Evolution of Tube Digestion Technology for Alumina Refining

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Abstract

Refineries processing Boehmitic or Diasporic bauxites require a high temperature digestion circuit to extract the alumina. These circuits typically operate at between 250°C to 280°C. Since the 1960's, many of the worlds high temperature digestion circuits operated as dual stream circuits with the caustic liquor heated progressively through shell and tube heaters using regenerative flash steam. The liquor and bauxite streams were then mixed at the autoclave or digester vessels. With increasing focus on maximizing extraction, energy efficiency, process simplicity and plant utilisation, tube digestion technology has been increasingly the technology selected for refineries around the world. The tube digestion flowsheet preferentially combines the bauxite and caustic liquor streams together in a single stream prior to regenerative heating. This paper provides a brief overview of the technology, outlining its evolution with a review of past, present and future installations. A comparative review of key refinery process parameters using the technology is also provided with the impact on capital and operating costs for the refinery as the process design deviates from the tube digestion flowsheet.

Keywords: Tube digestion; single stream.

Introduction

Alumina refineries use primarily the "Bayer" process to extract alumina from Gibbsitic, Boehmitic or Diasporic bauxites. The Bayer process utilises a recirculating stream of caustic soda to extract the valuable alumina from the bauxite in four main processing steps. These are: (i) Digestion, where the bauxite is dissolved in caustic soda generally at elevated temperature and pressure, (ii) Clarification, where the residue solids are separated from the now 'pregnant' caustic liquor, (iii) Precipitation, where the alumina is crystallized out of the caustic solution to alumina tri-hydrate ($Al_2O_3.3H_2O$) by seeding and cooling the solution, and (iv) Calcination, where the alumina is calcined from the trihydrate to alumina (Al_2O_3).

Refineries processing Boehmitic or Diasporic bauxites require a high temperature digestion circuit to extract the alumina. These circuits typically operate at between 250°C to 270°C. Since the 1960's, many of the worlds high temperature digestion circuits operated as dual stream circuits (refer Figure 1) with the caustic liquor heated progressively through shell and tube heaters using regenerative flash steam and mixed with the bauxite stream at the autoclave or digester vessels. In High Temperature facilities, duplex alloy steels and nickels are often employed in the heater tubes to offer erosion/corrosion resistance to caustic at elevated liquor temperatures above 170°C. Final digestion temperature conditions are typically attained with the use of direct steam sparging into the digester vessels.

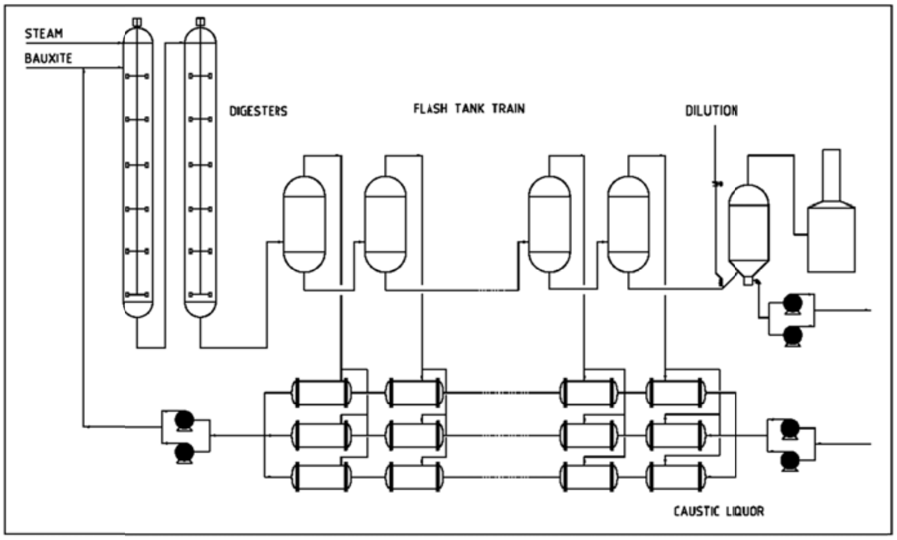

Figure 1: Dual Stream Digestion Flowsheet

1. Aluminium Oxide Stade – 0.6 Mtpa SGA 1973

In 1973, Aluminium Oxide Stade GmbH commissioned a greenfield alumina refinery using "Tube Digestion" technology (Figure 2). This flowsheet employed the use of four parallel digestion units to achieve its nameplate production capacity of 0.6 MTpa. The digestion unit employed the use of jacketed pipe heaters through which a combined slurry stream was heated continuously using recuperated flash tank heat. Final heating to the target digestion temperature of initially 260°C (and then 270°C) was via the use of indirect molten salt heating.

From 1973 to 2006, the production increased from 0.6 to 0.925 MTpa alumina.

The benefits of this digestion technology were;

- It maximised digestion temperature and therefore bauxite charge ratio. As a result, digestion flow productivity is maximised (alumina production per unit plant flow) and bauxite consumption minimised. In addition, liquor circuit evaporation through the digestion process is also maximised reducing the remaining liquor circuit evaporative load.
- It provides the best thermal match between heat source (flash tank train) and heat sink (heaters). No 'export' of recuperative flash tank energy is required.
- Single stream tube digestion with indirect heating eliminates plant liquor circuit dilution, reducing additional liquor circuit evaporative requirements, capital cost and energy consumption via reduced load (and cost) on the boiler plant.
- Gibbsite in the bauxite is digested through the low temperature heaters, with the alumina dissolution passivating the steel reducing the 'free' caustic and allowing (typically) the use of standard grades of carbon steel for the heater materials depending on caustic concentrations.
- It reduced heater cleaning frequencies from every 3 days on a rotating basis to every ~3 wks.
- It allowed the safe use of Wet Oxidation technology to reduce the build-up of organics in the liquor thereby improving liquor productivity, reducing liquor 'dead' volume and stabilising alumina particle size.

- boiler facility maintenance costs
- reduction in associated utilities and chemical treatment additives for the evaporator and boiler plants.

Prior studies by Hatch [5] have estimated at least a 7% reduction in refinery installed capital cost when substituting the historical dual stream flowsheet for the tubular digestion technology.

8. Conclusions

This paper outlines the evolution of tubular digestion technology over the last half century from the 1970's through to 2016. Through this evolutionary process, economies of scale have been leveraged to maximize the benefit of tubular digestion technology to industry. The technology provides optimal energy efficiency for the high temperature refineries reducing the operating and capital costs of the digestion facility and the entire refinery. As such, it has contributed significantly to a more environmentally sustainable aluminium industry.

Resulting from these benefits, greenfield alumina refinery projects since 2001 (from Australia to Saudi Arabia and the second middle east alumina refinery) have selected this technology for their refinery flowsheets.

The challenge for the future is to find strategic opportunities to take advantage of the benefits offered by this technology and integrating it, either partially or fully, into existing plants or brownfield refinery expansions.

9. References

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