Anode plants for tomorrow's smelters: Key elements for the production of high quality anodes

Substandard anodes can add as much as $100/t to the cost of metal produced in the pot line and increase the quantity of GHG emissions. Thus careful attention to the quality of raw materials and furnace design and operation are vital to produce anodes which give optimum performance in the pot line.

Werner K. Fischer and Felix Keller, R&D Carbon Ltd., Sierre, Switzerland
Dr. Ulrich Mannweiler, Mannweiler Consulting, Zürich, Switzerland

Why should smelter management care about anode quality? – From considering all the input materials required to produce primary aluminium, those for anode production have the greatest variation of properties relevant to quality. Substandard anodes have a significant impact on the cost of metal production and greenhouse gas (GHG) emissions.

Modern smelters typically have annual capacities in the range of 750'000 – 800'000t/y and are designed to double capacity in expansion phases. Such smelters require anode plants with an initial annual output of 500'000t/y which has to be doubled if the smelter is expanded to twice its size subsequently.

Many years of steady development and design work have enabled smelters to increase the amperage and number of cells and adapt rectifiers with higher voltages to boost output. Unfortunately similar developments and design of anode plants is practically non existent resulting in even the latest anode plants having low throughputs (35t/h) and limited availabilities.

Fig 1: Pre-baked anode blocks rodded for high amperage pots are increasing in dimensions

Therefore, a technology is urgently needed for the efficient production of high quality anodes, at the lowest possible production cost, and capable of using inferior raw material as premium grades become increasingly unavailable. These anode plants must also have the lowest possible environmental emissions and operate with a high standard of workforce safety and hygiene. Such a technology must be able to handle large volumes of raw materials each day and to produce move and store big quantities of green and baked anodes. The supplier of anode plant technology must also take into account that smelters will always try to increase output by further increasing cell amperage and are often asking for larger anodes.

This paper describes a technology approach for designing and operating large anode plants adapted to the needs of large smelters. It takes into consideration operational and maintenance aspects involving:

- Raw materials logistics;
- Paste plant design;
- Bake furnace design;
- Equipment and refractory maintenance;
- Emission control;
- Consumption figures and costs which represents.

Ramifications of substandard anodes

Poor anodes will not only increase metal production cost by as much as 60 $/t but will also increase GHG emission by up to 60%. The main portion of GHG emission is due to increased dust generation in the pots that leads to higher frequencies of anode effects which release the perfluorocarbons (PFCs) CF_4 and C_2F_6 that are GHG respectively 6500 and 9500 times more potent than is CO_2.

For a smelter with an aluminum capacity of 800'000t/y GHG emission from using substandard anodes increases by over 1 million tons of $CO_{2\ equivalent}$ which represents a value of US$ 30 million a year in CO_2 emission certificates.

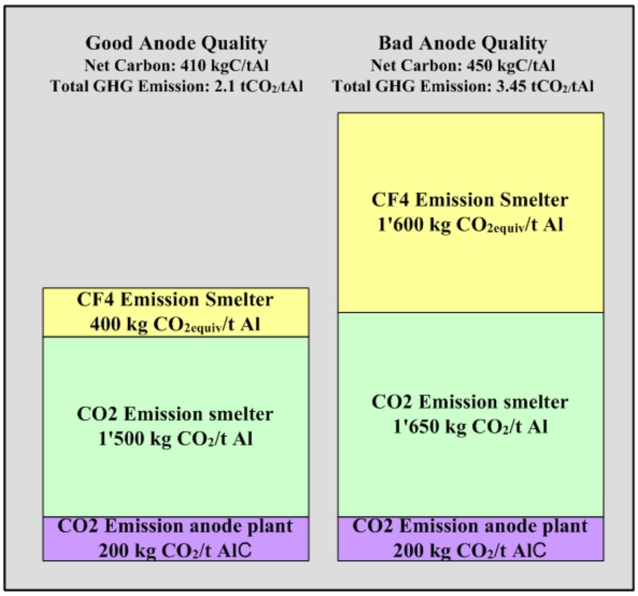

Fig 2: Impact of anode quality on Greenhouse gas emissions at smelter and anode plant

The total costs of using substandard anodes causing increased metal production cost and excess CO_2 emission is up to 100 $/t of aluminum produced.

General anode plant design

New smelters need sufficient storage capacities at the harbour for raw materials (petroleum coke, pitch etc), a well designed green paste and recycled material processing plant, as well as baking furnaces. RDC proposes the concept as shown in Table 1:

Smelter Capacity	**tpa**	**800'000**	**1'600'000**
Anode Capacity	tpa	500'000	1'000'000
Paste Plant	#	1	2
Capacity	tpa	600'000	2x600'000
Throughput	tph	80	2 x 80
Shifts/week	#	21	21
Weeks/year	50	50	50
Availability	%	86	86
Recycled processing	tpa	160'000	320'000
Throughput	tph	50	50
Shifts/week	#	8	16
Baking Furnace	tpa	510'000	2x510'000
Furnaces	#	1	2
Fires	#	8	2 x 8
Tons per fire	t	65'000	65'000
Fire cycle	hrs	28	28
Waste gas cleaning	Nm^3/h	240'000	480'000
Harbor Facility			
Coke silos	#/t	2 x 30'000	3 x 30'000
Pitch tanks	#/t	1 x 12'000	2 x 12'000

Table 1: General design data

Raw materials logistics

Large anode plants have two or even more sources of petroleum coke. Today 25'000 t vessels transport the pet coke and 10'000 t tankers transport liquid pitch.

Pet coke is discharged at 1000tph by vacuum unloaders to dedicated silos each of 30'000 t capacity. A facility allows blending of cokes of different qualities. Pitches of different brands are blended in the tank farm prior to being pumped to the paste plant

Fig 3: Liquid pitch terminal

Cleaned, stripped, uncrushed spent anode butts from the rodding shop are conveyed to the recycled material processing plant. As poorly cleaned anode butts have a significant negative impact on anode quality, great care has to be given to anode butts cleaning and processing. Baked scrap is processed together with the anode butts.

Paste plant design

'Simplification is the ultimate sophistication!'
quoted Leonardo da Vinci.

The quality and consistency of green anodes correlates strongly with the 'Mean time between failures' of anodes. When the paste plant is in stable operation, green anode quality will remain stable too. Every shut-down will result in large variations in anode properties. The best way to reduce the number of shutdowns is to use the smallest possible pieces of equipment with the highest possible throughput. The simpler the design, the more efficient the plant will be. Therefore, RDC designed a paste plant technology with a capacity of 600'000t/y and a throughput of 80t/h and a plant availability of 86%. Five process areas make up the paste plant:

- Storage of petroleum coke in dedicated silos and liquid pitch in tanks.

- ♦ Process plant for spent anode butts removed from the pot line and for carbon scrap generated during anode production. After crushing, screening and storage, a combined fraction consisting of: spent anode butts <16mm (85%); green anode scrap (10%) and baked anode scrap (5%) is transferred as 'recycled fraction' to the paste plant.
- ♦ Petroleum coke is screened and added to two scales, i.e.
  - Medium fraction: 8 – 2mm
  - Fines fraction: 2 – 0mm
  - Overflow >8mm from medium fraction and fines fraction (coke only) are fed to a vertical mill with an integrated classifier. The continuously produced dust with a fineness of 4'000 Blaine is stored in the ball mill dust bin.
- ♦ One cascade for dry aggregate preheating, paste mixing, paste cooling, pressing 60-80 anodes per hour. After cooling the green anodes are transferred to the green anode store where they remain for at least a day prior to being sent to the bake furnace.

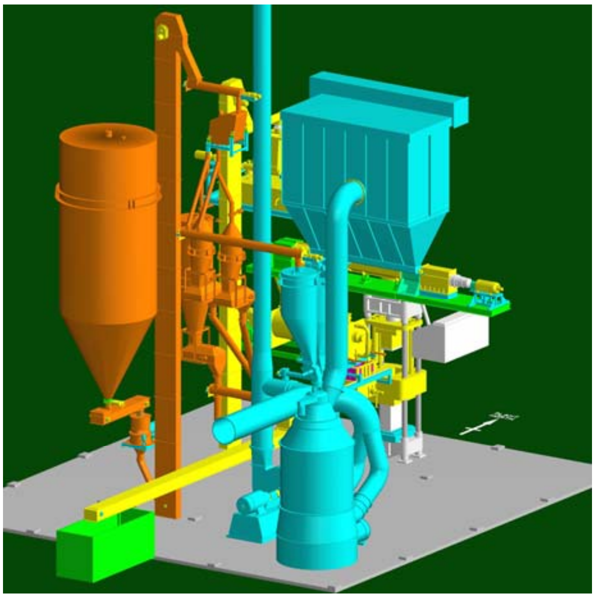

Fig 4: **Equipment arrangement in a 600'000 t/y paste plant**

- ♦ Tar containing gases from pitch feeding, mixing, cooling and forming are burned in a Regenerative Thermal Oxidation unit (RTO). Carbon dust is captured at the source and added to the ball mill circuit.

Bake furnace design

Open top ring type furnaces are considered state of the art. Five main elements have to be taken into consideration:

- Conceptional and refractory design;
- Energy consumption;
- Mechanical and refractory maintenance;
- Anode and packing material handling;
- Waste gas treatment.

A bake furnace with a net capacity of 500'000t/y has 8 fires all contained in a single building. To produce 65'000t of anodes per fire per year a section load of at least 200t with a fire cycle of 28 hours is required. The refractory design is derived using Computational Fluid Dynamics (CFD) to analyse gas flow. Refractory material is of proven quality and best brick layer practices have to be applied.

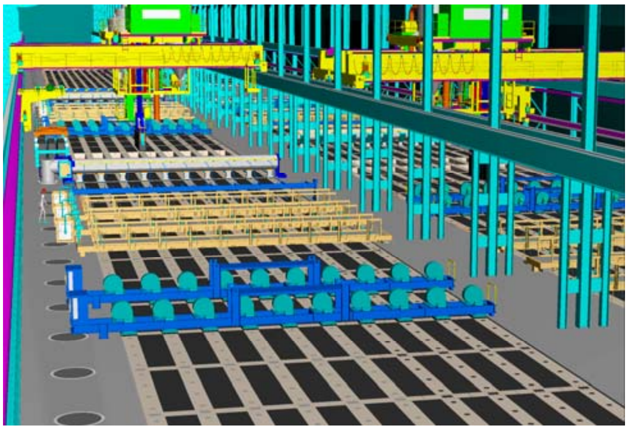

Fig 5: **Open top anode bake furnace**

The energy consumption of such a furnace depends on: refractory design, the firing and control system but, above all, on the pitch content of the anodes.

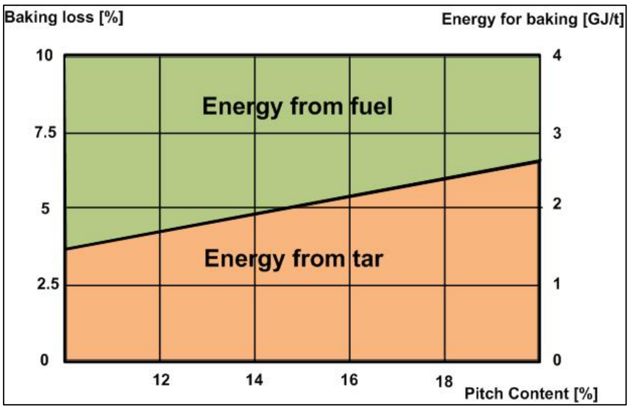

Fig 6: Energy supply distribution from fuel and tar

In normal bake furnace operation more than 98% of the pitch volatiles are burned. Volatiles released from the pitch during baking contribute about 50% of the energy input for baking. If the pitch content varies by 2% the natural gas consumption varies by 10 %.

For energy efficiency and to minimize emissions, total combustion of all tar fumes is mandatory. RDC has invested much research and development of bake furnace design, process control and total combustion of tar and fuel. As a result of these activities RDC can predict furnace behavior regarding anode quality as well as oxygen availability and thus predict combustion efficiency. For the first time it is possible to design furnaces scientifically and not by extrapolating and copying existing furnace designs. Also hardware has been re-designed and the process control system has been upgraded to implement crane operations and plant maintenance instructions.

Overhead cranes, anode conveying equipment, process control and waste gas treatment are all designed for the highest reliability. Together with a smart anode logistics system conditions are set for regular and undisturbed furnace operation including preventive or curative maintenance.

Emission control

In the paste plant and bake furnace, Polycyclic Aromatic Hydrocarbons (PAH-16) are the main concern regarding the impact of the anode plant on the environment. As PAH-16 is considered to be carcinogenic, these condensed and volatilised components are captured and destroyed completely in the Regenerative Thermal Oxidation unit (RTO).

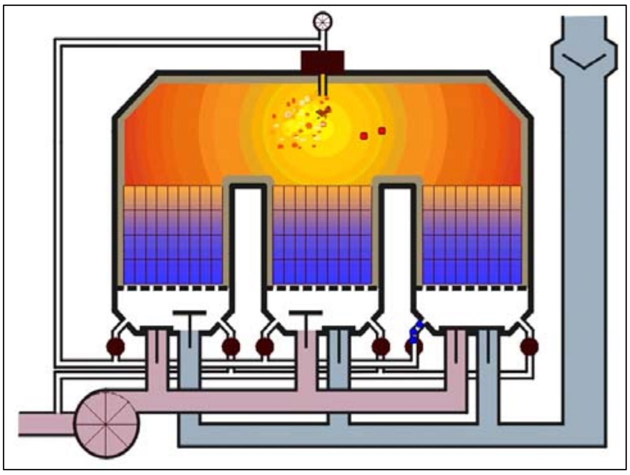

Fig 7: Regenerative Thermal Oxidation (RTO) for post combustion of volatiles.

The RTO consists of an afterburner combined with two heat exchangers. By switching the direction of the gas flow in 20 second intervals 95% of the combustion heat can be recuperated. RTO's are well proven having been in operation for several years in paste plants and bake furnace.

Consumption and costs

In Table 2 key quantities, cost and operating parameters are summarized for two anode production facilities of 500’000t/y and 1 million t/y respectively.

		Annual Consumption	
	Specific Consumption	500’000t/y Anode Plant	1'000'000t/y Anode Plant
Raw Material			
Petroleum coke	630kg/t anode	315'000 t	630'000 t
Coal tar pitch	160kg/t anode	80'000 t	160'000 t
Recycled material	300kg/t anode	160'000 t	320'000 t
Energy			
Electrical energy	MWh/t anode	50'000 MWh	100'000 MWh
Natural gas	100Nm^3/t anode	50M Nm^3	100M Nm^3
Labor		150 people	250 people
Investment cost	900-700 US$/t	450M US$	700M US$

Table 2 Typical annual consumptions and cost.

This technology has been developed by R&D Carbon Ltd in cooperation with the supplier of green paste plants “OUTOTEC” and “RIEDHAMMER” supplier for anode bake furnaces. Part of it has been applied in a large anode plant presently under construction in the Middle East.

For more information contact:

R&D Carbon Ltd.
R&D Carbon Ltd. P.O. Box 362, CH-3960 Sierre, Switzerland
Phone: +41 27 459 29 29, Fax: +41 27 459 29 25
rdc@rd-carbon.com www.rd-carbon.com

MANNWEILER CONSULTING
Mannweiler Consulting, ,
Hadlaubstrasse 71, CH-8006 Zürich, Switzerland
Phone: +4144 350 46 62, Fax: +41 44 350 46 61
ulrich@mannweiler.ch www.mannweiler.ch