August 2020

THE NITROLEE EXPERIMENT

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Nestled in the woods next to Fishing Creek near Great Falls in Chester County, South Carolina are the ruins of an experiment that briefly placed Great Falls in the forefront of technological development. In 1912, it was on the cutting edge of the new science of creating fertilizer on an industrial scale. Abandoned for over a century, the Nitrolee plant is now just a memory. This article is an attempt to describe that experiment and the men who undertook such a daring endeavor.

The Age of Natural Fertilizer

Over the millennia since mankind began a settled agricultural existence, practices spread to maintain the richness and health of the soil. The benefits of manure, composting, and crop rotation have been known since ancient times. The Romans even had a god of manure, Stercutius, and farming societies in various cultures perfected the right combination of animal waste, composting, cover crops to fix nitrogen, and other practices to suit their local soils and climate. Backyard gardeners still utilize these practices today. This system of natural fertilizers was sufficient for most of human history, as the vast proportion of the population consisted of subsistence farmers. Cities existed in all these societies, but they remained dependent on a nearby network of local farms to provide the necessary supply of food and other agricultural products.

During the nineteenth century, the human population began increasing rapidly. There were important developments in hygiene and medicine which led to an astounding increase in human lifespans, survival rates, and population. The industrial revolution in Europe caused millions of farmers to leave their land and move to mill communities and cities for a more stable income. These mills required huge quantities of raw materials, such as cotton. Farmers in many parts of the world were induced to grow these cash crops, and abandon their traditional methods of subsistence farming. Improvements in transportation, communication, and sources of energy led to an increasingly interconnected world, where the textile mills of northern England were intimately connected to the slave society of the American South. These dramatic changes in the world economy meant that the traditional means of maintaining soil health were no longer possible. The farmer who grew all the food needed by his family on a few acres could easily maintain the soil fertility by using the traditional methods. The farmer growing a single monoculture crop, such as cotton, on hundreds of acres needed an external source of soil fertility.

When we go to the store today to buy a fertilizer, we find a wide selection of products. Most products contain some combination of three elements: nitrogen, phosphorous, and potassium, known by the chemical symbols N, P, and K. Traditional farmers, without knowing the science behind fertilizers, were creating, by trial and error, a near-perfect combination of these elements for their soil and climate conditions. Today, they are available in combinations that we need for various crops and soil conditions, whether to benefit our vegetable garden or a large farm. In the 1800s, no such miracle commercial products were available on a large scale. The search for fertilizers led to new industries, wars over the resources, and international intrigue.

The challenge was perhaps best described by Sir William Crookes, who became president of the British Academy of Sciences in the fall of 1898. A physicist and inventor, Crookes used his inaugural address to the Academy to warn of a great danger to society. The increase in human population was so great that modern civilization was in peril of starving if radically new sources of fertilizers were not developed. He warned that the earth had been explored and mapped, and all the great agricultural areas have been found, such as the Great Plains of North America and the steppes of Asia. As agriculture becomes more intensive, Crookes warned, the soil will lose its fertility because we no longer have enough animal dung to apply to the vast lands needed. "As there was not enough natural fertilizer in the world to meet the needs of the coming twentieth century, some way would have to be found to make more, to make it systematically, to make it in factories. Finding new ways to make fertilizer, discovering what he called chemical manures, Crookes told his audience, was the great challenge of their time."[1]

Before Crookes' warning, there had been a world-wide search for natural sources of fertilizers. Guano, the collected droppings of bats, was long known to be a good source of plant nutrients. Sources of guano had long been exploited around the world. In the 1830s, the Chincas Islands off the coast of Peru were discovered to have a vast supply of guano. This was exploited using slave labor in dreadful conditions. The United States and Europe became large importers of Peruvian guano, touching off a brief economic boom in Peru. This source was largely exhausted by the 1870s.

The guano rush led to some major expansions in United States territory. In a break with the former policy of limiting U. S. expansionism, the Guano Islands Act of 1856 provided that whenever a U. S. citizen discovered guano on an unclaimed and uninhabited island, it could be claimed by the U. S. at the discretion of the President. By 1863, the government had annexed fifty-nine islands and by 1902 the list included ninety-four islands scattered across the Pacific

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[1] Thomas Hager, *The Alchemy of Air*, New York: Harmony Books, 2008, page 7.

and Caribbean.[2] This mania for guano led to a dramatic shift in U. S. policy. Since its earliest years, the U.S. had condemned the imperialism of the European powers. Following the guano island expansions and the territories gained as a result of the Spanish-American War, the U. S. gained an empire of its own. By the early twentieth century, there were more people under control of the government outside North America than inside the states that belong to the union.

Following the decline of guano production, a new boom began in exploiting the strange chemical mix found on the floor of the Atacama Desert in South America. This nitrate-rich mixture is called caliche by the natives, and can be processed to create both a fertilizer and an explosive. The source became an important resource for Great Britain in creating weapons for the Crimean War in the 1850s and for the United States during the Civil War of the 1860s. By the 1870s, the production of nitrates for fertilizer was being undertaken on a massive scale involving thousands of workers. Because the Atacama spans three countries, the value of this new resource led to international strife. In 1879, the "nitrate war" began, involving Peru, Chile, and Bolivia. Chile prevailed, and the international boundaries were redrawn, with Bolivia losing its access to the sea and Peru ceding all of its valuable nitrate area.[3] The nitrate boom provided Chile with great wealth and the consuming countries with a significant supply of nitrates for both fertilizers and explosives. But like the guano deposits, there was a limit to the nitrate available.

Other sources of fertilizers were exploited closer to home. Just after the Civil War, several corporations were created to mine and manufacture fertilizers from the phosphate rocks of the South Carolina Low Country. Among the first of these were the Wando Company in 1867 and the Etiwon Company in 1868. These beds were at the time the largest known source in the world, and the South Carolina-based companies developed methods for mining the phosphate, washing and preparing it for market, and grinding it for manufactured fertilizer. In 1867, the industry produced six tons of fertilizer. This production gradually grew to a peak of 673,192 tons in 1885. As volumes grew, the price of the product gradually declined, making it more economical for farmers to use. Before 1890, South Carolina had a practical monopoly on the market for phosphate fertilizer in North America and Europe. About that time, phosphate of a higher grade was found in Florida and Tennessee, and the market shifted.[4] By 1900, two large mining companies in Beaufort and Lady's Island closed, signifying a significant decline to this industry.[5]

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[2] Daniel Immerwahr, *How To Hide An Empire: A History of the Greater United States*. New York: Farrar Straus and Giroux, 2019, pages 50-53.
[3] Hager provides an extensive discussion of the guano and nitrate booms and conflicts in chapters 3 and 4 of his book.
[4] *South Carolina: A Handbook*, Columbia: South Carolina Department of Commerce and Industries and Clemson College, 1927. This state publication provides a full description of the phosphate industry.
[5] *Rock Hill Herald*, November 10, 1900.

As these natural sources of fertilizers were exploited throughout the nineteenth century, the demand kept growing. Sir William Crookes' dire warning at the turn of the twentieth century was that a new and inexhaustible source of fertilizer was needed.

The Race Is On

Three competing methods of producing fertilizer were being developed in the early twentieth century, with research in Germany leading the way. These included a process using Cyanamid; the Haber-Bosch process developed by German scientists; and the electric arc process. For a short time in the early years of the century, there were intense research and development efforts to find the most economical method among the three. The race was on.

The Cyanamid process used huge amounts of electricity to make calcium cyanamide from high-temperature reactions between N2 and calcium carbide. This process was being explored in both the United States and Germany. In New York, Frank Washburn established the American Cyanamid Company in 1907. It used electricity generated at Niagara Falls to undertake the Cyanamid process of creating fertilizer. German investors were seeking funds to begin their own plants using the process.

The second process, which later became known as the Haber-Bosch process, was developed over a period of time in Germany by a number of chemists and scientists. In the early twentieth century, the largest chemical company in Germany was BASF (Badische Anilin-und Soda-Fabrik). The head of the company was Heinrich von Brunck, who had been contemplating a process for nitrogen creation for years. Brunck gave a number of young researchers the opportunity to invest in untried processes in an attempt to find the most efficient methods. A chemist named Wilheim Ostwald had proposed a machine for creating nitrogen through a chemical process. This process was not successful, but BASF recruited other young researchers to work on the problem. Among them were Fritz Haber and Carl Bosch. By 1908, Haber and his associates were making quantities of ammonia from the air. He signed a contract to work for BASF on both the electric arc process and the ammonia process. The money from the company helped him invest in ever larger and more promising machines. Under very high pressure, and with the use of an obscure metal called osmium, he was able to create measurable quantities of ammonia by March 1909. Carl Bosch, who had extensive metal working experience, aided in the development of containers that could withstand the high pressures. The later discovery that a more common element, uranium, could be used as the catalyst in the process led to success. By later in 1909, what became known as the Haber-Bosch process was capable of changing atmospheric nitrogen into ammonia in substantial amounts, creating a ready supply of chemical fertilizer. It consumed just a fraction of the energy required for either the Cyanamid process or the electric arc process. BASF began to invest in larger facilities. In further testing, the catalyst for the process was changed to a mixture of aluminum oxide, iron, and calcium. These much more common elements made the process even more efficient. Haber eventually left the company, but Carl Bosch continued his work in expanding the process to an industrial scale. Soon BASF was investing heavily in the Haber-Bosch process.[6] So important was this chemical process that Fritz Hamer won the Nobel Prize for Chemistry in 1918 for the synthesis of ammonia from its elements and Carl Bosch won the Nobel Prize in Chemistry in 1931 for his chemical high pressure methods.

The final process used large amounts of electricity to separate nitrogen from the air and create a useable nitrogen-based fertilizer. The electric arc process relied on a ready supply of electricity in large quantities. This is the process undertaken in the backcountry of South Carolina near the little town of Great Falls.

The Nitrolee Experiment

In South Carolina, pioneers such as Dr. Gill Wylie and the Duke brothers had begun developing the hydroelectric resources of the Catawba River. Dr. Wylie, a native of Chester County, was a remarkable visionary whose story has been overlooked. He served in the Confederate Army as a teenager, studied engineering at the University of South Carolina, and graduated from medical school in New York City. He partnered in New York with Dr. J. Marion Sims, a Lancaster County native who is considered the father of modern gynecology. By 1896, Wylie had saved about $400,000 (the equivalent of around $12 million in today's money) and invested in a new technology at Portman Shoals near Anderson, S. C. Working with engineer William Church Whitner, Wylie was able to demonstrate for the first time that electrical current could be transported some distance from the source to a city efficiently and safely. The success of the Portman Shoals project led Wylie to look to a larger scale project on the Catawba River. Wylie can be credited with the concept of developing an integrated and connected system of hydroelectric projects throughout the Catawba River drainage. By 1901, he organized the Catawba Power Company and began working on a dam at India Hook in York County between Rock Hill and Fort Mill. He enlisted a young engineer named William States Lee, originally from Lancaster County, to assist in the work. While this was in progress, the North Carolina tobacco magnate James Buchanan Duke was in Wylie's office for treatment of an extended illness. In the time spent with Duke, Wylie shared his vision for the electrical empire on the Catawba River. Duke agreed to invest in the company, and together the men and Duke's brother Benjamin Newton Duke bought land along the river from the mountains to Columbia. With the help of Lee, the system of dams along the Catawba gradually began to develop. The India Hook plant, completed in 1904 and now known as Lake Wylie, was soon joined by several plants in the Great Falls area built by the Southern Power Company and built beginning in 1907. The

[6] An extensive description of the development of the process is found in Thomas Hager's *The Alchemy of Air,* already cited.

Duke brothers eventually bought out Wylie's interest, and consolidated the dams under the name Duke Power Company.[7]

Wylie and the Dukes planned to use most of the power generated to supply the textile mills which were sprouting along the river. The first mill at Great Falls was built in 1910. They also began selling power to towns and cities within their service area for municipal use. However, there was still a surplus, and J. B. Duke and the company engineer William States Lee began working on methods of using the excess electricity. Duke could not stand the idea of water flowing down the river without being put to use for a profit. Beginning in as early as 1908, Duke, with the assistance of Lee, began looking for ideas. After the pair made several trips to Europe, Duke secured the North American patent for the best electric arc process for creating nitrogen fertilizer.

It is important to note that the three various processes for synthetic nitrogen production were being developed concurrently, and no one knew which would turn out to be the most economically viable. The Haber-Bosch process was under development at the same time Duke was seeking to use the electric arc process. The first large-scale facility for implementing the Haber-Bosch system in Germany was under construction by May of 1911 and began operations on 1913. At exactly the same time, an electric arc plant was begin built in the back woods of South Carolina, the only one of its kind on the continent. An electric arc facility was also built in Norway, using the abundant water power there. The Cyanamid process was being used in Germany and in New York State, using power from Niagara Falls.

In the race to develop the electric arc system, Duke and Lee imported German and Austrian engineers, and a plant was under construction by late 1910 or early 1911.[8] To build the facility, a new company was created, the Southern Electro-Chemical Company. Specially fired bricks and porcelain conductors were imported from Germany, where engineers had experience in dealing with materials which could withstand extremely high temperatures. The plant was named "Nitrolee," a combination of "nitrogen" and "Lee" in honor of William States Lee, the engineer. In researching the plant, we are hampered by a lack of contemporary sources for information. This was a highly competitive situation and the development of the Nitrolee plant was not publicized. A few sources from scientific journals and from local newspapers have been found.

An early description found is from the *Bamberg Herald*, which may have secured the article from a local newspaper. On January 25, 1912, it reported "The Southern Power Company, or to

[7] The *Rock Hill Record* of November 25, 1907 contains a long letter written by Wylie describing his investments in the hydroelectric industry. His contributions are also noted in *Electrifying the Piedmont Carolinas: The Duke Power Company, 1904-1997* by Robert F. Durden.

[8] *The Metallurgical and Chemical Engineering* publication reported in October 1910 (Volume VIII) that the decision had been made by Southern Power Company to enter the field of atmospheric nitrogen development.

be exact, the Southern Electro-Chemical Company, is ready to begin the manufacture of fertilizer at its plant at Nitrolee, S. C. This plant will manufacture or produce fertilizer from the atmosphere. Nitric acid is the product and this will be mixed with limestone from the nearby hill to secure the commercial nitrate of lime. It is the first plant of its kind established in the country and all the machinery used in it was ordered and manufactured abroad. It could not be obtained in this country. Electric power, furnished by the Southern Power Company, will operate the plant. The plant is somewhat in the nature of an experiment, though such plants are successfully operated abroad, and the results will be watched with interest."[9]

Another early report on the plant was in a trade publication called *The American Fertilizer* in February 1912.[10] It reported that the Nitrolee plant had begun operations recently and included a photo of the complex. The article concluded "The far-reaching importance of this method of reducing nitrates from the air may be appreciated." The Southern Electro-Chemical Company had acquired the patent rights of Dr. Harry Pauling. Principals of the Pauling process were to use electric energy to raise the temperature of air blown through the electric arc to a heat of 3,000 to 3,500 degrees Celsius (about 6300 degrees Fahrenheit). The intense heat changes the elements of the air to a chemical combination forming oxide of nitrogen, which, when combined with water, forms nitric acid. The acid is then combined with limestone to form nitrate of lime. The article described the facility as consisting of several electric furnaces, oxidation tanks, steam receptacles, cooling chambers, and absorption towers. The finished product was estimated to be worth $50 per ton. The efficiency of the plant is that consumes surplus electric power and can operate 24 hours per day, consuming power when other users are not active. Another source reported that the Pauling process was in successful use in Europe at Innsbruck in the Tyrol and at La Roche de Rame in Haute-Alpes in France.[11]

Although these sources state that the plant had begun operations, an article in April 1912 reported that this was not the case. "The non-arrival of certain important pieces of machinery prevented the fertilizer from air plant at Nitrolee, on the Catawba Rover in Chester County, from beginning operations several weeks ago as was expected, but the machinery arrived a few days ago from Germany and the entire plant is being tested out with a view of starting operations in the near future. This is the only plant of its kind in the western world, and its operations will be watched with a great deal of interest."[12] On May 30, 1912, officials of the company visited the site. "R. B. Arrington, W. S. Lee, Z. V. Taylor and several other officers of the Southern Power Company spent Monday at the electro-chemical plant at Nitrolee, near Great Falls, S. C. This is the plant where fertilizer from the air is manufactured by the electro-chemical process."[13] Arrington was president of the Southern Electro-Chemical Company. By June, the plant seemed

[9] *The Bamberg Herald*, January 25, 1912.
[10] The article was in the February 24, 1912 issue of *The American Fertilizer*, "Nitrates From The Air," pages 45-46.
[11] *Metallurgical and Chemical Engineering*, Vol. IX, pages 102 and 196.
[12] *Yorkville Enquirer*, April 19, 1912.
[13] *The Fort Mill Times*, May 30, 1912.

to be in full operation. It was reported that the Nitrolee plant was using 4,000 horsepower of electricity, and the German experts on site felt that the plant would be commercially and scientifically successful.[14]

A Short Lifespan

The Nitrolee plant was successful in the sense that it created a usable and valuable product. However, it was soon realized that the electric arc process needed a dependable source of high levels of electric power on a constant basis. The Catawba River was subject to wide variations in river flow. The flow in the river during droughts was so reduced that the Nitrolee plant could not be supported. Constant stops and starts were not consistent with the operation of the nitrogen process. One engineer reported that the plant could only operate at full capacity for two to three months per year, resulting in no reliable production volume and no firm sales contracts.[15] It is likely that the Nitrolee plant was in operation by fits and starts for between two and two and one-half years.

By October 1915, the plant was being dismantled. "We were told today that the electrical machinery in the fertilizer-from-air plant at Nitrolee has been shipped to Mount Holly, N. C., our understanding that the fertilizer-from-air plant at Nitrolee is to be abandoned…The Nitrolee plant was the first of its kind in the Western Hemisphere, and considerable interest attached to its working. The fertilizer manufactured at the plant, we understand, has been of a high grade, but the output has been limited owing to unfavorable conditions. The working force has all left Nitrolee, with the exception of a watchman."[16] We have very little information on the individuals involved in the operation of the plant. Two employees were mentioned in local news accounts. In July 1915, it was reported that "Mr. John N. Carothers left Fort Mill last week for Washington, D. C., where he will take up electro-chemical work in the Bureau of Soils under the Superintendent of the Department of Agriculture. For several years past he has had charge of the plant at Nitrolee of the Southern Electro-Chemical Company."[17] Later, it was reported that "Mr. Ray Patterson, son of Mr. J. H. Patterson of Fort Mill, who has been working at the Southern Power Company at Nitrolee, Chester County, has been transferred to the company's chemical plant in Mount Holly, N. C."[18] Duke had begun work on a plant in Mount Holly that could produce phosphoric acid competitively.[19]

Many local residents in Great Falls believe that the German operatives and scientists left because of the start of World War I. Germany entered the war in August 1914, and public opinion of

[14] *The Yorkville Enquirer*, June 28, 1912.
[15] David Massell, *Amassing Power: J. B. Duke and the Saquenay River, 1897-1927*, page 65.
[16] *The Fort Mill Times*, October 7, 1915. It is noted this article was reprinted from the *Chester Reporter*.
[17] *The Fort Mill Times*, July 29, 1915.
[18] *The Yorkville Enquirer*, December 21, 1915.
[19] Robert F. Durden, *Electrifying the Carolina Piedmont: The Duke Power Company, 1904-1997*, page 42.

Germans in America began to sour. It is likely the closure of the plant and the desire of the Germans to return home happened at about the same time. Further research needs to be done to more fully document the German and Austrian scientists, engineers and workers who had such a major role in the development of the Nitrolee plant.

In Europe, the Haber-Bosch process had been fine-tuned and soon became the dominant means of producing nitrogen-based fertilizers. As World War I loomed, the German government realized that, with some alterations, the process could be used to produce huge amounts of munitions. BASF had built several massive plants using the Haber-Bosch process. The German war machine was fueled by the conversion of these fertilizer plants to munitions use.

Shortly after the abandonment of the Nitrolee plant, the Southern Power Company built a large hydroelectric plant on the Catawba River just east of the Nitrolee plant, which was located on Fishing Creek. This power plant, which is officially known as the Fishing Creek Hydro, is known locally as the Nitrolee hydro because of its proximity to the abandoned experimental plant.

Today, the land on which the ruins of the Nitrolee plant are located is owned by the Katawba Valley Land Trust. Duke Energy has plans for the development of a canoe-kayak launch facility on Fishing Creek which will use part of the property. Most of the buildings on the site are reduced to the ruins of their foundations. However, much of the building housing the actual electric arcs is still standing. With support from Duke Energy, this building will be stabilized and used as a means of explaining the site to the public so that a new generation can learn about the time this lonely spot was on the forefront of world scientific progress.