Environmental Aspects of UC RUSAL's Aluminum Smelters Sustainable Development

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Abstract

UC RUSAL is currently implementing an environmental strategy that includes increasing the number of pre-bake (PB) potlines and implementing global environmental standards at the existing smelters. The following has been achieved:

- Implementation of new Eco-Søderberg cells with environmental results that are comparable to PB cells;
- Construction of a pilot area for inert anode cells that are designed to replace VSS cells;
- Implementation of cutting-edge online and video systems for both emissions control and monitoring of cell condition;
- Testing of new types of binder with either a reduced or a close-to-zero content of benzo(a)pyrene;
- Construction of high-performance GTCs; and
- Development and implementation of technologies for sulfur recovery, SPL recycling, and solid waste treatment and recycling.

This paper provides an overview of the results of more than 10 years of effort to reduce the environmental footprint of RUSAL's smelters.

Keywords: Pollutant emissions, Eco-Søderberg technology, extractive pitch, gas treatment center (GTC) for aluminum production, spent potlining (SPL).

1 Introduction

Among the top priorities of its environmental and technical policy UC RUSAL proclaims the following: minimization of "carbon footprint" in the products; maximum switching over to the use of hydroelectric power; implementation of eco-friendly technologies; the most efficient treatment of air emissions; complete treatment and recycling of toxic wastes. Under its environmental strategy the Company performs the following:

- Development of new technologies for aluminum production with pre-baked anodes operating at of 500 to 700 kA with improved environmental properties;
- Implementation of eco-friendly upgrade solutions at existing Søderberg aluminum smelters;
- Development of new types of binder with a close-to-zero content of benzo(a)pyrene to produce anode paste;
- Testing of carbon-free electrolytic reduction technology with inert anodes;
- Implementation of highly efficient technologies for gas treatment;
- Implementation of technologies for recycling and treatment of potlining.

2 New Prebake Technologies for Greenfield Aluminum Smelters

The Company has already developed the entire series of high-amperage RA-300, RA-400 and RA-550 cells for its greenfield projects [1]. Khakass (Figure 1) and Boguchany (Figure 2) aluminum smelters are constructed using RA-300 technology, and RA-400 and RA-550 technologies are key technologies for Taishet aluminum smelter (Figure 3 and Figure 4) [2].
The technology proves to have high performance results and low pollutant emissions (Table 1).

Table 1. Process and environmental performance.

Parameter	RA-300	RA-400	RA-550
Amperage, kA	320	440	545
Current efficiency, %	94.5	95.0	95.5
Power consumption, kWh/kg Al	<13.7	<13.3	<12.9
F emissions, kg/t	0.26	0.25	0.20

When smelters are constructed with the implementation of new technologies one of the aims of the Company is to use 100 % power supplied by hydroelectric power plants. It will provide for minimization of “carbon footprint” during the primary aluminum production, as coal combustion is no longer required for generating power for the process.

Figure 1. Khakass Aluminum Smelter (RA-300 technology).

Figure 2. Boguchany Aluminum Smelter (RA-300 technology).

Figure 3. Taishet Aluminum Smelter (RA-400, RA-550 technologies) – in construction.

Figure 4. RA-550 Cells.

All greenfield smelters are constructed for the power supplied by hydroelectric power plants (HPP) (Figure 5):

- Sayano-Shushenskaya HPP – Khakass aluminum smelter.
- Boguchany Energy and Metals Complex (BEMO) – Boguchany aluminum smelter and Boguchany HPP.
- Taishet aluminum smelter and Angara cascade of HPP.

Figure 5. Boguchany HPP.

3 Søderberg Technology Enhancement, Environmental Performance Improvement

Currently at the Company's smelters many Søderberg cells, that require retrofitting, are in operation. For that purpose the Company has developed and is successfully implementing process solutions that provide for reduction of pollutant emissions from Søderberg cells (Figure 6).

Eco-Søderberg technology comprises the following complex of technological solutions [3]:

- Current-efficient cathode assembly with power consumption of approx. 15 kWh/kg Al;
- New ad hoc tending machines for major process operations;
- Automated raw material feeding systems including centralized alumina distribution system and automated feeding system of alumina and aluminum fluoride to the cell;
- A gas removal system with upgraded gas collection that provides for efficient cell cover similar to PB cells;
- Underfloor and side wall gas ducts equipped with air-impact cleaning systems to ensure stable and continuous gas removal from the cells (Figure 7).

Figure 6. Eco-Søderberg Cells.

Figure 7. Automated gas duct blowdown system.

Implementation of Eco-Søderberg technology provides for establishing better environmental performance indicators as compared with PB technology (Figure 8).

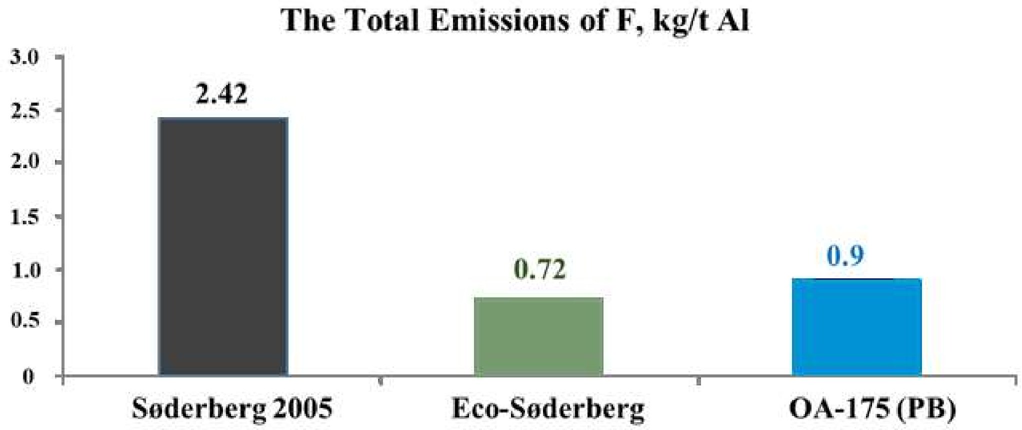

Figure 8. Eco-Søderberg fluorine emissions as compared with conventional Søderberg and PB technologies.

In 2018 ten potlines at the Krasnoyarsk and Bratsk aluminum smelters were switched over to Eco-Søderberg technology. The implementation of the technology along with construction of dry gas scrubbers is in progress at aluminum smelters in Irkutsk, Novokuznetsk and Volgograd. The percentage of upgraded Eco-Søderberg cells at the Company's smelters is indicated in Figure 9.

Figure 9. Implementation of Eco-Søderberg technology, showing % of upgraded pots.

4 Extractive Pitch

As is shown above the implementation of process solutions for upgrade of Søderberg technology provided for achievement of environmental performance comparable to current PB technologies of total fluorine and dust emissions; but these solutions did not solve the issue with emissions of benz(a)pyrene and tarry matters from VSS anode surface.

To reduce emissions of benz(a)pyrene and tarry matters an innovative technology was developed to produce extractive pitch with a reduced content of benz(a)pyrene used for anode paste production. The technology is based on the thermal dissolution of coal in by-products of petroleum and coke production. The technology is currently being tested at a pilot production scale (Figure 10).

Figure 10. Pilot plant for production of extractive pitch.

After pressure-and-temperature dissolution of coal, the coal fluid is separated from the undissolved solids and ash impurities then distilled to remove the light fraction. Extractive pitch is tank cleanings from distillation.

Benz(a)pyrene content in the extractive pitch is three times lower than in conventional coal tar pitch that allows for pro rata reduction of carcinogenic emissions and maintaining the required performance indicators of aluminum production upon switching over to the use of extractive pitch.

5 Inert Anode Cell

However, to eliminate the problem with "carbon footprint" and benz(a)pyrene emissions and to replace VSS cell technology the Company has been developing the electrolytic reduction technology with the use of inert anodes. Due to this technology all emissions of carbon oxide and dioxide, polyaromatic hydrocarbons, and sulfur dioxide are eliminated; and emissions of fluoride and dust are reduced to half the amount of upgraded PB technologies. A pilot plant for industrial testing of this technology has been established. Presently, over 1000 tonnes of aluminum have been produced by the pilot plant.

The proprietary composition and design of inert anodes was developed; and the production facilities were established. The Company is undertaking work to improve cell performance results.

6 Gas Treatment Technologies

Considerable work is being executed by UC RUSAL to equip existing production facilities with additional dry gas scrubbers while maintaining wet gas treatment centers (Figure 11).

6.1 RUSAL's Dry GTC

The Company is revamping gas treatment facilities by installation of gas treatment centers of proprietary design. At present dry gas treatment centers designed by UC RUSAL are installed at aluminum smelters in Irkutsk (2 GTCs), Volgograd (2 GTCs), Urals (1 GTC) and Novokuznetsk (1 GTC). As per the environmental action plan of the Company 100 % of aluminum smelters will be equipped with dry GTCs.

RUSAL's dry GTC is a low-pressure self-supported bag filter with increased filter area and low gas to cloth ratio. Due to implemented technological solutions GTC performance efficiency is over 99.0 % for any alumina grade thus maintaining zero wear of gas ducts and metal structures. Implemented technical solutions, i.e., stand-by feeding lines, minimum airslide length, and equipment operation under partial vacuum provide for continuous adsorbent supply. Design solutions and efficiency of RUSAL's GTC comply with the best world practice.

Comparative study of capital expenditures for GTC construction by other suppliers (earlier projects) proves that due to implemented design and construction solutions the cost of RUSAL's GTC is lower by 20 %.

a) b) c)

Figure 11. RUSAL's Dry GTC: a) Gas dynamic modelling b) GTC 3D model c) GTC construction at Irkutsk Aluminum Smelter.

6.2 Wet GTC with Liquor Recycling

Dry scrubbers are efficient for capture of gaseous fluorides, coke, fluoride and alumina dust, tarry matters (incl. benz(a)pyrene) but they do not ensure efficient capture of sulfur dioxide. For this purpose at RUSAL's smelters wet scrubbers are used after dry scrubbing where sulfur dioxide is captured with calcined soda to form sodium sulfate [4].

Under wet gas scrubbing technology that was used prior to the implementation of dry scrubbers concentrated sodium sulfate liquors were discharged to landfills that due to liquor recycling circuit caused an increase of its concentration in the liquors, a decrease of wet scrubber equipment efficiency, and a reduction of landfill service life. To eliminate these factors for wet scrubbers the technology for removal of sodium sulfate from gas cleaning liquors was developed (Figure 12).

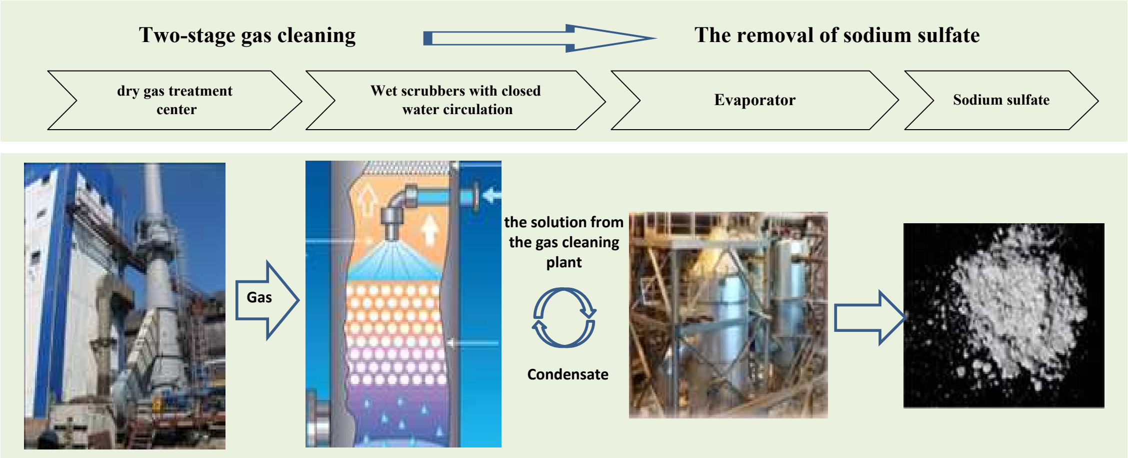

Figure 12. Two-stage gas treatment technology.

This technology was implemented at Krasnoyarsk and Novokuznetsk aluminum smelters and provides for the following:

- Sodium sulfate concentration of recycled liquors in the landfills decreased from 110 - 120 g/L to 70 g/L and consequently performance results of wet scrubbing stage is at least 96.7 %.
- Waste discharge to landfills is reduced so that the requirement for new landfills construction is eliminated.

Under this technology GTC liquors are evaporated with indirect steam in the evaporation column to generate concentrated sodium sulfate solution with subsequent sodium sulfate dehydration in a pusher centrifuge and drying in a electric tray drier.

At present research work is being undertaken to improve the process flow sheet and reduce the impurity content in the sodium sulfate obtined to produce a commercial grade product that can be sold in the market. This product is extensively used in pulp and paper, textile, chemical, and glass industries, in non-ferrous metallurgy and other sectors.

6.3 Environmental Performance Results

Table 2 presents the data on dynamics of gas cleaning efficiency at the Company's smelters after construction of dry gas scrubbers and upgrade of wet gas scrubbing technology.

Table 2. Performance indicators of one-stage and two-stage gas treatment.

Pollutant	**One-stage wet treatment**	**One-stage dry treatment**	**Two-stage gas treatment**
HFgas, %	Up to 98.0	Min. 99.0	Min. 99.4
Fsol, %	Up to 90.0	Min.99.0	Min. 99.75
Dust,%	Up to 95.0	Min. 99.0	Min. 99.5
SO_2	Up to 96.7	20.0-30.0	Min. 97.5

7 Emissions Monitoring System in Potrooms

The key efforts to provide for further reduction of pollutant emissions are directed to reduce of roof emissions.

For that purpose a complex control system of cell cover tightness is being developed comprising the systems of automated registry and analysis of process operation performance quality (“ECOLOGIST” AWS) (Figure 13).

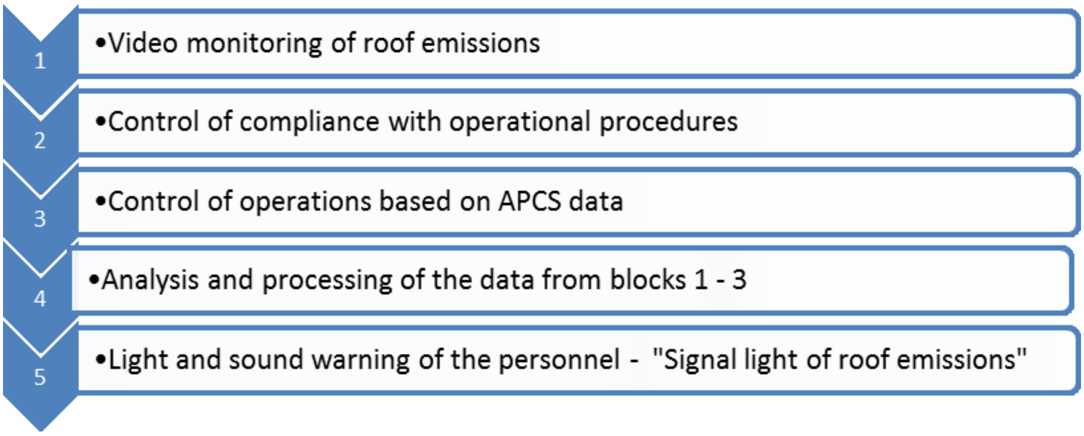

Figure 13. “ECOLOGIST” Automated Workstation.

Video monitoring of the atmosphere in the potroom (Figure 14) enables the system to detect, localize, classify the intensity of smoke and flame occurrences; by comparing these information with the data on the current cell status (APCS data) the system makes conclusions on the degree of cover failure and notifies the process personnel with light and sound alarms. Based on the analysis of data array the system provides for analysis and comparative facility-level and time-line analysis of condition\status of the smelter, potrooms and cells to evaluate the environmental performance of the reduction area.

The system is implemented to minimize fugitive emissions from the cells due to prompt response to detected failures and control of proper execution of cell tending operations. This system is currently being tested on VSS potlines 5 - 6 at the Krasnoyarsk aluminum smelter.

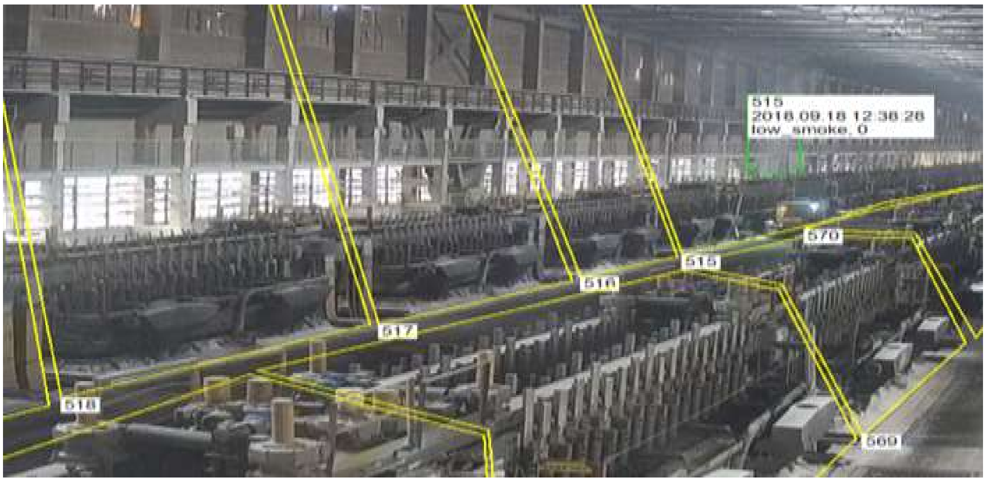

Figure 14. Display screen of monitoring system with detection of smoke from the cell.

8 Use of Un-shaped Refractory Materials to Reduce the Potlining Wastes

In addition to the measures on reduction of pollutant emissions UC RUSAL also developed the technologies for recycling and treatment of wastes from the reduction area. The Company developed the technology of using un-shaped refractory materials (URM) that provides for recycling of spent potlining from the cathode pedestal and reduction of solid wastes.

The technology comprises the use of multi-layer pedestal from a number of fine un-shaped lining materials installed and compacted with the use of special mechanical devices – installation and vibrocompaction units (Figure 15, Figure 16, Figure 17) that provides for the quality parameters similar to the parameters of shaped refractory and heat insulating materials.

Figure 15. Installation unit.

Figure 16. Compaction unit.

Figure 17. Recycling unit.

This technology is implemented at the Company’s smelters and provides for reduction of spent cathode pedestal materials amount up to 63 % due to material recycling that increases disposal efficiency of the remaining un-shaped materials unavailable for recycling by 70 – 80 %.

9 Conclusion

The efforts taken to improve the environmental efficiency of the production process provided for significant reduction of environmental impact in the Company’s footprint and decrease of gross emissions (Figure 18).

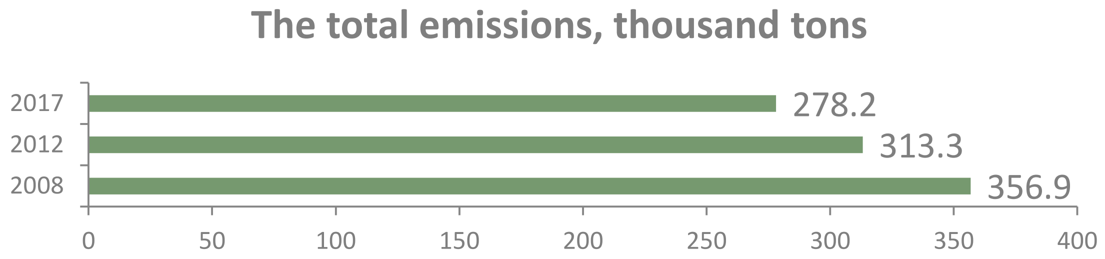

Figure 18. Reduction of gross emissions from Companies smelters.

The Company undertakes continuous measures to reduce its environmental impact as follows: further improvement of Søderberg technology; construction of new dry gas scrubbers that in conjunction with wet scrubbing technology ensures high efficiency of flue gas treatment; development of advanced extractive pitch and inert anode technologies to achieve even higher pollutant emission reduction values.

10 References

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