
L to R seated: J. T. Morehead; E. C. Brown, editor, *Progressive Age*; Leonard P. Kinnicutt, chemical consultant; Edwin J. Houston, electrical consultant: L to R standing: Guillaume de Chalmot, plant superintendent; Arthur E. Kennelly, electrical consultant.

Backgrounds:
This page: Schematic drawing of 1892 arc furnace.
Page 1: L. P. Kinnicutt, E. J. Houston, and J. T. Morehead showing a 220-pound carbide ingot, March 1896.
Page 2: J. T. Morehaed's textile factory, ca. 1880.
Page 3: Apparatus for the manufacture of acetylene from calcium carbide, 1895.
Page 4: Double electric-arc furnace, 1896.

Acknowledgments:

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INDUSTRIAL PROCESSES DISCOVERED BY CHANCE

May 2, 1998, marks the 106th anniversary of an unexpected discovery in the village of Spray (now Eden), North Carolina, that proved to be a milestone in the history of the chemical industry. On that date, Thomas L. Willson, a struggling young Canadian inventor, accidentally discovered the processes for making calcium carbide and acetylene in commercial quantities.


Thomas Leopold Willson

Acetylene, when burned in air, gave a light far brighter than any in use at the time for home lighting. When burned with oxygen, it gave a flame that was 1000 °C hotter than any other, leading to the development of commercial oxyacetylene welding and cutting. Most important, acetylene later became the starting material in the synthesis of hundreds of aliphatic organic chemicals used worldwide, particularly solvents, plastics, and synthetic rubber.

Thomas Leopold Willson (1860–1915), discoverer of these processes, was born in Princeton, Ontario, the grandson of John Willson, speaker of the United Canadian Assembly. He attended Hamilton Collegiate Institute; but after his father died, he withdrew from school to develop an arc-lighting system, the first seen in Hamilton. At age 22, he moved to the United States, where he held various jobs in the mechanical and electrical trades before settling in Brooklyn, New York, in 1887. His work over the next three years resulted in six patents, which secured for him the rights in the United States for use of the electric-arc furnace in ore smelting. Aluminum metal was a primary target.


James Turner Morehead

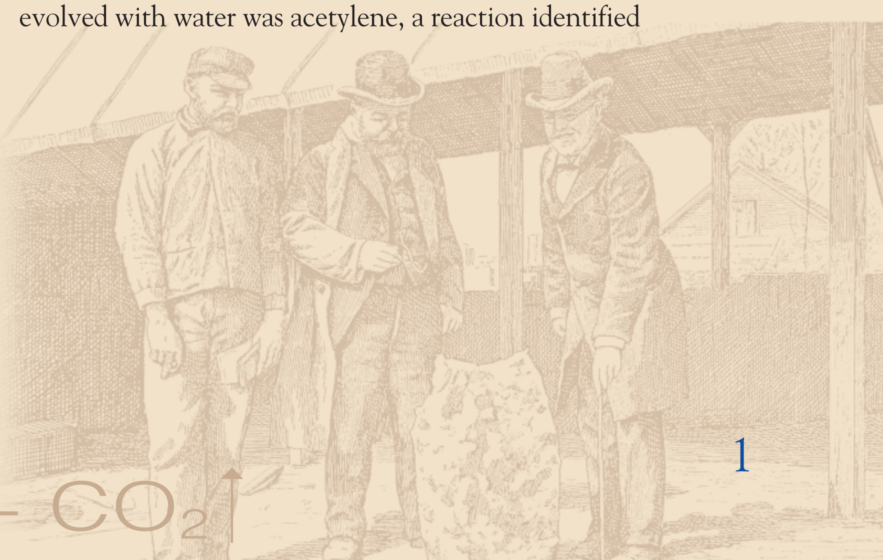
In December 1890, the Willson Aluminum Company was formed to exploit Willson's patents. In 1891, Willson moved to Spray to build a small 300-horsepower plant along the Smith River on land owned by one of the company's financial backers, James Turner Morehead (1840–1908). Morehead, a graduate of the University of North Carolina and a Confederate army veteran, was a textile manufacturer, land and water power developer, and former state senator. Although most of Morehead's business ventures prospered, failure of a railroad in which he had invested left him deeply in debt. To raise cash, he looked for new uses for his abundant supply of water power. This search led him to Willson.

Thomas Willson was just one among many seeking an economical way to make aluminum. His approach was to reduce the aluminum ore with carbon in a high-temperature, electric-arc furnace, a process explored in the laboratory about the same time by the French chemist Henri Moissan.

In practice, Willson was able to produce only a few globules of aluminum. He then reasoned that if he could make a more chemically active metal, such as calcium, he could, in turn, use the calcium to reduce alumina. Accordingly, on May 2, 1892, a mixture of lime (calcium oxide) and coal tar (carbon) was subjected to the heat of the arc. When the furnace was tapped and the resulting product thrown into water, it produced a flammable gas thought to be hydrogen, as was expected from calcium.


Spray, N.C., October 1886.

However, unlike clean-burning hydrogen, this gas burned with a sooty flame, for which there was no ready explanation. Willson then retained Francis P. Venable (1856–1954), of the University of North Carolina, as a consultant. During the summer and fall of 1892, Venable proved that the furnace product was calcium carbide and that the gas it evolved with water was acetylene, a reaction identified



$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2\uparrow$$

Employees of Willson Aluminum Company, 1895. James T. Morehead, second from left; Guillaume de Chalmot, second from right. This is a double exposure.

in 1862 by the German chemist Friedrich Wöhler. Although there were no uses for either calcium carbide or acetylene at the time, Willson filed for a patent on this process on August 9, 1892.

Meanwhile, the experimental work to make aluminum continued. By the spring of 1893, however, it was obvious that Willson's process was a failure. The stock market crash in May 1893 and the ensuing depression bankrupted the company, leaving Morehead virtually penniless.

Failing to find anyone willing to buy their calcium carbide and acetylene patents, Morehead and Willson turned their attention to finding and promoting uses for the products themselves, beginning with acetylene in lighting. After they showed that acetylene could produce a flame 10 to 12 times brighter than that of coal gas, its use as an illuminant developed rapidly. Willson made the first sale of calcium carbide, 1 ton, to Eimer and Amend, a New York chemical and apparatus supply house, on January 29, 1894. Fortune smiled again when, in August 1894, they sold their patents for the use of carbide and acetylene in lighting to a new firm, the Electrogas Company, but retained the rights for chemical manufacturing. Electrogas Company, in turn, began to sell carbide manufacturing rights worldwide. As part of the agreement, Willson reserved all rights for Canada, and Morehead bought a manufacturing franchise.

Willson moved back to New York in the fall of 1893 and set up a laboratory at Eimer and Amend to explore chemical uses for acetylene. After making small quantities of chloroform and aldehydes, he filed for a patent in February 1894 to cover the use of acetylene in the manufacture of "hydrocarbon products."

By borrowing more money, Morehead was able, in August 1894, to complete at Spray the first commercial calcium carbide plant. Its 8-foot high, double-sided furnace was capable of continuous operation. While a charge of lime and tar was being processed on one side, a completed run of carbide could be cooling on the other. The furnace produced 1 ton of carbide every 24 hours, which yielded 4.8 cubic feet of gas per pound, 80% of the theoretical. As publicity about acetylene's possibilities soared, so did the demand for carbide. On May 1, 1895, the plant began to operate around the clock. The months that followed were giddy with success, but then disaster struck; the Willson plant was destroyed by fire on March 29, 1896.

Morehead built a much larger plant on the James River near Lynchburg, Virginia. Almost simultaneously, he opened a plant at Kanawha Falls, West Virginia, to make ferroalloys, processes that had been developed at Spray by Willson and Guillaume de Chalmot (1870–1899), the plant superintendent. Eventually, Morehead sold his holdings to Union Carbide Company, which had been formed in 1898 to consolidate the interests of the Electrogas Company. He paid off his debts and, at his death, left an estate of $200,000.

Double electric-arc furnace, Willson Aluminum Company, 1896.

Willson returned to Canada in 1895, where he became one of its wealthiest and best known citizens. By 1896, he was constructing a carbide plant at Merritton, Ontario, and later he built plants in Ottawa and Shawinigan Falls. As he sold rights for carbide manufacture to others, he developed many interests, forming new companies and plants as he proceeded to produce hydroelectric power, acetylene-lighted marine buoys, fertilizer, cement, ammonia, phosphoric acid, and paper. He sold his marine buoy business in 1909 and his interests in carbide manufacture to a new firm, Canada Carbide Company, formed in 1911. He died of a heart attack in New York while raising money for yet another project. His home in Woodstock, Ontario, is now a national historic site, and his summer home on Meech Lake in Quebec is a government conference center and retreat.

$$CaO + 3C \xrightarrow{\Delta} CaC_2 + CO\uparrow$$

AN ABUNDANT HARVEST FROM CHANCE DISCOVERIES

In 1800, while experimenting with a voltaic cell, Humphry Davy produced the first arc light by passing an electric current between two carbon rods, which touched each other, and then drawing them apart. When an electric current meets with resistance, its energy is transformed into heat, and because the carbon vapor in the arc offers high resistance to the electric current, temperatures as high as 3700 °C are attainable, high enough to melt or vaporize any known substance.

The carbon-arc furnace, which dates from 1845 when it was battery operated, was of no practical value until after the development in 1867 of the electrical dynamo for converting water or steam power into electricity. Not until the work in Spray, did the arc furnace become an industrial reality.

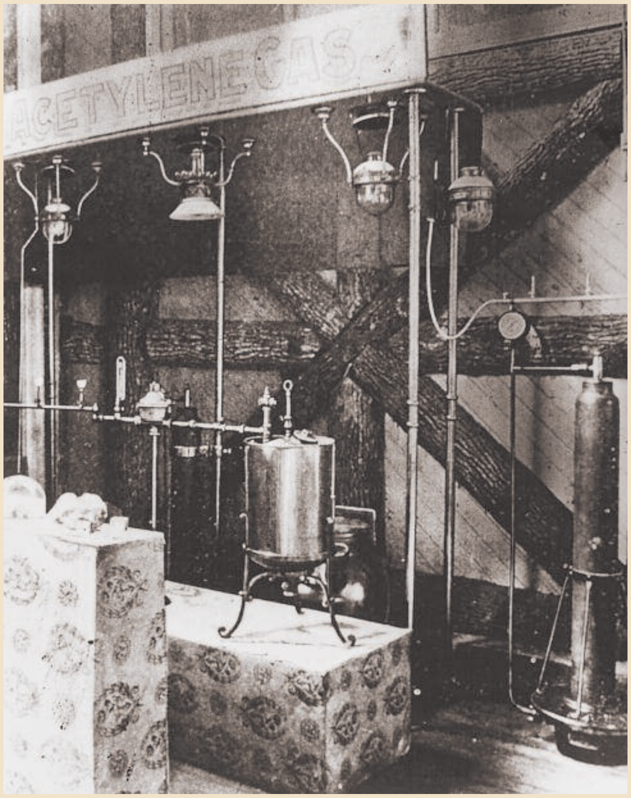
Improved Lighting

Over the half century following its discovery in 1836 by Edmund Davy, a cousin of Humphry Davy, acetylene was only a laboratory curiosity. After Thomas L. Willson's discovery of a cheap commercial process for making acetylene in 1892, massive quantities of the gas were in demand for lighting.

A newly developed acetylene burner, designed to bring adequate air to the flame to eliminate smoke and soot, gave a brilliant white light, 10 to 12 times brighter than that of any commercial fuel then in use. By 1897, acetylene generators and compressed acetylene were successfully competing with the fledgling electric light industry to provide excellent lighting, particularly in country homes and those not accessible to gas utilities.

Portable acetylene generators, which worked simply by dropping water on calcium carbide, provided a practical way for lighting railways, mines, bicycles, and automobiles. Acetylene lighting was used in transportation for a decade or more until electrical generation systems and shock-resistant light bulbs were developed. Miners continued to use carbide lights on their caps until long-lasting, dry-cell electric batteries were perfected in the 1920s.

Acetylene also replaced oil in marine buoys because it provided a far brighter light. The automatic carbide acetylene generators used at first were not very reliable and were replaced by compressed acetylene. Swedish engineer Gustaf Dalén received the 1912 Nobel prize in physics for his discovery of techniques that allowed safe compression of acetylene. A few of the acetylene buoys were still in operation in the 1960s.

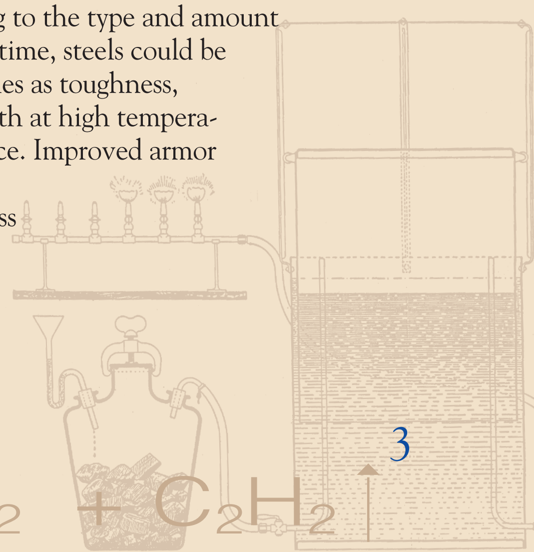


Acetylene generator, compressed gas cylinder, and acetylene lights, on exhibit at the Atlanta Exposition, August 1895.

High-Quality Alloy Steels

In 1894, Thomas Willson began experiments at Spray with smelting metals in the carbon-arc furnace. After 1895, this work was carried on by Guillaume de Chalmot. The high temperature of the arc furnace provided a more efficient means for alloying iron with chromium, manganese, and other metals.

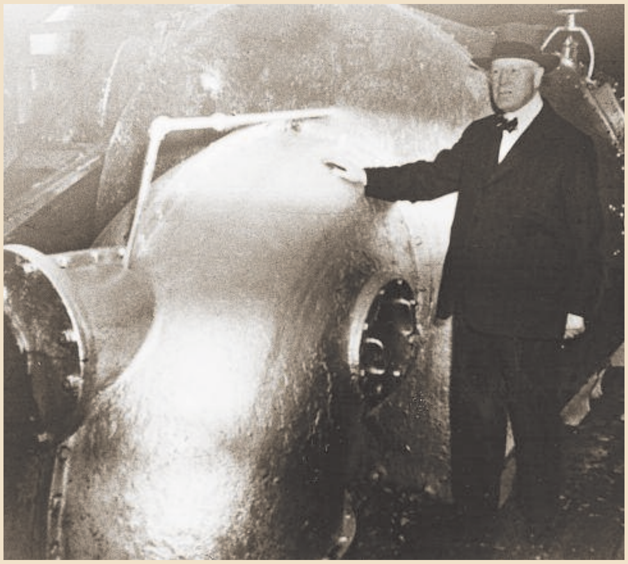
As a group, these low-iron alloys, called ferroalloys, can be readily dissolved in steel to impart predictable properties according to the type and amount of metal added. For the first time, steels could be tailor-made for such properties as toughness, impact strength, high strength at high temperatures, and corrosion resistance. Improved armor plate for battle ships, high-speed tool steels, and stainless steels are just three of the hundreds of specialized steel products now in use.



$$CaC_2 + 2H_2O \longrightarrow Ca(OH)_2 + C_2H_2 \uparrow$$

Rapid Welding and Cutting of Metals

During the 19th century, the only means of continuously joining two pieces of iron or steel was to heat them in a forge and hammer them together. In 1886, electric welding was introduced, but it was of no practical value because the electric power industry was not sufficiently developed to sustain it. Oxyhydrogen and thermite welding were known but had not been perfected.



John Motley Morehead, plant chemist in 1892, standing by the Willson Aluminum Company waterwheel at Spray Cotton Mills, ca. 1950.

When burned with oxygen instead of air, acetylene gave a flame temperature of 3000 °C compared with 1900 °C for the Bunsen burner flame. This high-flame temperature was reported in 1895 but not exploited until about 1901, when a commercial oxyacetylene welding apparatus was developed in France. The first oxyacetylene welding shop in the United States was set up in 1906, and in 1907 the technique was adopted at the Brooklyn Navy Yard. There, oxyacetylene torches could cut a porthole in 3-inch armor plate in 30 minutes, a task that formerly had required five men working for two weeks to complete. The sudden, great demand for oxygen for welding launched oxygen as a commodity product.

Nitrogen Fixation and Fertilizer Manufacture

Henri Moissan observed in 1893 that calcium carbide absorbed atmospheric nitrogen. In 1898, Fritz Rothe of Germany found that the compound formed by this absorption was calcium cyanamide. In the soil, calcium cyanamide decomposes to yield urea and ammonium carbonate, both potent fertilizers. A commercial process patented by Adolf Frank and Nikodem Caro for making calcium cyanamide from carbide was perfected in Germany in 1903 and was widely adopted almost immediately. This was the first commercial process that was used worldwide to fix atmospheric nitrogen. World output of calcium cyanamide increased from 1700 tons in 1907 to an estimated peak production of 1.5 million tons in 1945.

Organic Chemicals and Macromolecules

Following Willson's synthesis of chloroform and aldehydes from acetylene in 1894, acetylene soon became the starting material in the synthesis of a host of organic substances, particularly for the solvent, plastics, and synthetic rubber and fiber industries. By 1896, work in Germany led to chlorinated solvents by partial or complete chlorination of acetylene, and in 1908 to a full-scale plant producing 1,1,2-trichloroethene. These solvents were used extensively after 1920 for degreasing metals in preparation for electroplating or painting. By 1912, Germany was producing polyvinyl acetate for use in varnishes. Subsequently, polyvinyl acetate was used in adhesives, paints, paper, textiles, glue, and flooring materials.

During World War I, commercial processes for the production of acetaldehyde, acetic acid, and acetone (by passing acetic acid over a hot catalyst) were installed in Canada; acetone in particular was needed for making explosives. Similar processes in the United States in the 1920s served the cellulose acetate industry for the production of fibers and film. In the same decade, the synthesis of vinyl acetylene by Julius Nieuwland led to the development in 1932 of the synthetic rubber, neoprene, by DuPont. Its annual output reached 120,000 tons by 1960.

In Germany after World War I, butadiene made from acetylene was the basis of a rubber substitute that made the country self-sufficient in rubber. Also in Germany, beginning in 1925, J. Walter Reppe pioneered the study of acetylene chemistry at pressures as high as 200 atmospheres. This opened up a vast new field, often known as "Reppe chemistry." Reppe even managed to form cyclooctatetraene by linking four acetylene molecules in a ring, thereby confirming Richard Willstätter's much contested claim that he had made the same compound in 1911.

With hydrocyanic acid, acetylene forms acrylonitrile, which can then be polymerized and spun into acrylic fibers. World production of acrylic fibers in 1988 was 2,523,00 tons.

In the past 40 years or so, acetylene has increasingly been derived from petroleum, but if petroleum reserves dwindle sufficiently to raise the price above that of coal, industry might return to coal, and calcium carbide would again become a main path to organic chemicals.

$$CaC_2 + N_2 \longrightarrow CaCN_2 + C$$

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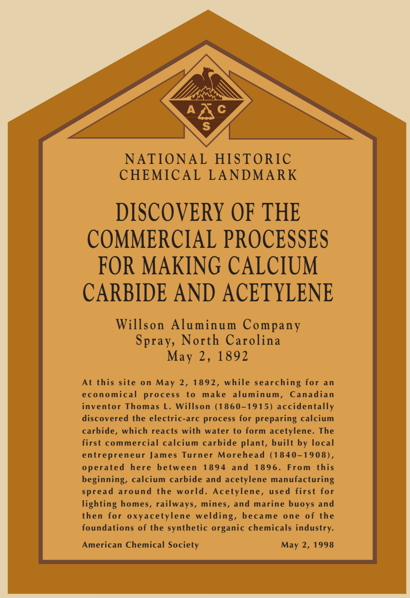
THE NATIONAL HISTORIC CHEMICAL LANDMARKS PROGRAM OF THE AMERICAN CHEMICAL SOCIETY



The ACS National Historic Chemical Landmarks Program recognizes our scientific and technical heritage and encourages the preservation of historically important achievements and artifacts in chemistry, chemical engineering, and the chemical process industries. It provides an annotated roster to remind chemists, chemical engineers, students, educators, historians, and travelers of an inspiring heritage that illuminates where we have been and where we might go when traveling the diverse paths to discovery.

An ACS historic chemical landmark represents a distinctive step in the evolution of the chemical sciences and technologies. Designations of sites and artifacts note events or developments of clear historical importance to chemists and chemical engineers. Collections mark the contributions of a number of objects with special significance to the historical development of chemistry and chemical engineering.

The NHCLP began in 1992, when the Division of the History of Chemistry of the ACS formed an international Advisory Committee. The committee, composed of chemists, chemical engineers, and historians of science and technology, works with the ACS Office of Communications and is assisted by the Chemical Heritage Foundation. Together, these organizations provide a public service by examining, noting, recording, and acknowledging particularly significant achievements in chemistry and chemical engineering. For further information, please contact the ACS Office of Communications, 1155 Sixteenth Street, N.W., Washington, DC 20036; 800-ACS-5558, ext. 6274.

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