

AL09 - Research and Discussion on High Quality Technology Upgrade Plans for Chinese Smelters under New Government Policies

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Abstract

In recent years, under the background of new policies for China's aluminum smelters, the hot topic is how smelters can align high-quality technology upgrade plans to government policies, and find the best balance between meeting new policy requirements and creating good economic benefits, and thus achieve their own sustainable development. The authors take some typical smelters in China as examples to propose and conduct in-depth research and demonstration of some high-quality upgrading and transformation models and plans for discussion, and reference by industry peers at home and abroad.

Keywords: Aluminium electrolysis, Smelter technical upgrades, China's new government policy for aluminum smelters.

1. Introduction

In recent years, the primary aluminum industry under new policy background in China has confronted with challenges and opportunities both. Smelters urgently need to choose high-quality technology upgrading schemes which are suitable for themselves and seek for the best balance between catering to the new policy requirements and creating good economic benefits, so as to realize the sustainable development of smelters.

To go for customized technology upgrading schemes depends on external conditions of each domestic aluminum producers, namely in terms of production : the energy price is restricted to the external environments such as the source of power, the national or regional mandatory regulations and etc.; alumina and anodes are subject to raw material quality, market fluctuations; operation management level by operators are prone to the smelter's treatments and culture; the sale cost of hot metal is constrained by factors like surrounding aluminum processing enterprises operated and product price fluctuations. In terms of technical design, the potroom configuration of different aluminum producers is given with the design features according to the on-site implementation conditions, introducing some difference.

Therefore, it is very prudent for various aluminum smelters to choose and implement technology upgrading schemes which are only suitable for its own characteristics. By this way, the indeed high-quality technology upgrading realized will achieve ultimate goals and results.

The author, with reference to kinds of policies issued by Chinese ministry and commissions in recent years, studies and demonstrates the rationality of high-quality technology upgrading schemes adopted by a couple of typical aluminum smelters. Those technology upgrading modes and schemes can be used for discussion and reference in the industry.

2. Policy Background

2.1 China's Dual Carbon Policy

In September 2020, Chinese leader announced at the United Nations General Assembly that China will increase its nationally determined contribution, adopt more effective policies and measures, and strive to peak its carbon dioxide emissions before 2030, and achieve carbon neutrality before 2060.

In December 2020, Chinese leader further announced at the climate summit that by 2030, carbon dioxide emissions per unit of GDP would fall by more than 65 percent compared with 2005 levels. It stated also that forest stock volume would increase by 6 billion cubic meters, also non-fossil energy would account for about 25 percent of its primary energy consumption, with a total installed capacity of wind and solar power that would reach over 1200 GW.

2.2 Differentiated Stepwise Electricity Charges for Aluminum Smelters

In August 2021, the National Development and Reform Commission (NDRC) issued and improved policies on differentiated electricity charges for the electrolytic aluminum industry, which encourage aluminum smelters to improve the utilization level of non-water renewable energy such as wind power and photovoltaic power generation, and reduce the consumption of fossil energy. To promote energy conservation and emission reduction in the electrolytic aluminum industry, the NDRC has gradually introduced a differentiated electricity charges policy for the electrolytic aluminum industry. According to its requirements, the comprehensive AC power consumption of hot metal (composed of DC power consumption of pot and auxiliary power consumption in electrolytic aluminum production) in year of 2022, 2023 and 2025, shall respectively reach to 13 650 kWh/t Al, 13 450 kWh/t Al and 13 300 kWh/t Al. In the case of every 20 kWh increase, the electricity price per kWh for production will be risen by 0.01 yuan, equivalent to 0.0013 USD.

2.3 Policy of Benchmark Level and Base Line of Energy Consumption by Aluminum Smelters

In October 2021, NDRC and other sectors has released a notice aimed at issuing the “Benchmark Level and Base Line of Energy Efficiency in Key Areas of Energy-Intensive Industries” (2021 edition), which has explicitly addressed the proposed and under construction projects shall be implemented against the Benchmark Level, striving to reach Benchmark in full aspects. For existing smelters, which have operated at a lower level of energy efficiency than Base Line, it is reasonable to set up a transition period for policy implementation, and guide smelters to carry out energy conservation and carbon reduction technologies in an orderly manner, improve the efficiency of operation, and resolutely shut down outdated production facilities, backward process and products.

It is clearly stated that the top level of the electrolytic aluminum industry is 13 000 kWh/t Al of AC power consumption of hot metal, the average level is 13 350 kWh/t Al of AC power consumption of hot metal. It is worth noting that the AC power consumption of hot metal is generally obtained from the DC power consumption of the electrolytic cell divided by the rectification efficiency of the rectifier.

2.4 Controlling Policy of Energy Consumption Target of Greenfield and Brownfield Aluminum Projects

On 29 December 2022, the State Administration for Market Regulation and the Standardization Administration of China released “Energy consumption quota on unit product of electrolytic aluminum and alumina” (GB 21346-2022), which has specified the grades of energy consumption quota of unit product of electrolytic aluminum and alumina, technical requirements, statistical range and calculation method. It is applicable for calculations of energy consumption per unit product in electrolytic aluminum and alumina, assessment, also for the energy consumption control of the greenfield, expansion and brownfield projects.

The new rules clearly lay out that the limit value of energy consumption per unit product for the existing aluminum producers shall be no more than Grade-3. For the greenfield, expansion and brownfield aluminum smelter projects, its accessible value shall be no more than Grade-2 (see Table 1). The standard is scheduled to be implemented from January 1, 2024.

Table1. Energy consumption quota on unit product of electrolytic aluminum.

Index	Grades of Energy Consumption Quota		
	Grade-1	Grade-2	Grade-3
AC power consumption of hot metal (kWh/t Al)	≤ 12 950	≤ 13 000	≤ 13 350
Comprehensive AC power consumption of hot metal (kWh/t Al)	≤ 13 250	≤ 13 350	≤ 13 700
Comprehensive AC power consumption of ingot (kWh/t Al)	≤ 13 300	≤ 13 400	≤ 13 750
Comprehensive specific consumption of ingot (kgce/t Al)* (kWh/t Al) (converted from kgce with below factor)	≤ 1670 ≤ 13 592	≤ 1680 ≤ 13 673	≤ 1720 ≤ 13 999

*kgce = kg coal equivalent. 1 kgce = 29.3 MJ = 8.139 kWh.

It is understood from the above table that the admittance value of energy consumption per unit product aimed at the greenfield and brownfield electrolytic aluminum smelters to achieve the Benchmark level issued by NDRC in October 2021, i.e., AC power consumption of hot metal below 13 000 kWh/t Al, meanwhile the comprehensive AC power consumption of hot metal shall below 13 350 kWh/t Al. For the existing aluminum producer, it shall achieve the Base Line of AC power consumption of hot metal below 13 350 kWh/t Al, and comprehensive AC power consumption of hot metal below 13 700 kWh/t Al.

2.5 Policy of Emission Reduction Production as per Environmental Performance in the Heavy Pollution Weather

In conformity with the “Technical Guidelines for Emergency Emission Reduction Measures in Key Industries under the Heavy Pollution Weather” rolled out by the Ministry of Ecology and Environment, all provinces and cities across the Country are required to implement the "Guidelines", according to regulations, smelter environment performance is categorized as A, B, C, D grade, among which Grade A smelters can only implement independent emission reduction under the heavy pollution weather. For Grade B and below smelters as well as non-leading smelters, particles of emission reduction shall be no less than the requirements of Guidelines.

2.6 Philosophy of Green Development

To concretely implement the thought on Ecological Civilization of China, it is required to uphold the philosophy of green development and unswervingly advance green development, so as to make the contribution to friendly environments.

The environment-friendly Grade A smelter can essentially reduce the emission of air pollutants, shape the smelter image, which is more in favor of sustainable development. Smelters must make every effort to achieve Grade A. It can implement independent emission reduction in a condition of heavy pollution weather, which decrease the loss of production caused by shutdown, and effectively ensure the production and operation of the smelter. Finally, it ensures the smelter to go for green and high-quality development path.

2.7 Summary

In recent years, China in one respect, has sustained to standardize the investment behavior in aluminum industry positively responding to the policies circulated in the era of carbon peaking and carbon neutrality. On the other hand, aiming at excess production capacity of aluminum industry, Chinese government has continued to advance the supply-side structural reform of the aluminum industry, encouraged and guided the withdrawal of low-competitive production capacity from the market, and held the achievements by controlling the excess production capacity of electrolytic aluminum.

Various measures are being taken as the new increase of electrolytic aluminum production shall be firmly curbed. The capacity substitutions must be strictly implemented, strengthening environmental supervision, carrying out environmental improvement actions, controlling total volume of emissions, and promoting the orderly, green, and healthy development of the aluminum industry.

By means of stepwise electricity charging, energy consumption controlling on the greenfield expansion and brownfield aluminum smelters, setting up benchmark level and base line of energy efficiency, Chinese Government has promoted aluminum smelters in various categories to improve the efficiency up to the expected target. It implemented up-gradation in batches and eliminated outdated production capacity within a time limit, which push the electrolytic aluminum industry to carry out technology upgrading in terms of energy-saving and carbon emission reduction and accelerate to shut down outdated production facilities.

After the release of policies by Chinese Government, most Chinese aluminum smelters under such background have implemented the technology upgrading on critical equipment based on their own conditions, to realize the sustainable development. Guiyang Aluminum Magnesium Design & Research Institute Co., Ltd (hereinafter referred as “GAMI”) has undertaken various technology upgrading projects and obtained favorable achievements from practical application. We will make introductions on the three typical technology upgrading models prevailing in China respectively.

3. High-Quality Technology Upgrading through Model of Relocation

On top of it, highlights of relocation may improve the external environments and brings opportunities for smelter development. It makes layout of workshop reasonable in terms of process design, optimize and upgrade key areas of pot, which is purposed to make the operation index satisfying with the requirements of various state policies, and finally facilitate the smelter with new dynamism and vitality.

Some aluminum smelters located in the central region of China operated with full use of state grid power supply. It has been entitled with preferential price by direct electricity purchase as large user. However, the coal price stood at high level, and electricity cost was double compared to other smelters at that time, i.e., 0.6 yuan/kWh minimum, equivalent to 0.083 USD (8.3 US cent). But due to the involvement of upstream and downstream industries, and in order not to affect

local economic development and social stability, this smelter was forced to maintain production through long-term losses.

In early 2017, Ministry of Environmental Protection has strengthened its supervision and “Beijing-Tianjin-Hebei Region and Surrounding Areas 2017 Air Pollution Control Work Plan” went into effect, the area where the said smelters are located had been listed into the “Focus of Supervising Area”.

In 2018, the smelter, facing various difficulties proposed to relocate its aluminum production capacity to area/region with cost advantage, rebuild an industrial base with forming new profit growth point, then further optimize smelter portfolios, make capital’s improvement etc. It finally decided to relocate the complete production line of 250 kt/a of electrolytic aluminum 400kA potlines to the industrial park of a southwestern city following multiple exchanges and on-site inspections, encouraged by the preferential policies from local municipal.

By the end of 2018, GAMI was engaged in undertaking the engineering and design of such assignment of production capacity relocation. On the premise of completely reserving electrolytic core equipment as much as possible, GAMI has rearranged the workshop layout, optimized and upgraded the important structure of the electrolytic pot [1], aiming at obtaining preferable operation performance. The measures and effects before and after the technology upgrading are shown in Table 2.

Table 2. Technology upgrading through model of relocation.

SN	Before Relocation	After Relocation	Effects by Upgrading
1	234 pots arranged into 6 sections	Rearranged in 4 sections	One passage corridor less, equivalent to power consumption reduction by 8 kWh/t Al
2	Poor MHD in 6 terminal end pots	Re-study and design on end busbar	Equivalent to power consumption reduction by 12 kWh/t Al
3	Poor fume collection efficiency of pot flue duct	Optimize the configuration on the gas collection duct of pot superstructure	Equivalent to power consumption reduction by 30 kWh/t Al
4	High heat dissipation of pot lining	Upgrading of local lining insulation	Equivalent to power consumption reduction by 200 kWh/t Al
5	Outdated fume scrubbing technology, 3 sets of gas scrubbing system were for 6 sections	Adopting updated FTP, 2 FTPs are arranged for 4 sections	After upgrading, energy consumption of fume treatment achieves 100 kWh/t Al
6	Air compressed station was far away from potroom, High air pressure loss	Reasonable layout of air compressed station is given and ensure its supply with close distance	After upgrading, energy consumption of compressed air reach to 70 kWh/t Al
7	Long distance of dense phase conveying from alumina storage warehouse to fresh alumina silo	The proper layout of alumina storage warehouse is made, dump truck, airslides and bucket elevator are arranged for discharging alumina into fresh silo.	After upgrading, energy consumption of storage and handling is approx. 5 kWh/t Al
Total	Comprehensive power consumption of hot metal is approx. 13 700 kWh/t Al	Comprehensive power consumption of hot metal is approx. 13 300 kWh/t Al	Total 400 kWh/t Al are saved.

The above-mentioned project was put into production in November 2019, following preferential electricity price. With favorable pot operation performances and high price of aluminum, the technology upgrading project ran with great economic benefits, shortening the payback of project investment.

Presently, 3 years after project's operation at full, review of the design/study on the relocation project has highlighted some inadequacies: due to the investment restriction at the time of the project, the entire existing power transformer and rectifier system was completely relocated for use, without up-grading, so the current rectifier efficiency is only 97.6 %, which is far below the expected value of 98.3 %, resulting in the limits of further improvement.

4. High-Quality Technology Upgrading through Model of In-Situ Partial Retrofitting

Highlights of in-situ partial retrofitting are that full production has been mandatorily shut down subject to external environments. Prior to restart-up, a strategic plan was put forward by smelter to implement the in-situ partial retrofitting, which shall place more emphasis on key areas of electrolytic pot, aiming at seeking for much better operation performance, to boost the competitiveness and profitability of smelter.

In the last three years from 2020~2023, China has been hit by pandemic heavily, under strict prevention and control measures, aluminum smelters have generally conducted closed-loop production by the means of plant isolation. In February 2022, some aluminum smelter located in southern China urgently evacuated all operators from the production line due to COVID-19. Total 420ktpa production with two 400 kA potlines were stopped.

In March 2022, with alleviation of Pandemic, it was decided that partial retrofitting, energy-saving improvement should be carried out on overhaul pot lining and key areas of potline, which would be ready for restart-up as far as the pandemic was lifted.

In April 2022, GAMI was engaged in undertaking engineering and design on partial retrofitting works. According to scope of the project, the optimization and upgrading have been implemented mainly on the pot lining, potline busbar and etc., in order to obtain the better operation performance.

Technical upgrading measures and effects before and after In-situ Partial Retrofitting are shown in Table 3.

Table 3. Technology upgrading through model of in-situ partial retrofitting.

SN	Before	After	Effects
1	High heat dissipation of pot lining	Upgrading of area lining insulation	Equivalent to power consumption reduction by 200 kWh/t Al
2	Smaller section area adopted in potline busbar	Increasing the busbar section area	Equivalent to power consumption reduction by 9 kWh/t Al
Total	Comprehensive power consumption of hot metal is approx. 13 455 kWh/t Al	Comprehensive power consumption of hot metal is approx. 13 246 kWh/t Al	Total 209 kWh/t Al are saved.

It is noted in particular that pot lining is considered as “Heavy-Asset”, thus GAMI has always put its focus on the lining investment and cost of operation performance. On the premise of energy consumption as primary control index, GAMI has adopted an appropriate anode current density, and a lining structure characterized by strong competitiveness of investment cost, performance, and service life. Finally, the investment cost of lining per pot (400 kA) was targeted at 1.5 million yuan, equivalent to 207 000 USD.

After six months of implementation, the comprehensive power consumption of hot metal achieves at 13 246 kWh/t Al, the AC power consumption of hot metal is below 13 000 kWh/t Al, which reaches the Benchmark level by NDRC. Even though the smelter is under circumstance of high electricity price of 0.6 yuan/kWh, it remains with strong competitiveness and profitability. The owner is very satisfied with the operation effect of the technology upgrading undertaken by GAMI.

In contrast, the other two 600kA potlines operated under this smelter in the same location have been struggling owing to some inadequacy of design in current density and pot lining structure. Whatever it adopted the expensive lining structure or reduced the operating current, its operation performance still could not meet the State energy consumption requirement. Also, it may no longer have the ability to survive in market with high electricity price of 0.6 yuan/kWh, equivalent to 0.083 USD (8.3 US cent), and it is always at risk of shutdown and assets idled.

5. High-Quality Technology Upgrading through Model of In-situ Full scaled Retrofitting

Highlights of in-situ full scaled retrofitting are that the smelter has shut down pots at his own discretion in period of the seasonal power curbs and requested the contractor to carry out “Area-wised production, retrofitting section by section” by which the impact on the potline production shall be minimized as much as possible. Meanwhile, during upgrading and transforming, the smelter shall still have a certain level of production and benefit availability.

In 2020, with various policies and regulations issued, the smelter located in southern China has confronted with big challenges, its 300 kA potline operating with comprehensive AC power consumption of hot metal was 13 770 kWh/t Al, which cannot meet the requirement of the said energy consumption control policy. In the other hand, this smelter was established in 2003 with 20 years of operation, its building, flooring, dust collecting facilities etc., had got damaged to a great extent and most of them were outdated also, which was far below the standard of environmentally friendly Grade A smelters. In the heavily polluted weather of this region, the smelter subject to the restriction of emission reduction shall be at huge risk of production reduced or shutting down mandatory by government.

In May 2023, GAMI has undertaken engineering and design of full scaled retrofitting work in this smelter and given a priority to the optimization and upgrade of pot, busbar, air compression station, anode rodding shop and bath transfer facility etc. in order to obtain better operation performance and be recognized as environment-friendly Grade A smelters.

The smelter operates with 300 kA potline with total 168 pot installed, arranged into 8 sections, each section with 21 pots. The pot design was done 20 years ago. With limit by the design level at that time, there are certain shortcomings in the busbars surrounding pot and gas collection flue. Regarding the magnetic field design of the busbars surrounding pot, its MHD stability could not back up the high efficiency of pot operation. The pot shell was also damaged seriously, the air compression station was improperly configured, which caused heavy loss from compressed air route. Based on those issues, GAMI has proposed the solution accordingly.

In comparison to the first two models, it is noted that one special device has been applied creatively in this model, to achieve the target of “section-wise production, and section-wise retrofitting.

Such model has been implemented with 3 steps as Original State, Transformation Step1 and Transformation Step 2, as shown in Figure 1.

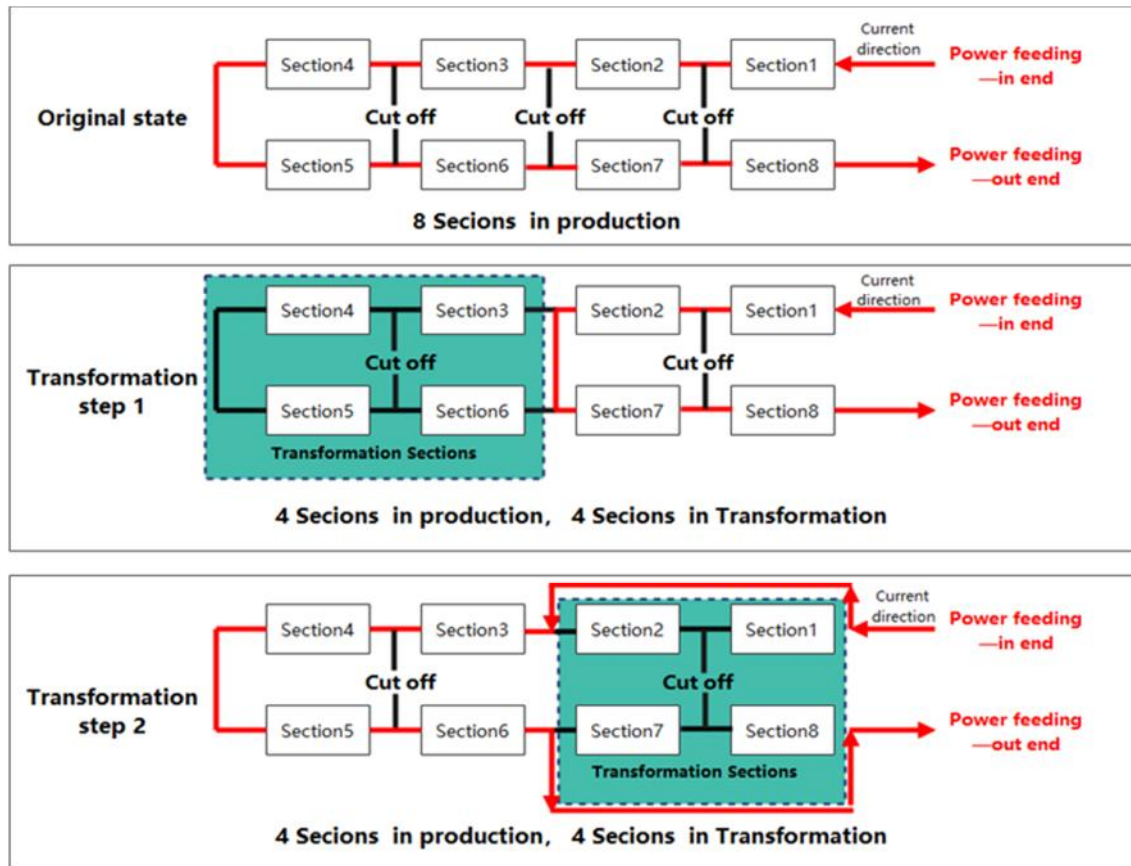


Figure 1. Diagram of retrofitting section by section.

The red line in Figure 1 represents the path line of the current, and all 8 sections are in production state in their original state. When performing step 1 of retrofitting, sections 3, 4, 5, and 6 are in retrofitting state, while sections 1, 2, 7, and 8 are still in production. After completing step 1 of retrofitting, proceed to step 2, sections 1, 2, 7, and 8 are in retrofitting state, while sections 3, 4, 5, and 6 are still in production state, finally the whole potline is completed until the retrofitting for the 8 sections.

Technical measures and effects before and after in-situ full scaled retrofitting are shown in Table 4.

Table 4. Technology upgrading through model of in-situ full-scaled retrofitting.

SN	Existing	Targeting	Effects to be achieved
1	Severely damaged of pot shell	Redesign and upgrading of pot shell	The safety of pot to be enhanced
2	High heat dissipation of pot lining	Upgrading of area lining insulation	equivalent to power consumption reduction by 200 kWh/t Al
3	Poor gas collection efficiency of flue in the pot superstructure	Optimize the configuration of the flue in the superstructure	equivalent to power consumption reduction by 30 kWh/t Al
4	Poor stability of pot MHD	Redesign busbar around pot and improve the stability of MHD	equivalent to power consumption reduction by 248 kWh/t Al
5	The material of stud was outdated and its voltage drop is high.	Upgrading with energy-saving typed material of stud, decrease of voltage drop	equivalent to power consumption reduction by 75 kWh/t Al
6	The pot hood has outdated structure, the heat loss is high.	Upgrading with new-typed insulation hood	equivalent to power consumption reduction by 40 kWh/t Al
7	Smaller section area of connecting busbar and busbar between power feed-in and out.	Increase of section area of busbar	equivalent to power consumption reduction by 5 kWh/t Al
8	Poor MHD in 6 terminal end pots	Re-study and design on end busbar	equivalent to power consumption reduction by 12 kWh/t Al
9	Air compressed station was far away from potroom, High air pressure loss	Reasonable layout of air compressed station is given and ensure its supply with close distance	equivalent to power consumption reduction by 10 kWh/t Al
10	Bath transfer facility by dense phase conveying system, which brought high energy consumption of compressed air.	dump truck of unloading and bucket elevator are arranged instead.	After upgrading, energy consumption of storage and handling is approx. 3 kWh/t Al
11	Rectifying efficiency is only 97.6%	After retrofitting, it will target at 98.3 %.	equivalent to power consumption reduction by 92 kWh/t Al
Total	Comprehensive power consumption of hot metal is approx. 13 770 kWh/t Al	Comprehensive power consumption of hot metal will be approx. 13 055 kWh/t Al	There will be 715 kWh/t Al saved in total.

In addition, the smelter has also carried out upgrading works in terms of environmental protection as shown in Table 5 below, to strive for Grade A smelters of environment-friendliness.

Currently, the full-scale retrofitting measures and environment protection upgrading are being implemented in order. It is believable that the smelter will be brimming with vigor and vitality.

Table 5. Technical upgrading for environment-friendliness.

SN	Existing	Targeting	Effects to be achieved
1	Fugitive emission from butts in potroom	Increase of butt cooling down device and cooling chamber	Emission will be improved.
2	Severe fugitive emission of pot overhaul workshop	The functional zoning will be given to pot overhaul workshop including of delining area, SPL temporary storage area, superstructure maintenance area and potlining construction area. Also closing-up dust points and dust collecting	The environment of workshop will be greatly improved.
3	Poor dust-collection of facilities like cast station, medium frequency induction furnace, thimble press machine etc.	Introducing more dust collecting system as well as closing up dust points.	The environment of workshop will be greatly improved.
4	The alumina storage warehouse is poor of closure, the spillover of alumina powder from discharging chute of belt conveying outlet	Installing the electric door of the workshop, the alumina conveying feeding area is separated from the alumina storage by isolation measures, and upgrading the gas collector and dusting until of the belt conveying outlet	The environment of workshop will be greatly improved.

6. Conclusions

With reference to various energy consumption and environmental protection policies issued for aluminum industry in China in recent years, this paper has deeply studied and discussed the three typical high-quality technology upgrading models of aluminum smelters. Three types of technology upgrading models have their own characteristics, all of which have been implemented by GAMI.

Insisting on the basic principle of "To create the greater benefit for aluminum smelters, less investment, significant achievements", GAMI has referred to the different features from them and proposed the customized upgrading and retrofitting. The smelter after upgrading and retrofitting operates potline comprehensive AC power consumption of hot metal between 13 000 ~ 13 300 kWh/t Al, which is able to fully meet the requirements by China stringent electrolytic aluminum energy consumption policy.

The "high-quality technology upgrading" schemes promoted by GAMI has enabled the smelters to keep the optimum balance between catering to the new policy requirements and creating good economic benefits, finally in favor of smelters for a sustainable development.

7. References

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