New Energy-saving Technologies in the Evaporation Section of Alumina Production

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Abstract

Under the background of the global "Dual Carbon" strategy, the alumina industry needs to reduce energy consumption in its evaporation process urgently. Based on engineering practices at Henan Jiuye Chemical Equipment Co., Ltd., this paper provides an introduction to such energy-saving technologies as seven-effect sectionalized evaporators (Patent No.: ZL201220432718.4) and evaporative condensers (Patent No.: ZL201821142093.1). The seven-effect evaporator uses such patented designs as sectionalized structures, innovative film distributors, vortex demisters, etc. to address such issues as uneven liquid films and low demisting efficiency in conventional equipment, achieving over 10 % improvement in evaporation efficiency. The evaporative condenser integrates flash steam condensation with circulating water cooling, significantly reducing equipment footprint and energy consumption, and it has brought annual cost savings of 11.22 million RMB (1.57 MUSD/y approx.) in the Guangxi Huasheng project. The eight-effect evaporator solution proposed for low-concentration spent liquor can further reduce steam consumption through optimized heat balance and temperature distribution, saving over 27 million RMB annually (3.77 MUSD/y approx..). The research results in this paper can provide technical references for the green transformation of the alumina industry.

Keywords: Alumina, Evaporation, Seven/Eight-effect evaporator, Evaporative condenser, Energy saving and consumption reduction.

1. Company Profile

Founded in 1999, Henan Jiuye Chemical Equipment Co., Ltd. is an integrated high-tech enterprise that focuses on scientific research, design, fabrication, installation and service, and is a “National Specialized, Sophisticated, Distinctive and Innovative Little Giant Firm” in Henan Province.

The company specializes in the design, manufacturing, and installation of pressure vessels, various evaporators, chemical storage tanks, towers, and bio-fermentation equipment. Its flagship products – evaporators and crystallization equipment – are widely used in such industries as alumina production, hydrometallurgy, papermaking, wastewater treatment, bio-fermentation, food processing, chemical engineering, pharmaceuticals, salt production, etc. The company's energy-saving seven-effect two-stage falling-film evaporator technology is in the leading position around the world, earning the company the Second Prize for Technological Progress from the China Nonferrous Metals Industry Association in 2013. The company holds over 37 patents on technologies for evaporators and other equipment [1–3].

Throughout its development journey, the company has successfully sold its products to such alumina refineries as Weiqiao Aluminum & Power, Xinfa Group, Chinalco Group, Jinjiang Group, Rusal Group, Guanglv Group, Jisco Group, Tiangui Aluminum, Guizhou Qiya, Lubei Chemical

Group, and Zhongchao Aluminum, earning excellent reputation. Meanwhile, its products have been successfully exported to overseas markets, including Rusal's Kenya Project, Jisco's Jamaica Project, Jinjiang's Indonesia Project, Chinalco's Indonesia Project, etc., gaining extensive market presence and good social reputation. In 2022, the company designed a seven-effect 580 t/h evaporator for Guangxi Tiandong Jinxin Chemical Co., Ltd.'s alumina production project, which became the world's largest seven-effect tubular falling-film evaporator in the alumina industry and was awarded the "Outstanding Contractor" award. In the same year, the sodium aluminate solution evaporation system of Chinalco Guangxi Huasheng New Materials Co., Ltd.' s 2 Mt/y alumina project contracted by the company was rated as a "Quality Project" in the non-ferrous metal industry for 2020–2021, fully demonstrating the company's outstanding capabilities in design, construction, and installation.

2. Advent and Practice of New Seven-effect Sectionalized Evaporator Technology and Equipment

The company independently developed seven-effect evaporator (Patent No. ZL201220432718.4) uses a unique design and innovative manufacturing process to achieve more efficient energy utilization during evaporation [1]. The multi-effect evaporation principle allows for full recovery and utilization of latent heat from steam, significantly reducing steam consumption. In 2013, this technology passed the scientific evaluation by the China Nonferrous Metals Industry Association, with attending academicians and experts unanimously judging that the equipment reached international leading levels and recommending accelerated promotion. Shandong Xinfa Group became the first to use this patented technology by retrofitting three sets of six-effect evaporators into seven-effect evaporators, achieving remarkable energy savings.

2.1 Applications of New Seven-effect Evaporator Technology and Equipment in Alumina Industry at home and Abroad (Including Eight-effect Evaporator)

(1) Weiqiao Group's 2 sets of newly constructed 280 t/h seven-effect falling-film evaporators for low-concentration applications at Binzhou Beihai Huihong New Materials Co., Ltd. in 2015.
(2) Shanxi Xinfa Chemical Co., Ltd.'s 1 set of newly constructed 300 t/h seven-effect falling-film evaporators for high-concentration applications in 2015.
(3) Shandong Xinfa Group's 1 set of 400 t/h seven-effect split evaporators for high-concentration applications in 2015.
(4) Yunnan Wenshan Aluminum's 1 set of 300 t/h seven-effect falling-film evaporators for high-concentration applications in 2017.
(5) Guizhou Guang Aluminum's 1 set of 360 t/h six-effect falling-film evaporators for high-concentration applications in 2017.
(6) Jingxi Tiangui Aluminum's 1 set of 370 t/h evaporators for high-concentration applications in its Phase I 2500 kt/a alumina refinery project in 2017.
(7) Jisco's 2 sets of 300 t/h seven-effect falling-film evaporators for low-concentration applications at its Alpart alumina refinery in Jamaica in 2018.
(8) Rusal's 1 set of 220 t/h seven-effect falling-film evaporators for low-concentration applications at its alumina refinery in Kenya in 2018.
(9) Chinalco's 2 sets of 400 t/h evaporators for low-concentration applications at Guangxi Huasheng New Materials Co., Ltd. (Phase I) in 2019, which was awarded the "First Prize of Quality Engineering in China Nonferrous Metals Industry" after being put into operation.
(10) Guangxi Longzhou Xinxiang Ecological Aluminum Industry Co., Ltd.'s 2 sets of 330 t/h seven-effect falling-film evaporators for high-concentration applications in 2020.
(11) Jingxi Tiangui Aluminum's 1 set of 370 t/h evaporators for high-concentration applications in its Phase II 1700 kt/a alumina refinery project in 2020.
(12) Guizhou Guang Aluminum's 1 set of 360 t/h seven-effect falling-film evaporators for high-concentration applications in 2020.

seven-effect unit design by the equipment manufacturer only achieved 220 tonnes of water evaporation, merely 60 % of the required capacity in the tendering document, with both water evaporation and steam-to-water ratio never up to standards.

6.3 Widespread Alkali Leakage of Last-effect Evaporators in Large Evaporator Units

The alkaline leakage in the last effect primarily stems from flawed evaporator unit design. For instance, the design data specifies 80 t/h water evaporation for the last effect, but the actual maximum last-effect water evaporation reaches 140 t/h, and the evaporator manufacturer configures the separation chamber and circulating cooling water system based on the 80 t/h water evaporation. This results in the separation chamber diameter being significantly smaller than required, causing alkaline leakage in the last effect due to high steam velocity in the empty towers. Additionally, the circulating cooling water system is configured much less than required, leading to high circulating cooling water outlet temperature and the failure to meet the design vacuum level requirements. The reduced effective temperature difference of the evaporator unit results in the evaporator unit failing to achieve the designed capacity and leads to high steam-to-water ratio. Solutions: Stabilize the vacuum degree of last effect at -0.088 MPa, control the temperature of the last-effect solution at 65–75 ℃, configure appropriate circulating water volume according to the evaporation capacity of the last effect, avoid overload operation, and design an appropriate volume for the last-effect separation chamber according to heat balance calculation.

7. Conclusions

1) The application of the innovative seven-effect evaporator technologies has reduced the steam-to-water ratio of the original evaporator station from 0.3 to below 0.17, lowering the production cost per tonne of alumina by approximately 50 RMB. Based on China's alumina output of approximately 80 million tonnes in the last year, it results in a decrease of up to 24 million tonnes in steam consumption, a production cost reduction of up to 40 billion RMB, and a carbon emission reduction of up to 6.31 Mt.

2) The innovative application of evaporative condensers in alumina evaporator stations has brought approximately 3 kWh of electricity savings per tonne of water evaporated. With each tonne of alumina production requiring 3 tonnes of water evaporation, it enables China's alumina industry to save up to 720 GWh of electricity annually, resulting in an electricity cost saving of up to 500 million RMB and a direct carbon reduction of up to 484 kt.

3) 6.794 million tonnes of CO_2 is equivalent to the annual carbon sequestration of approximately 1.85 million hectares of forest (based on 3.67 tonnes sequestrated per hectare of forest per year) or the reduced annual emissions from 2.83 million fuel-powered vehicles (based on 2.4 tonnes emitted per vehicle per year). It has made a great contribution to the evaporator technologies in the alumina industry.

Henan Jiuye Chemical Equipment Co., Ltd.'s new evaporator technologies prove that: "Low carbon is not a cost, but competitiveness; innovation is not an option, but the law of survival." We are willing to join hands with partners in the industry and use the pen of technological innovation to write a green chapter for the high-quality development of the alumina industry.

8. References

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