Freshwater Free Alumina Refinery

David Brodie[1], Geoff Xu[2], Benyan Pei[3] and Jock Armstrong[4]
1. Principal Process Engineer
2. Process Engineer
3. Principal Process Engineer
4. Principal Process Consultant
Worley Pty Ltd, Brisbane, Australia
Corresponding author: David.Brodie@Worley.com

Abstract

When designing future refineries, more sustainable outcomes that embrace circular economy principles must be incorporated. The reality of a net zero carbon world approaches, demanding net zero carbon refineries. Another key design criterion is the freshwater footprint. Fresh water is a precious resource, essential for life. Climate change will amplify its scarcity in many regions. A refinery that needs no fresh water would be of greater benefit for local communities, reducing environmental impact and risk as well as improving energy efficiency. In this paper a typical alumina refinery water balance is described, highlighting areas of opportunity. Potential technologies for reducing water footprint are assessed. Incorporating selected technologies into a single process model, a "freshwater free" design is proposed. Designing future refineries for a more sustainable world will require innovative thinking, development of technology and a lot of hard work to deliver robust solutions. These challenges, and a path forward, are discussed within the context of the "freshwater free" refinery.

Keywords: Bayer plant, Water balance and consumption, Seawater cooling, Mechanical vapor recompression (MVR), Alumina sustainability.

1. Introduction

The Bayer plant, used worldwide predominantly for production of smelter grade alumina from bauxite, is a hydrometallurgical process. In simple terms bauxite is treated with a caustic soda solution at elevated temperature and pressure to dissolve alumina. The dissolved alumina is then separated from the insoluble residue before being precipitated in a granular form suitable for smelting to aluminium. The following discussion assumes a typical modern alumina refinery of two parallel trains of 1.0 million tonne/year capacity each.

As the Bayer plant is a hydrometallurgical process, a large amount of water is used in the process. The liquor stream in the process is recirculating around the refinery, constantly being loaded with alumina in the digestion area and then stripped of alumina in the precipitation area. The spent liquor stream generated in the precipitation area is concentrated by evaporation and returned to the digestion area. In this way caustic soda is reused and caustic consumption kept to an economically viable level. There is a varying degree of recycle and reuse of water streams in a Bayer plant refinery, often driven by the need to limit freshwater input, conserve energy and to limit water losses to the environment. Minimization of freshwater usage has become increasingly important in terms of sustainability of the alumina industry, particularly for site locations where freshwater is scarce. It is also critically important for drought situation which can sometimes put strong pressure on the refinery (see Pei et al [1]).

The overall water balance for the entire facility required to produce alumina can be divided into eight elements. The interaction of these elements numbered from 1 to 8 is typically shown in Figure 1.

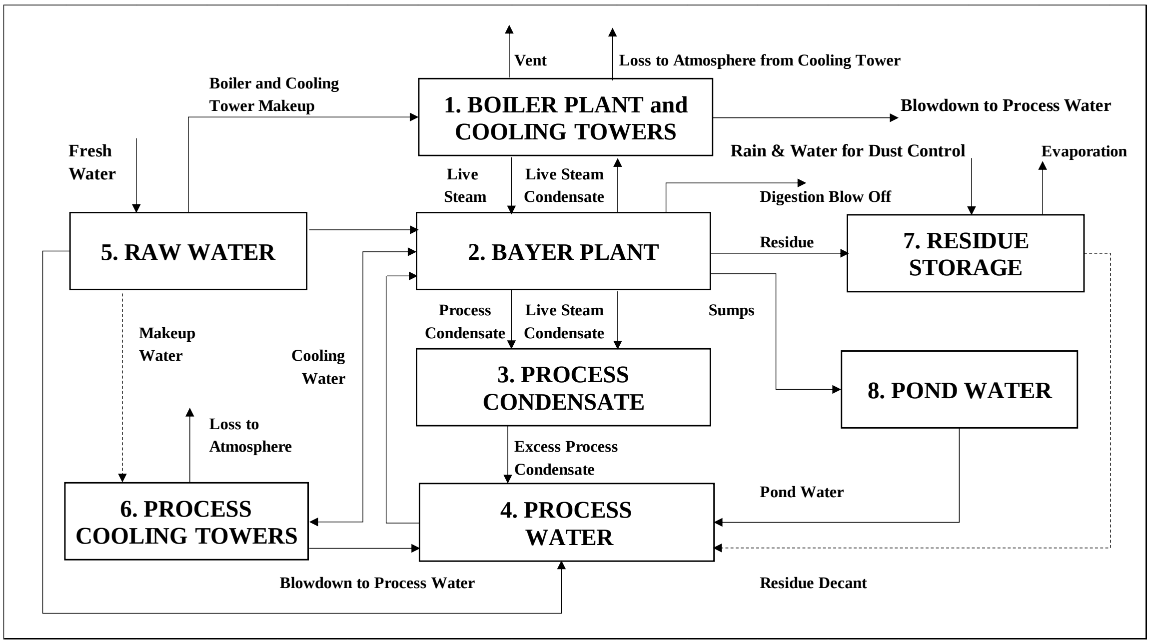

Figure 1. Overall water balance.

Most Bayer plants use bauxite containing predominantly Gibbsite (aluminium tri-hydrate) that can be readily digested at relatively low temperatures in the range of 140 to 170°C. For the bauxite containing an appreciable amount of Boehmite (aluminium monohydrate), digestion at high temperatures in the range of 230 to 280°C is required to improve the refinery economics.

In terms of the water balance, the major difference between high and low temperature Bayer plants is in the proportion of evaporation that occurs in digestion and evaporation areas. Because of the high temperature in digestion, more water is evaporated in more than three flash stages, so the demand for additional evaporation downstream is reduced comparing to low temperature digestion.

As condensate can potentially be contaminated with slurry or caustic in the process, it must be properly controlled and classified according to the conductivity level. Some of the usages will require good quality condensate, for example, process condensate for product washing and high purity live steam condensate as boiler feed water.

A process simulation model has been developed in this study to represent the overall water balance towards achieving zero freshwater consumption. Several potential technologies are discussed for possible water reductions.

Whilst this paper will focus on the water balance of low temperature Bayer plant, some comments on the effect of proposed changes to reduce water consumption in high temperature plant will also be made where applicable.

The aim of the paper is to highlight the most feasible technologies for freshwater reduction, yet including some potential, but less feasible or not yet matured technologies, for further reductions. Evaluation of capital cost, operation cost, and technology risk has been intentionally excluded.

6. References

1. Benyan Pei, Dirk Stegink, Joe Lane and David Baker, Water usage reductions at Queensland Alumina", *Proceedings of Water in Mining Conference*, Brisbane, QLD, Australia, 13 – 15 Oct 2003.
2. Brad Hogan and Andrew Furlong, Going FAR (Floating Alumina Refinery), *Proceedings of 10th International Alumina Quality Workshop*, Perth, WA, Australia, 19 – 23 Apr 2015.
3. Dean Ilievski, New two-stage calcination technology, *Proceedings of the 9th International Alumina Quality Workshop*, Perth, WA, Australia, 18 – 22 Mar 2012.
4. GEA, Solutions for alumina refineries, https://www.gea.com/en/binaries/alumina-refinery-evaporation-precipitation_tcm11-39468.pdf/ (accessed on 18 Aug 2021).
5. GEA, Evaporation technology using mechanical vapor recompression, https://www.gea.com/en/binaries/mechanical-vapor-recompression-evaporation-distillation-gea_tcm11-34894.pdf/ (accessed on 18 Aug 2021).