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HISTORY OF THE ROTARY KILN

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RESUMEN

Los hornos rotatorios (o rotativos) fueron inventados en la mitad del siglo XIX. Inicialmente fueron empleados, preferentemente, en la industria química y ya en el siglo XX empezaron a emplearse también en la industria metalúrgica.

PALABRAS CLAVE: Proceso Leblanc, horno de carbonatar, horno de cal, cemento, Fredrik Læssöe Smidth, Thomas A. Edison, José Francisco de Navarro, mena de hierro en Mayari (Cuba).

ABSTRACT

The rotary kiln was invented in the middle of the nineteenth century as a continuous reactor to solve the problem of the tedious and high man power batch processes in the chemical industry. It was then applied at the beginning of the twentieth century in the metallurgical industry and became later an essential reactor in both industries.

KEY WORDS: Leblanc process, Black-ash furnace, Lime kiln, Cement, Fredrik Læssöe Smidth, Thomas A. Edison, José Francisco de Navarro, Mayari iron ore in Cuba.

INTRODUCTION

The Leblanc process for the manufacture of soda ash [sodium carbonate] is considered the beginning of the inorganic chemical technology [industrial chemistry]. It was in this industry that the rotary kiln was invented. Once the reactor became functional it was immediately applied in the production of lime from limestone then the manufacture of cement. It did not take much longer when the metallurgical industry also benefitted from this invention.

The alkali industry

About 1775 the French Academy of Science offered a large prize for a method of making soda. Among the processes submitted was one by Nicolas Leblanc (1742-1806), which seemed promising, and being granted a patent in 1791, he began manufacturing on a commercial scale. However, during the French Revolution the factory was seized because it belonged to Louis Philippe II the Duke of Orleans (1747-1793), the patent was declared public property, and no indemnity was paid to the inventor. Having lost his property, he finally committed suicide.

The process involves the reaction of salt with sulfuric acid to form sodium sulfate [salt cake] which is then reduced by carbon to form sodium sulfide which, in presence of limestone, forms sodium carbonate and calcium sulfide known as "black ash". Black-ash is a dark gray substance containing about 45 % sodium carbonate, 30 % calcium sulfide, 10 % CaO, and 10 - 12 % impurities such as sulfate, silicate, aluminate, and chloride of sodium, calcium carbonate, coal, and iron oxide, with traces of cyanides and of sulfides of sodium. Sodium carbonate is then extracted from the black mass by water, concentrated by evaporation, and crystallized. The reaction mixture of finely-crushed salt cake, limestone, and coal is heated to about 1000ºC in a reverberatory furnace known as "black-ash furnace" (Fig. 1). The charge is raked manually or by means of chains hanging in the furnace. The operation was so difficult and tedious and there was a need to have a more effective furnace.

In order to work larger charges, without the expensive hand labour, the rotating furnace (Fig. 2) was introduced in England by W.W. Pattinson in 1848 and an improved design was introduced in 1853 by G. Elliot and W. Russell at Jarrow Chemical Company in South Shields at the mouth of the River Tyne in England. The furnace

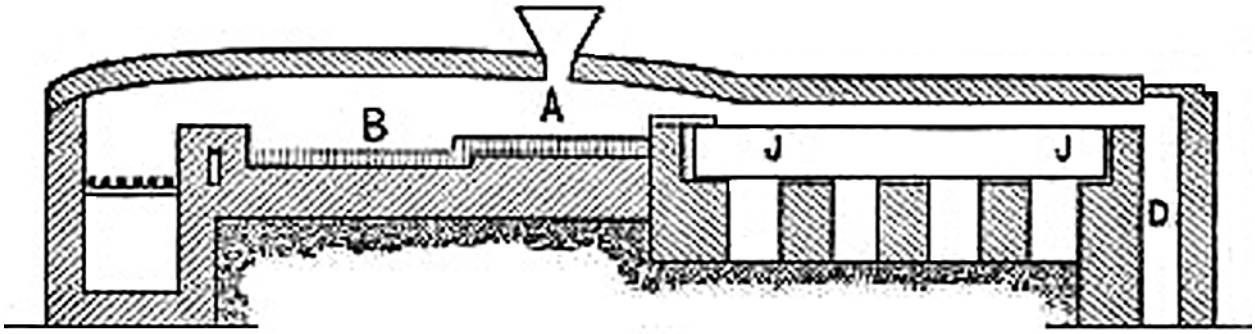

Figure 1. Reverberatory furnace for the production of soda ash by Leblanc process [1791].

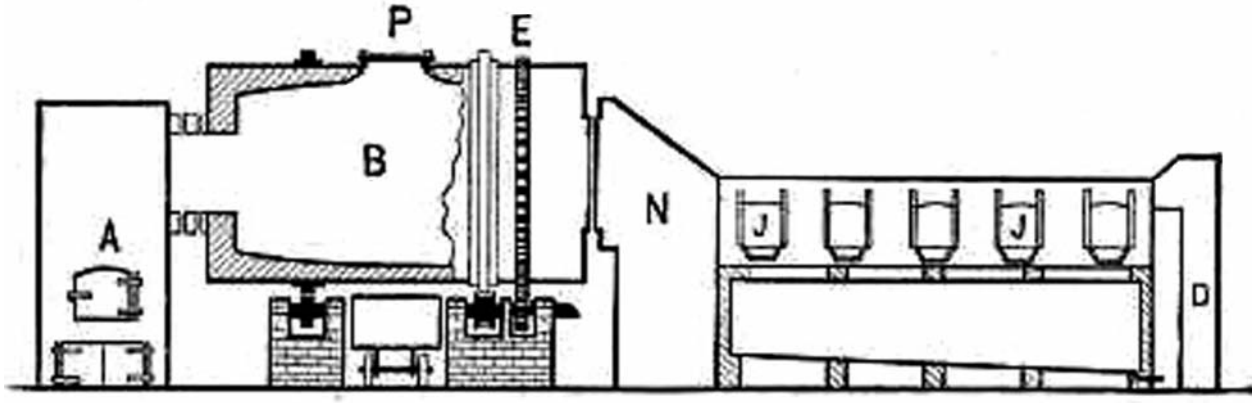

Figure 2. Rotary kiln invented in 1853 to replace the reverberatory furnace used for the production of sodium carbonate by Leblanc process.

was 10 m long and 3 m diameter. The hot gases from the furnace, pass through the dust box (N), and then through the long flue over the pan (J, J) on their way to the chimney (D). In this shallow pan, the liquor obtained by leaching the black-ash is evaporated. When crystallized, the salts are removed through the small doors (J). Leblanc's process has been in use for nearly a century, until displaced by the ammonia process developed by Ernest Solvay (1838-1922).

The lime kiln

Lime was usually produced in a vertical kiln (Fig. 3). The process was operated batch-wise; at the end of heating the charge, the kiln was allowed to cool and the product raked out. Naturally, this was a wasteful process due to the consumption of large amounts of fuel. In 1885, a patent was granted to Henry Mathey of New York, on a process of making lime which consisted "in first crushing the stone to a suitable degree of fineness then burning the crushed or pulverized stone in a revolving cylinder, whereby the particles of stone are subjected to a constant and uniform heat". In 1906 the New York Lime Company started to burn lime at Satural Bridge in New York using a 30 m by 2 m rotary kiln fired by producer gas, and shortly after this rotary lime kiln plants were built by both the Union Carbide Co. and the Aluminum Ore Co.

The cement industry

In 1885 a continuous reactor was needed to replace the shaft furnace which was operated batch-wise. The shaft furnace was used for making cement clinker and was borrowed from the limestone calcination industry, which was usually known as lime kiln. Since the process was operated batch-wise, at the end of heating the charge, the kiln was allowed to cool and the product raked out. Naturally, this was a wasteful process due to the consumption of large amounts of fuel. The rotary kiln was adopted by cement manufacturer in 1824 as soon as Joseph Aspdin (1788-1855), the brick-layer and mason in Leeds, England discovered what he called Portland cement[1]. Although Portland cement had been gaining in popularity in Europe since 1850, it was not manufactured in the US until the 1870s. The first plant to start production was that of David O. Saylor at Coplay, Pennsylvania in 1871.

In 1885, an English engineer, Frederick Ransome, patented a slightly titled horizontal kiln which could be rotated so that material moved gradually from one end to the other. Because this new type of kiln had much greater capacity and was heated more thoroughly and uniformly, it rapidly displaced the older type. In 1880, about 42 000 barrels of Portland cement were produced in the United States; a decade later, the amount had increased to 335 000 barrels. One factor in this tremendous increase was the development of the rotary kiln.

[1] The name was so-chosen, because the color of his product resembled the stone quarried on the Isle of Portland off the British coast. Aspdin's method involved the careful proportioning of limestone and clay, pulverizing them, and calcining the mixture into clinker, which was then ground into finished cement.

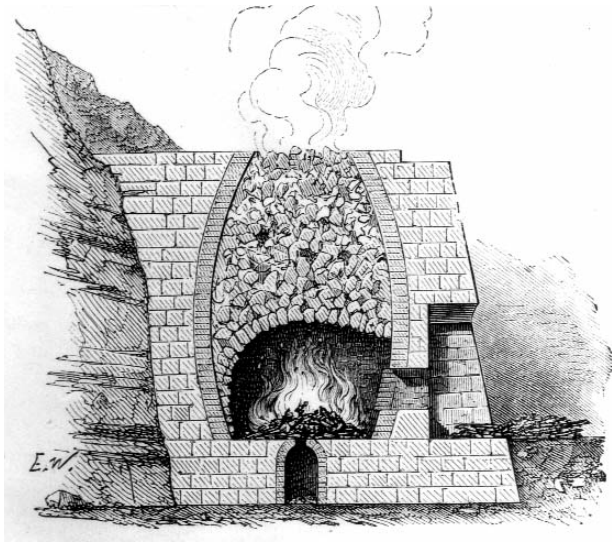

Figure 3. Lime kiln.

Figure 4. Fredrik Læssöe Smidth (1850–1899).

In 1888, Fredrik Læssöe Smidth (1850–1899) (Fig. 4), Danish engineer and industrialist in Copenhagen, in association with two other Danish engineers, Alexander Foss and Paul Larsen, delivered the first cement plant to a manufacturer in Sweden. In 1898, he was the first to introduce the rotary kiln in the cement industry and became later one of the major suppliers of rotary kilns worldwide.

Thomas A. Edison (1847-1931) (Figs 5 and 6), the American inventor, was a pioneer in the further development of the rotary kiln in his Edison Portland Cement Works in New Village, New Jersey where he introduced the first long kilns used in the industry 46 m long in contrast to the customary 18 to 24 m. In 1902, together with José Francisco de Navarro (1823–1909) (Fig. 7) founded the Universal Atlas Portland Cement Company whose largest plant was in Northampton, PA and won the enormous contract for supplying cement for the Panama Canal. By 1904, Navarro became the largest cement manufacturer in the world, producing 8 million barrels per year. Today, some kilns are more than 150 m long. The increased production of cement due to the use of efficient rotary kilns has a parallel improvement in crushing and grinding equipment.

Edison was born in Milan, Ohio. During his childhood, he received only three months of schooling. When he was 12 years old, he got a job selling newspapers in Port Huron, Michigan. During his spare time as a paperboy, he would experiment with the printing press and other appliances. He learned how to operate a newspaper printing press, and in 1862, he published his own weekly paper. When he saved the life of a child he was rewarded by being taught telegraphy. He showed his engineering genius when he designed a telegraphic instrument. This invention would later on make him very rich. Inventor Edison profoundly influenced modern life through inventions such as the incandescent light bulb, the phonograph, and the motion picture camera. During his lifetime, he acquired 1,093 patents.

Navarro was born in Spain, graduated from the Spanish Royal Naval Academy and came to the United States to teach at a Jesuit college in Maryland. After a few years, teaching gave way to railroad investments, then insurance, and by the 1870s he had a number of successful enterprises.

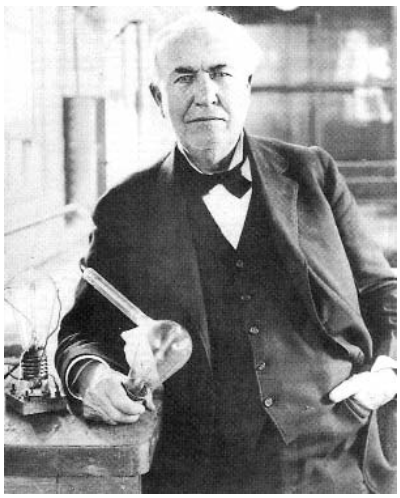

Figure 5. Thomas A. Edison (1847-1931).

Figure 6. A bag of Edison Portland cement.

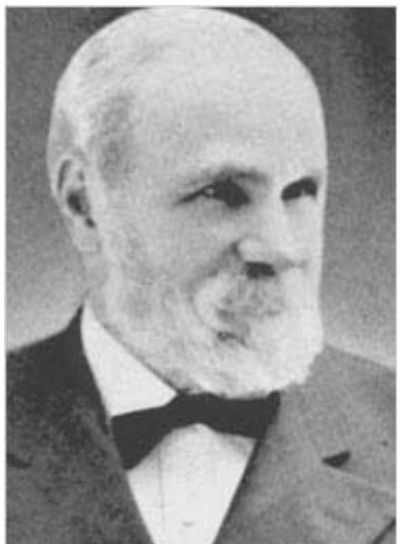

Figure 7. José Francisco de Navarro (1823-1909).

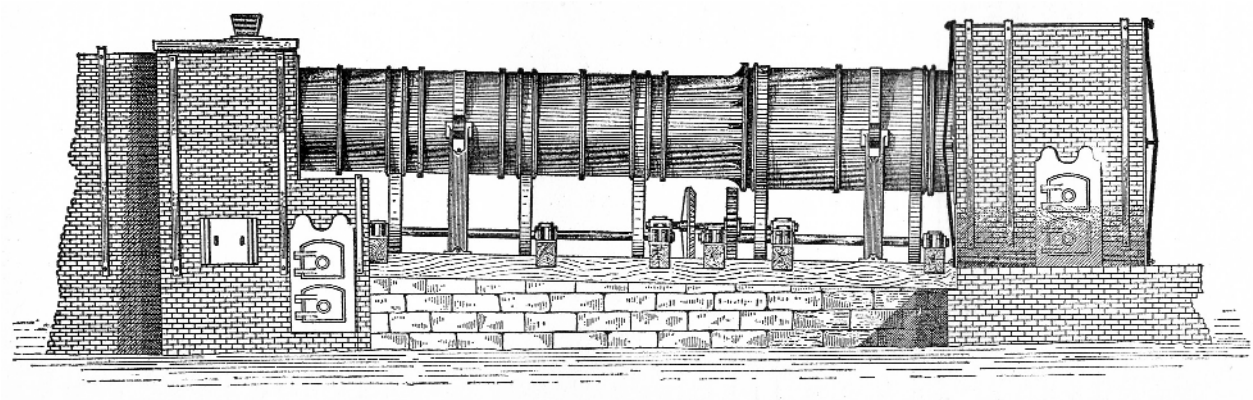

Figure 8. The rotary kiln was first applied in metallurgy for the partial roasting of copper sulfide concentrates prior to charging to the reverberatory furnace, now replaced by fluidized bed reactor.

THE ROTARY KILN IN THE METALLURGICAL INDUSTRY

About 1900, various metallurgists were experimenting with the rotary kiln for nodulizing flue-dust, fine iron ores, etc. Edison conducted experiments, for example, on the fine concentrates obtained from his magnetic separators. Within a few years plants were established for this purpose. The rotary kiln also furnished a simple means of utilizing the soft clayey ores, such as that of the Mayari field in Cuba. Practically all of the schemes tried for placing this ore in satisfactory condition for the blast furnace were unsatisfactory until the rotary kiln was tried. The plant in Cuba consisted of twelve kilns 30 m long and 3 m in diameter and producing 1500 - 2000 tonnes per day.

In 1914 application of the rotary kiln for the partial roasting of copper sulfide concentrates containing appreciable amounts of pyrite, to decrease the sulfur content before charging to the reverberatory furnace was conducted in USA. The kiln was 2 - 2.5 m diameter and 5 - 8 m long laid horizontally and operated batch-wise. In later design the inclined kiln was used; the charge was introduced at the burner side with provision of introducing secondary air through a pipe in the center of the kiln (Fig. 8). At present, rotary kilns are used for drying ores and the production of alumina by the dehydroxylation of $Al(OH)_3$, reduction of iron oxide by the Krupp–Renn process, in the TiO_2 pigment manufacture, and other processes (Fig. 9).

Figure 9. A rotary kiln in a nickel laterite plant.

REFERENCES

Anonymous, 1964. *Cement and Concrete Reference Book*, Portland Cement Association, Chicago, Illinois.

Dwight, A.S. 1945. Roasting and Sintering. In *Handbook of Nonferrous Metallurgy. Principles and Processes*, edited by D.M. Liddell, McGraw Hill, New York, 299-300

Edison, T.A. 1904. Rotary Cement Kiln. *US Patent* 775600 deposited July 22, 1903, granted November 22, 1904.

Gowland, W. 1921. *The Metallurgy of Nonferrous Metals*. Griffin, London.

Markworth, E. and Mennicken, G. 1951. Drehöfen. In *Ullmann's Enzyklopedie der technischen Chemie, Volume 1: Chemischer Apparatebau und Verfahrenstechnik*. Urban & Schwarzenberg, Munich, 834-867

Meade, R.K. 1914. The Development of the Rotary Kiln and Its Application to Various Chemical and Metallurgical Processes. *Industrial & Engineering Chemistry,* 6(9), 754-760.

Ransome, E. 1887. A Cement Rotary Kiln. *English Patent* 5442 (1885), *Tonind.-Ztg.* 11, 547 (1887).