# Study and Judgement on the Technological Dilemma and Trend of Three-Layer Liquid Electrolysis of Refined Aluminium

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**Abstract**

Three-layer liquid electrolysis, a century-old high purity aluminium production technology, still retains a certain proportion in countries such as Norway, Japan, China and Russia. However, under the immense pressure of emission reduction and energy consumption cost competition, caused mainly by recent-year excess refined aluminium production capacity and trade barriers between countries, it seems to have become an industry consensus that this increasingly niched process will be completely replaced by other purification processes – the segregation method, which has significant advantages in energy saving, environmental protection and broad-spectrum product applicability. Based on a comprehensive comparison and analysis of the strengths and weaknesses between these two, this article proposes feasible paths for breakthroughs and enhancements of industrial competitiveness of the three-layer liquid electrolysis process from the perspectives of process improvement, product upgrading, advantageous industrial chain combinations, and technological innovation.

**Keywords:** High purity aluminium, Refined aluminium, Three-layer liquid electrolysis, Segregation method.

## 1. Introduction: Definition, Production Capacity, and Applications of Refined Aluminium

In China, refined aluminium is customarily classified under the category of high purity aluminium. According to the Chinese Nonferrous Metals Industry Standard [1], aluminium with a purity ranging from 99.90 % to 99.996 % (corresponding to grades 3N0 to 4N6) is designated as refined aluminium. This classification aligns respectively with the definitions of high purity and ultrahigh purity aluminium in the American standards – -Grade 1 and Grade 2 aluminium in the Japanese standards, and high purity aluminium under the Russian standards [2].

The global annual production capacity of refined aluminium has currently reached approximately 330 000 tonnes, excluding 3N aluminium products directly manufactured from conventional aluminium electrolysis cells. Major production regions include China, Japan, North America, Norway and Russia. After decades of technology introduction, assimilation, and independent innovation, China's refined aluminium industry has achieved significant growth, with an annual production capacity rising from less than 10 000 t at the beginning of this century [3] to nearly 201 500 t presently (see Table 1).

Approximately 80 % of the refined aluminium is used to produce aluminium foil for electrolytic capacitors. About 10 % is utilized in the manufacture of new energy battery electrodes, hydrogen energy storage and transportation tanks, high-performance conductive wire, cryogenic electromagnetic components, magnetic levitation materials, advanced packaging and coating materials, as well as special aluminium alloys for aerospace and military applications [4]. The remaining 10 % is used for further purification into high and ultrahigh purity aluminium.

**Table 1. Changes in China's refined aluminium production capacity over the past 20 years (excluding 3N aluminium produced directly from conventional electrolytic cells).**

| Purification process | Company | Completed production capacity (kt/y) | Capacity under construction (kt/y) | Potline current (kA) | Year of commissioning | Operational status |
|---|---|---|---|---|---|---|
| Three-Layer Liquid Electrolysis | Guizhou Aluminium Plant | 5.5 | | 60 | 2003 | Closed in 2005 |
| | Xinjiang Joinworld Co., Ltd. | 5 | | 65 | 2003 | Closed in 2008 |
| | | 12 | | 80 | 2005 | Closed in 2022 |
| | | 15 | | 100 | 2023 | Exists |
| | Shanxi Guan Aluminium Group Co., Ltd. | 12 | | 70 | 2008 | Closed in 2009 |
| | Inner Mongolia XinChangjiang Mining Investment Co., Ltd. | 10 | | 60 | 2011 | Closed in 2021 |
| | Inner Mongolia Huomei Hongjun Aluminium & Electricity Co., Ltd. | 12 | | 80 | 2008 | Closed in 2014 |
| | Yidu Dongyangguang Industrial Development Co., Ltd. | 5 | | 60 | 2003 | Closed in 2017 |
| | Qinghai Qiaotou Aluminium and Electricity Co., Ltd. | 20 | | 70 | 2010 | Closed in 2015 |
| | Henan Shenhuo Group Co., Ltd. | 10 | | 80 | 2005 | Closed in 2016 |
| | Baotou Aluminium Co., Ltd. | 3.5 | 3.5 | 105 | 2025 | Exists |
| Segregation method | Baotou Aluminium Co., Ltd | 60 | | -- | 2007–2022 | Exists |
| | Xinjiang Joinworld Co., Ltd | 40 | | -- | 2008–2013 | Exists |
| | Tianshan Aluminium Group Co., Ltd. | 40 | 60 | -- | 2023 | Exists |
| | Guangxi Zhengrun New Material Technology Co., Ltd. | 5 | | -- | 2016 | Exists |
| | Guangxi Laibin Guangtou Yinhai Aluminium Co., Ltd. | 10 | | -- | 2024 | Exists |
| | Guangyuan Huabo Precision Aluminium Technology Co., Ltd. | 20 | | -- | 2024 | Exists |
| | Nanshan Aluminium Co., Ltd. | 8 | | -- | 2024 | Exists |
| | Inner Mongolia Chuangyin New Materials Co., Ltd. | -- | 50 | -- | Put into operation by 2026 | Exists |
| | Jili BaiMine Group Co., Ltd. | 10 | | -- | 2023 | Exists |
| | Tongchuan Aluminium-based New Material Co., Ltd. | -- | 30 | -- | Put into operation by 2026 | Exists |

## 2. The Industrial Predicament Faced by the Three-Layer Liquid Electrolytic Refined Aluminium Production Process

Three types of processes can be employed to produce refined aluminium of different grade: First, conventional electrolytic aluminium plants, utilizing high-grade alumina, anodes, and fluoride

Feasible recycling routes include removing impurity elements to produce reusable aluminium-copper anode alloys or utilizing the impurity elements to prepare high-value aluminium alloys. The spent electrolyte contains a high concentration of fluorides, chlorides, and other compounds, which increase the cost of hazardous waste treatment. However, how to achieve efficient purification or high-value utilization of the spent electrolyte-turning waste has not yet attracted sufficient attention from researchers.

## 6. Conclusion

The three-layer liquid electrolysis process for refined aluminium faces an industrial dilemma due to its high energy consumption, high emissions, and limitations in product grade, resulting in ~~it~~ being increasingly displaced by segregation processes. This paper, through a comparative analysis of the advantages and disadvantages of two aluminium refining technologies, proposes approaches such as:

1) Developing high-conductivity, anti-aging, and environmentally friendly electrolyte systems;
2) Achieving high levels of automation and intelligence in the electrolysis process;
3) Developing new corrosion-resistant cell lining materials to extend cell life and seeking advantageous industrial chain combinations.

These strategies aim to significantly reduce energy costs, minimize pollution emissions, and improve product grade and competitiveness. Additionally, the feasibility of upgrading three-layer liquid electrolysis technology is discussed by exploring the development of new “small-scale” variant three-layer liquid electrolysis cells and new applications such as the preparation of high purity alloys from waste anode alloys and spent electrolyte regenerating treatment.

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