Enhancing Evaporator Economy: A Key Strategy for Sustainability and Decarbonization

Rohit Chourasia[1], Ameet Chaure[2], Deepanshu Bisht[3], Rahul Singh[4] and Praveen Vishwakarma[5]
1. Joint President, Renukoot Alumina
2. Assistant Vice President, Alumina Technical
3. Manager, Alumina Operation
4. Assistant Manager, Alumina Technical
5. Assistant General Manager, Alumina Technical
Hindalco Industries, Renukoot, UP, India
Corresponding author Email: ameet.chaure@adityabirla.com
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Abstract

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The Evaporation process is an important section in alumina production using the Bayer process. It consumes a large amount of thermal energy but helps to manage the water balance in a refinery. To produce alumina from bauxite ore, the weak aluminate liquor has to be concentrated through evaporators, so that it can be recycled back to digestion. Reducing energy consumption is always an important research topic in alumina refining. The Renukoot Alumina Refinery is one of the oldest refineries in the world and operates some of the oldest technology evaporation units. It has therefore always been a challenge to achieve benchmark energy performance.

Being the oldest refinery, various evaporation technologies are installed in the plant, i.e., multistage flash evaporation, multistage falling film evaporation and multistage rising film evaporation. A comprehensive analysis was carried out considering drawbacks in existing systems and consequently actionable points were identified for attaining the energy efficiency objectives. In this case we describe the stepwise analytical approach on the successful journey of steam economy improvement by 23 % which helps to reduce the carbon footprints through process re-engineering, refinement in process control through analytical study and improvement of operational practices.

Keywords: Evaporation technology, Steam economy, Process re-engineering, Energy reduction, Lower carbon footprint.

1. Introduction

The cost of alumina production has been rising significantly in recent years, with steam consumption identified as a key cost driver. At the Renukoot Alumina Refinery, steam contributes approximately 17 % to the total production cost, underscoring the critical need for energy optimization. The refinery operates three evaporation units i.e. Evaporation Units #1, #3, and #4 with an average steam economy of approximately 3.0 tonnes of water evaporated per tonne of steam (t/t). However, among these units, Evaporation Units #3 and #4 have consistently demonstrated lower performance. Specifically, Unit #3 has operated in the range of 2.5–2.6 t/t, while Unit #4 has maintained a steam economy between 3.0–3.1 t/t over the past several years. Although the refinery has occasionally achieved an overall steam economy of up to 3.3-3.4 t/t, these improvements have not been consistently maintained under standard operating conditions.

Achieving sustained improvements in steam economy from a baseline of 2.95 t/t to a peak of 3.63 t/t required the implementation of targeted process modifications alongside refined operational practices. This enhancement translated into significant reductions in overall steam consumption across the refinery, contributing directly to cost efficiency.

This paper presents a systematic, stepwise methodology employed to drive steam economy improvements through process re-engineering, control strategy optimization, and operational excellence. The approach outlined herein serves as a representative case study for identifying and mitigating inefficiencies, thereby delivering measurable energy savings within the alumina refining process.

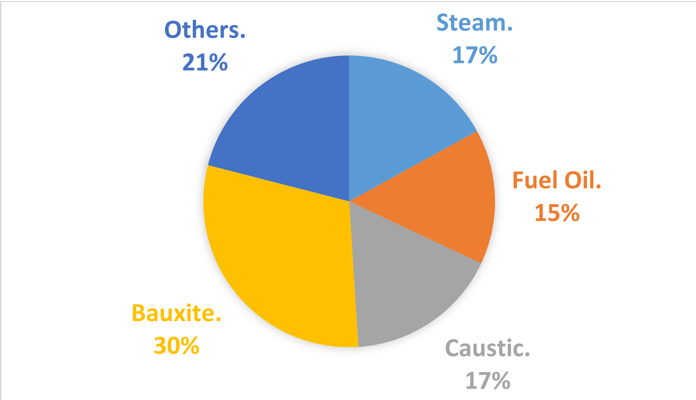

Figure 1. Alumina cost of production elements.

2. Conceptual Approach

A comprehensive analysis was conducted by the operations and process engineering team to assess the inherent limitations of the existing evaporation system at the Renukoot Alumina Refinery. This in-depth review was aimed at identifying opportunities to enhance the overall steam economy and reduce energy costs associated with alumina production. The study revealed several critical shortcomings in the current setup and led to the development of a set of targeted, actionable improvement strategies.

One of the key measures identified is that the increasing in feed liquor temperature of evaporation unit will enhance thermal efficiency for reducing the overall steam requirement. In parallel, a data-driven optimization of feed flow rates, vacuum levels, and associated process parameters was undertaken. Advanced data analytics and historical process performance reviews enabled the identification of optimal operating windows that directly impact steam economy.

Another major initiative was the utilization of feed flash vapor enthalpy by redirecting its thermal energy into the evaporation process. This approach reduces the demand for live steam by recovering otherwise wasted heat. Furthermore, a significant process re-engineering effort involved the replacement of traditional steam ejectors with mechanical vacuum pumps. This change improved vacuum control and stability while eliminating the need for motive steam, resulting in both energy and operational efficiency.

Collectively, these interventions formed the foundation for a sustainable improvement framework, enabling the refinery to move towards its goal of achieving a consistently higher steam economy across all evaporation units.

3. Methodology Adopted

The following multi-faceted approach was implemented to enhance the steam economy and overall process efficiency:

- Process re-engineering: redesigning process flows and system configurations to eliminate inefficiencies and optimize energy utilization.

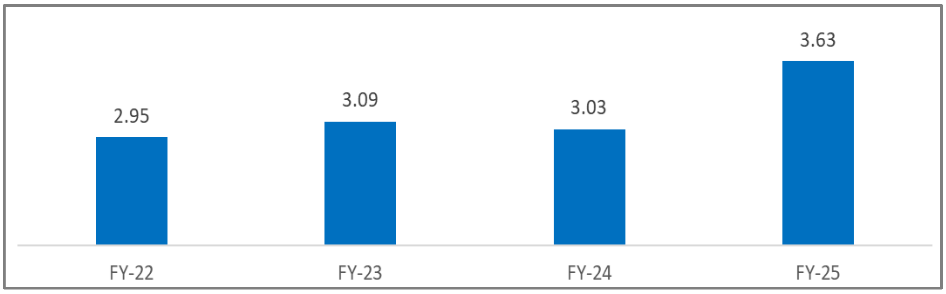

Figure 9. Steam economy (t/t) improvement trend.

9. Conclusion

The optimization of evaporation technology at the Renukoot Alumina Refinery has led to substantial improvements in steam economy and energy efficiency. Through systematic process re-engineering, data analytics-driven refinement, and enhanced operational practices, significant reductions in steam consumption have been achieved across multiple evaporation units.

Key modifications—such as bypassing the feed flash tank, utilizing feed flash vapor enthalpy, optimizing evaporation feed flow, and replacing steam jet ejectors with vacuum pumps – have collectively contributed to enhanced thermal efficiency and sustainability. These changes resulted in measurable gains, including a 23 % improvement in steam economy, substantial reductions in carbon footprint from evaporation area (CO_2 emission reduction by 15 %), and enhanced process stability. The successful implementation of these strategies reinforces the importance of continuous innovation in alumina refining. By leveraging advanced process control methodologies and adopting energy-efficient technologies, the refinery has demonstrated how targeted interventions can drive operational excellence while reducing environmental impact.

These findings offer valuable insights into energy optimization, serving as a benchmark for future refinements in evaporation systems within the alumina industry. Further advancements in digitalization, predictive analytics, and automation could potentially unlock even greater efficiencies, paving the way for sustainable and cost-effective refinery operations.

10. References

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