Tube Digestion – Late Success of a VAW Technology

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Abstract

The Bayer process for leaching bauxite with caustic soda to produce aluminium oxide and the Hall-Héroult process for the extraction of aluminium using fused-salt electrolysis were decisive in providing the basis in 1888 for the production of aluminium on an industrial scale. Aluminium production is still based on these processes today. In the beginning, the introduction of these technologies was somewhat slow, there was a lack of suitable production equipment and a lack of markets for aluminium. Increased aircraft production resulting from the First World War created new demand and forced production to follow suit. This article describes the development of alumina production technology. The tube-digestion process, which Vereinigte Aluminium Werke A.G. (VAW) brought into industrial production as long ago as 1956, is now used in numerous modern alumina plants.

Keywords: Alumina plant, monohydrates, tube digestor, high-temperature digestion, organics.

1. Historical Review

The extraction of aluminium was carried out for the first time in 1825 by the Danish chemist Hans Christian Oersted. He reduced aluminium chloride ($AlCl_3$) using potassium amalgam and extracted relatively pure aluminium particles.

In Germany, aluminium is associated with the name of Friedrich Wöhler. In 1821, Wöhler began studying chemistry under Gmelin in Heidelberg. Gmelin arranged for him to make a study visit to Berzelius in Stockholm. During his return journey, Wöhler visited Oersted in Copenhagen to find out more about the process for extracting aluminium. Oersted suggested that Wöhler should continue the work on aluminium because he himself was busy carrying out other research. The aluminium particles that Oersted gave Wöhler can be seen in the museum of the Institute for Chemistry in Göttingen.

Wöhler adopted Oersted's process. He used metallic potassium as the reducing agent and obtained pure aluminium in 1827. However, the cost of producing aluminium was higher than the price of gold so that industrial extraction was unattractive. Wöhler was appointed to the Chair of Chemistry and Pharmacy at the University of Göttingen in 1836. At the time, Göttingen was the hub for natural sciences and attracted students from all over the world, including Frank. F. Jewett from the USA from 1874 – 1875. He later became a professor at Oberlin College in Ohio, where he awakened the interest of one of his students, Charles Martin Hall, for the industrial extraction of aluminium – with success.

In 1886, Hall in the USA and Héroult in France applied for a patent for a process to extract aluminium using fused-salt electrolysis that they had developed independently at about the same time. Then in 1887 and 1892 Carl Joseph Bayer applied for patents for his inventions regarding the digestion of bauxite with caustic soda using the hydrothermal process that subsequently became known as the Bayer process. From 1864 onwards, Bayer had studied chemistry under Fresenius in Wiesbaden and then from 1869 – 1871 under Bunsen in Heidelberg.

These inventions provided the basis for the industrial production of aluminium and allowed aluminium's triumphal march to begin.

2. Development of Bauxite Digestion at VAW

When Vereinigte Aluminium-Werke A.G. (since 2002 Hydro Aluminium, although developments described were carried out exclusively at VAW), was founded in 1917 it was also assigned the task of producing the upstream and downstream products associated with aluminium production, with specific instructions to ensure that all raw materials used could be sourced within Germany. With this in mind, and given the scarcity of raw materials caused by the war, the Lautawerk in the Lusatia region was chosen as the location for an alumina plant, using the pyrogenic digestion of bauxite with soda and lime as the production process. The capacity was initially planned to be 36 000 tonnes a year but with the possible outcome of the war in mind it was limited to 24 000 tonnes. Commissioning proved to be extremely difficult; there was a whole host of so-called teething troubles, which were eventually solved.

It became necessary to increase the capacity for the first time in 1934. A decision to use the Bayer process for digestion had already been made because the question regarding raw materials appeared to have been solved with VAW's financial participation in Bauxit Trust A.G.. The superiority of the Bayer process was confirmed by tests carried out at the Lautawerk plant. The expansion was carried out in two stages and amounted to a total of 36 000 tpy. The expectations associated with the use of the Bayer process were fully met.

In keeping with the state of the art around about 1900, C.J. Bayer used an autoclave for his digestion process. Single-autoclave digestion remained standard practice until about 1940. However, despite the benefit of having a uniform residence time, the inadequate utilization of the plant (4 – 5 m^3 per tonne of Al_2O_3 per day) was unsatisfactory. The workforce needed, the incomplete heat utilization and the difficult control of the method of operation constituted additional major disadvantages. An alternative approach was looked for from about 1930 onwards.

Tower digestion represented a move away from the use of a suspension; it used the digestion solution to leach out solid chunks of bauxite. Although the mode of operation was only semi-continuous, it brought with it major process benefits, which resulted in significant steam savings. The process was tried out at the Lautawerk plant from 1934 onwards and used on a large-scale from 1938 onwards at the Lippewerk plant in Lünen. It had to be abandoned however, because the bauxite chunks broke down on digestion and this led to difficulties in emptying the towers. In addition, it was only possible to process lumpy bauxites. Connecting the individual autoclaves in a continuous series was therefore investigated for fine bauxites. A test unit with a capacity of 0.25 m^3/h was operated at the Lautawerk plant from 1935 to 1938. Production units went into operation at the Lippewerk plant and the Nabwerk plant in Schwandorf in 1940 and 1941, respectively.

This technique managed to establish itself once pumps could be found that could convey the strongly abrasive suspension against the digestion pressure (the level of which depends on the temperature). Only piston pumps are suitably reliable for this. It was only after the Second World War that these were sufficiently well-developed for autoclaves in series to find general use. The level of control engineering that had been achieved by then was also contributory because it enabled the number of workers to be reduced significantly.

There are drawbacks to both types of autoclave:

- High investment costs, above all at high temperatures,

5. Summary

Since the Second World War, global aluminium production has shown a dramatic increase from about five million tonnes in 1960 to some 40 million tonnes in 2014. This has been achieved by upscaling the amperage from 50 kA to up to 600 kA in new smelters. About 80 million tpy of alumina are needed to produce 40 million tpy of aluminium.

On the alumina side, autoclave technology has reached economic and technical limits. It is not possible to increase the size of the reaction area in autoclaves arbitrarily. In addition, the availability of readily digestible trihydrate bauxites is declining. The digestion temperature has to be increased to 250 – 300°C to achieve economic efficiency with an increasing fraction of monohydrates. Here autoclaves have their limitations and tube digestion is an option. Since 1956, VAW has developed this technology to the production stage. A number of alumina plants built in the past 20 years operate using VAW tube-digestion technology.

At about the same time as the development of the tube-digestion process, VAW began to develop rotary tubular-kilns in cooperation with Lurgi to replace the calcination of aluminium hydroxide to aluminium oxide with a more energy efficient process. A successful process was developed with fluidized-bed calcination. Fluidized-bed calcination plants are now built and marketed by Outotec (formally Lurgi) and have achieved a dominant position in the global market.

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