R&D Carbon

KAN-NAK

Anode Issues during Smelter Capacity Creep

19TH INTERNATIONAL CONFERENCE ON NON-FERROUS METALS 2015 BHUBANESWAR

Jean-Claude Fischer

07/2015

Improve Smelter Profitability

Profitability of a smelter can be improved by

- Higher metal output
- Lower energy consumption
- Higher current efficiency

Influence of production parameters on earnings		
Parameter	Change	Earnings / year
Production +10%	+ 60'000 tAl/year	+ 30.0 Mio $
Energy consumption	- 0.5 MWh/tAl	+ 6.0 Mio $
Current efficiency	+ 1 %	+ 7.8 Mio $

Example

Smelter	600'000	tAl/year
Production cost	1'500	$/tAl
LME	2'000	$/tAl
Energy	20	$/MWh
Al_2O_3	350	$/t

R&D Carbon

KAN-NAK

Impact of Increased Line Current

Higher metal output through increased line current

Interdependance between line current, pot voltage and energy consumption by constant ohmic pot resistance			
Line current	kA	**300**	**360**
Pot voltage	V	4.1	4.6
Energy consumption	kWh/kgAl	12.9	14.5

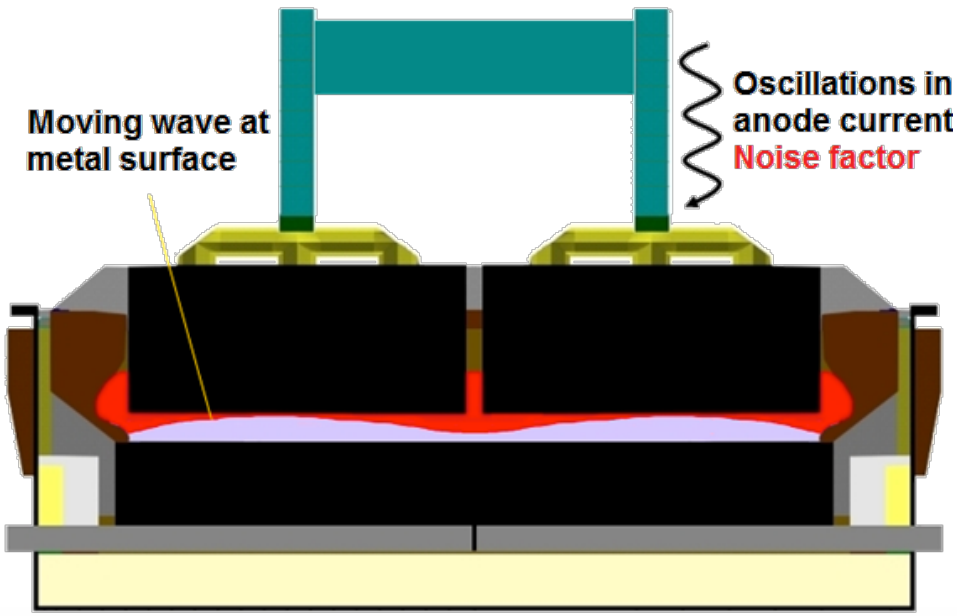
- Increased line current by constant cell ohmic resistance leads to higher cell voltage and increased energy consumption
- Increasing the line current rises the heat input
- By unchanged cell ohmic resistance and insulation, the thermal equilibrium is disturbed

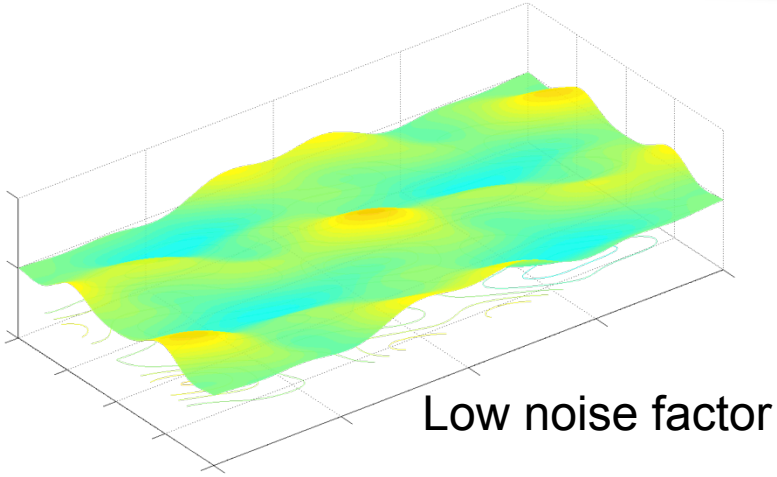
Maintain Thermal Equilibrium

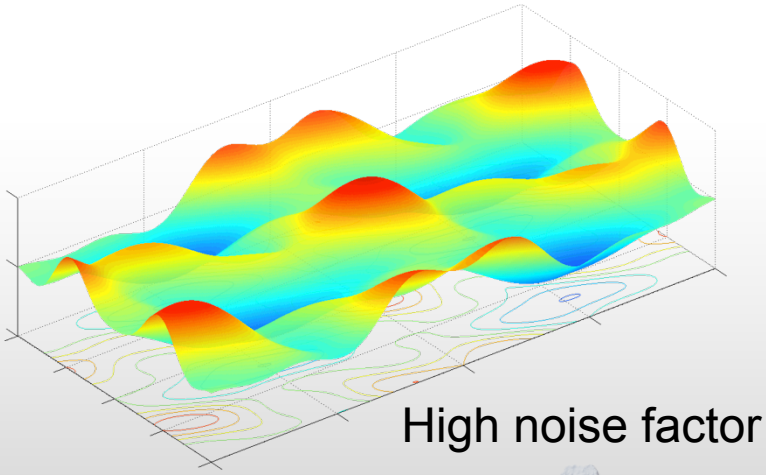
The thermal equilibrium by line current creep can be maintained through

- **Decreasing cell voltage**
  - Lower bath resistance by squeezed anode-cathode distance
  - Higher bath electrical conductivity (chemistry)
  - Cathode design and materials improvement
  - Longer and slotted anodes
- **Higher heat losses**
  - Collector bars design and materials
  - SiC sidewall block
  - Anode cover bath material
  - Higher metal level
  - Anode stub design
  - Cell tub design

Magnetic Stability







- A high noise factor is an indication for thermal-electrical and magneto-hydrodynamic instability
- Risk of «shorting» between anode and metal
- Increasing ACD damps waves at the metal-bath interface (noise)

Improve Magnetic Stability

The magnetic stability of the cells can be improved by

- Thermal-electrical (TE) and magneto-hydrodynamic (MHD) optimization
- Precise anode setting
- Shaped cathode surface
- Improved cathodic current distribution
- Optimized busbar design
- BETTER ANODE QUALITY

Influence of Anode Quality on Cell Performance by Line Current Creep

Thermal-electrical and magneto-hydrodynamic computation

- **Parameters**

  - Line current 360 kA to 410 kA

  - Anode properties

Anode parameters	Unit	Range
Specific electrical resistance	µΩm	46 - 60
Thermal conductivity	W/mK	3 - 5
Baked apparent density	kg/dm^3	1.50 – 1.64
Butt cross section	%	60 - 100

- **Goal**

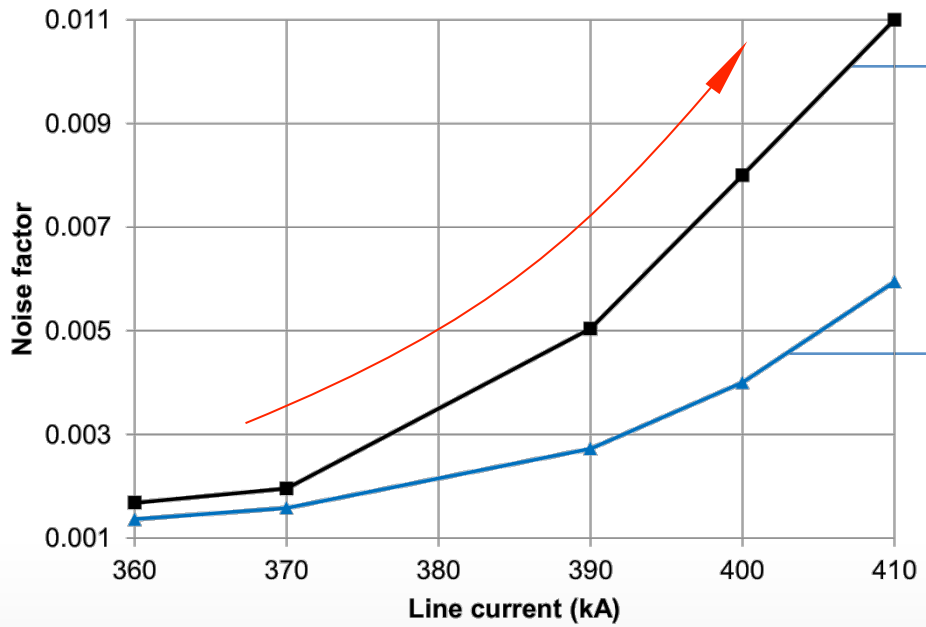
  Quantification of the impact of anode properties on thermal and magnetic cell stability by line current creep

R&D Carbon

KAN-NAK

Anode Specific Electric Resistance SER and Thermal Conductivity TC

Calculated noise factor by increased line current



Anodes with high standard deviation of SER and TC

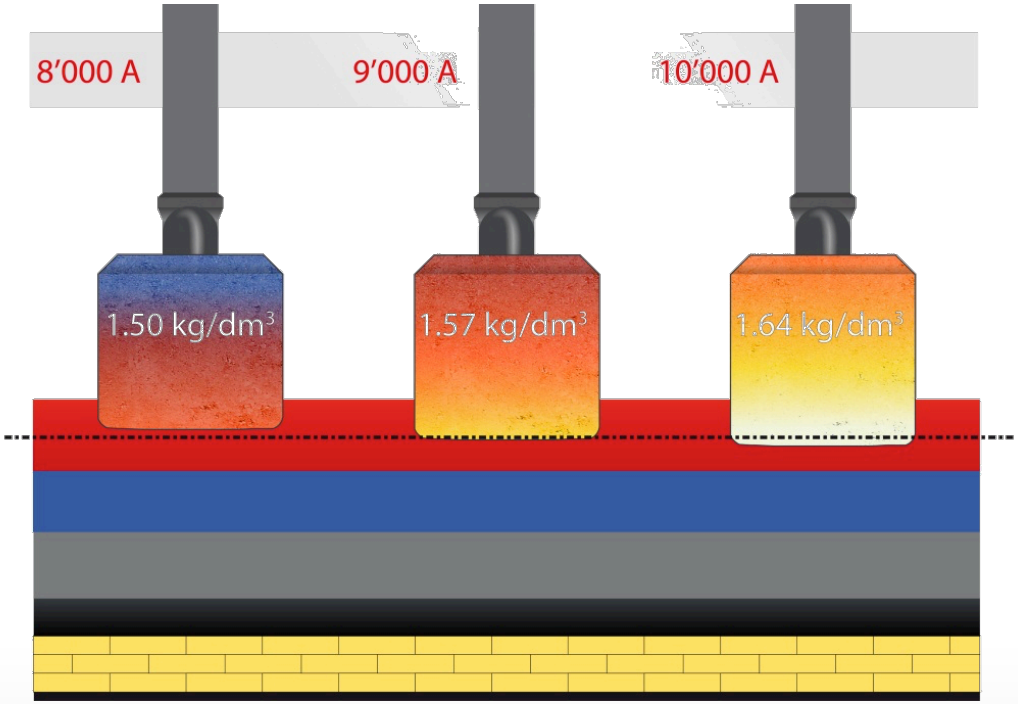
Anodes with low standard deviation of SER and TC

- Cell instability (noise) increases over-proportionally by line current creep
- Anodes with high standard deviation of SER and TC lead to higher noise by increased line current

R&D Carbon

KAN-NAK

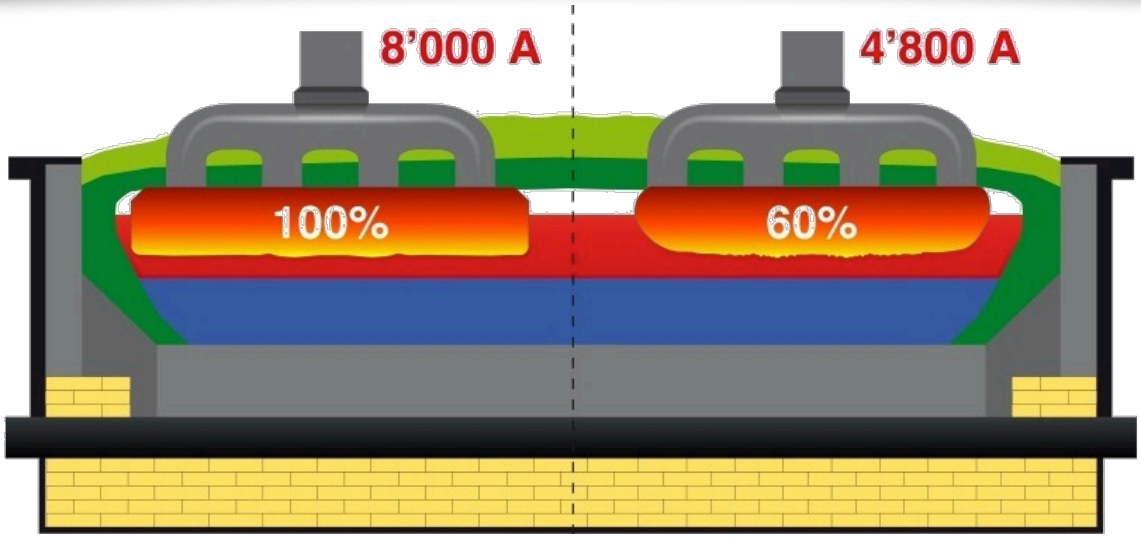
Anode Apparent Density Variations



Anode density variations

Anodes with **different densities** (weight) in the same cell disturb **current distribution up to 25%**

Anode Reactivity and Permeability



Influence of butt section on anode current.

Anodes with poor **CO_2-**, **AIR-reactivity** and **permeability** lead to reduced butt size and formation of **carbon dust**

- Reduced butt size disturbs the anode **current distribution up to 40%**

Carbon Dust in the Bath

Carbon dust

Spikes

Excessive **carbon dust** in the bath leads to:

- A **significant** increase of the **ohmic bath resistance**, which causes a squeezed anode-cathode distance (**ACD**)
- The formation of anode **spikes**
- Higher **bath temperature** and lower **current efficiency**
- **Disturbed magnetic** and **thermal stability**

Vicious circle!

Influence of Anode Quality on Cell Performance by Line Current Creep

Results

- Anode properties influence significantly the magnetic and thermal cell stability
- Anodes with high quality variations deteriorate the cell stability dramatically
- Cells with high current density are more sensitive to anode quality variations

High current density cells require better and more consistent anodes (BENCHMARK anode quality)

BENCHMARK Anode Quality for High Current Density Cells

BENCHMARK anode properties	Unit	Mean	Max 2 STD
Baked apparent density	kg/dm^3	min. 1.58	0.015
Specific electrical resistance	µΩm	max. 54	3
Thermal conductivity	W/mK	4	0.4
Air permeability	nPm	max. 0.6	0.4
Air reactivity residue	%	min. 85	4
Air reactivity dust	%	max. 3	2
CO_2 reactivity residue	%	min. 90	3
CO_2 reactivity dust	%	max. 2	2

- **BENCHMARK** anodes compared with **state of the art** anodes show significantly **better mean values** and at least **50% lower standard deviations**
- **Important**: Routine representative anode quality control is mandatory

R&D Carbon

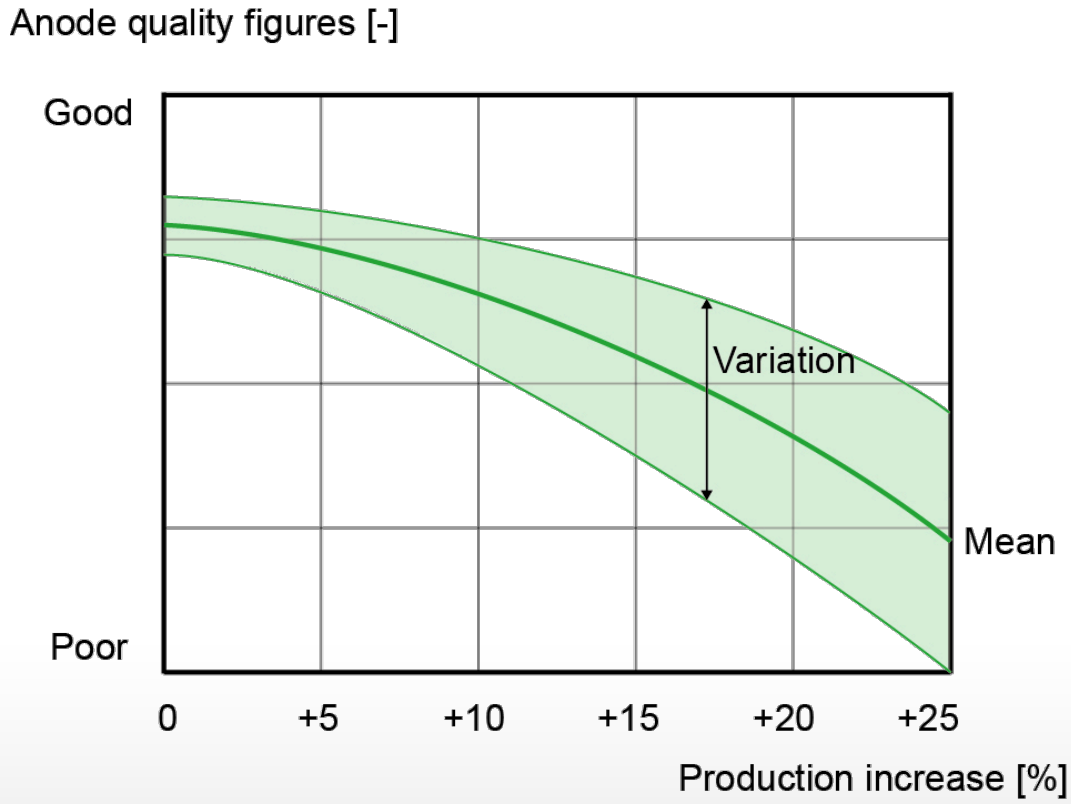
KAN-NAK

Raw Materials for BENCHMARK Anodes

- **Calcined petroleum coke**
  - High bulk density
  - Low specific electrical resistance
  - Excellent CO_2 and AIR reactivity
- **Coal tar pitch**
  - Constant physical properties
  - Low Na and Ca content
- **Butts**
  - Well cleaned, Na < 300 ppm
  - Coarse
  - No burnoffs

- **Important**: Routine quality control of all raw materials

Increased Line Current Require More and Better Anodes



Increasing production in existing paste plant and baking furnace leads to lower quality and higher variations

R&D Carbon

KAN-NAK

Paste Plant Requirements

Paste plant operation parameters

Paste plant	Unit	Start-up	Actual	Future
Line current	kA	**300**	**360**	**410**
Green paste production	t/year	315'000	375'000	420'000
Green anode weight	kg	915	1'030	1'120
Green mill throughput	t/h	2 x 28	2 x 33	2 x 36
Specific mixing energy	kWh/t	**10**	**8.5**	**7.8**

Bottlenecks by higher throughput

- Coke blending facility
- Ball mill production capacity
- Preheating of dry aggregate
- Insufficient specific mixing energy
- Paste cooler capacity
- Vibroformer availability and process control
- Green anode cooling capacity

Estimated cost 20 to 30 Mio $

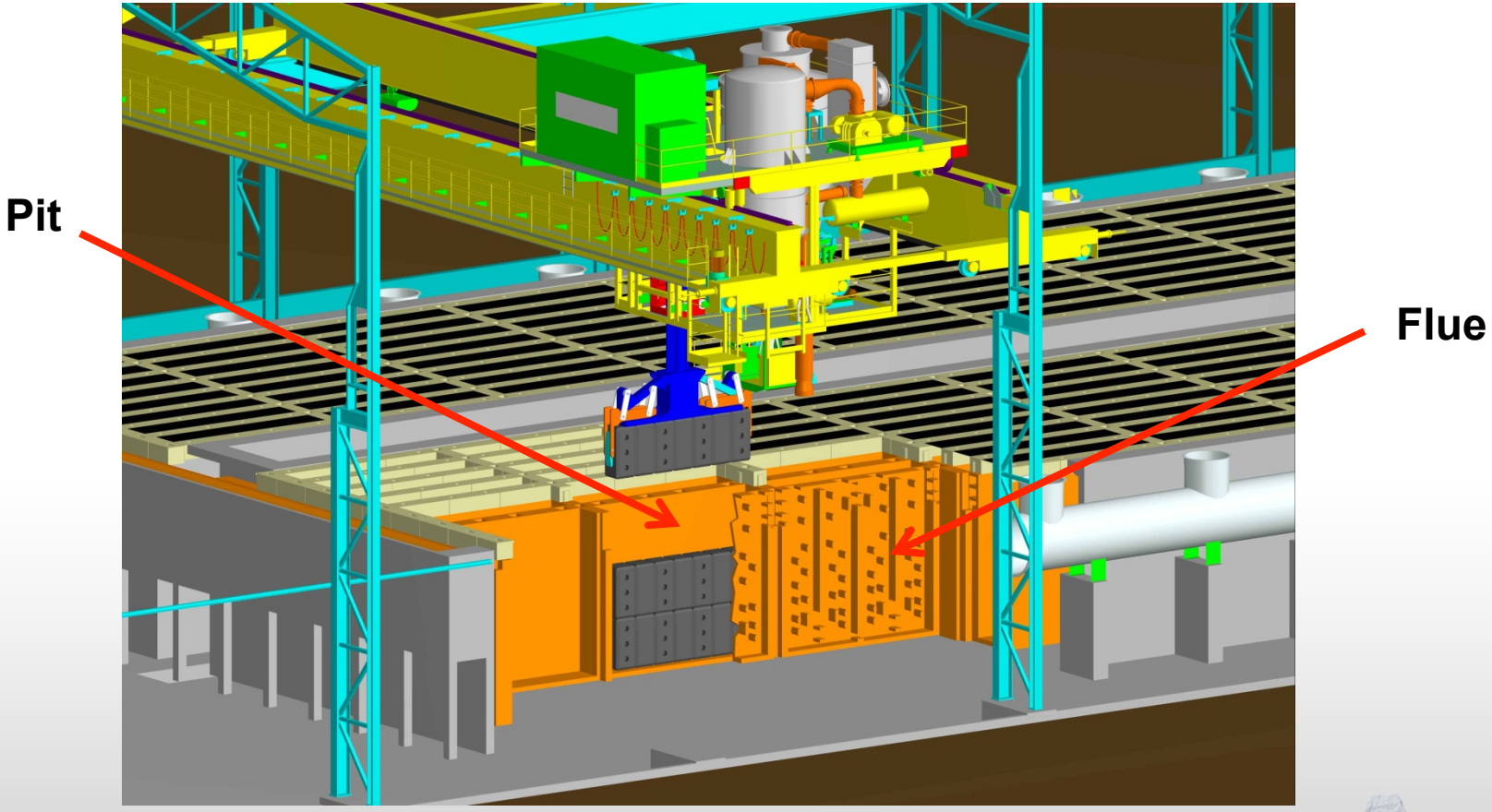
Downtime 2 to 3 months

R&D Carbon

KAN-NAK

Baking Furnace Productivity and Quality

- **Anode handling and flue design**

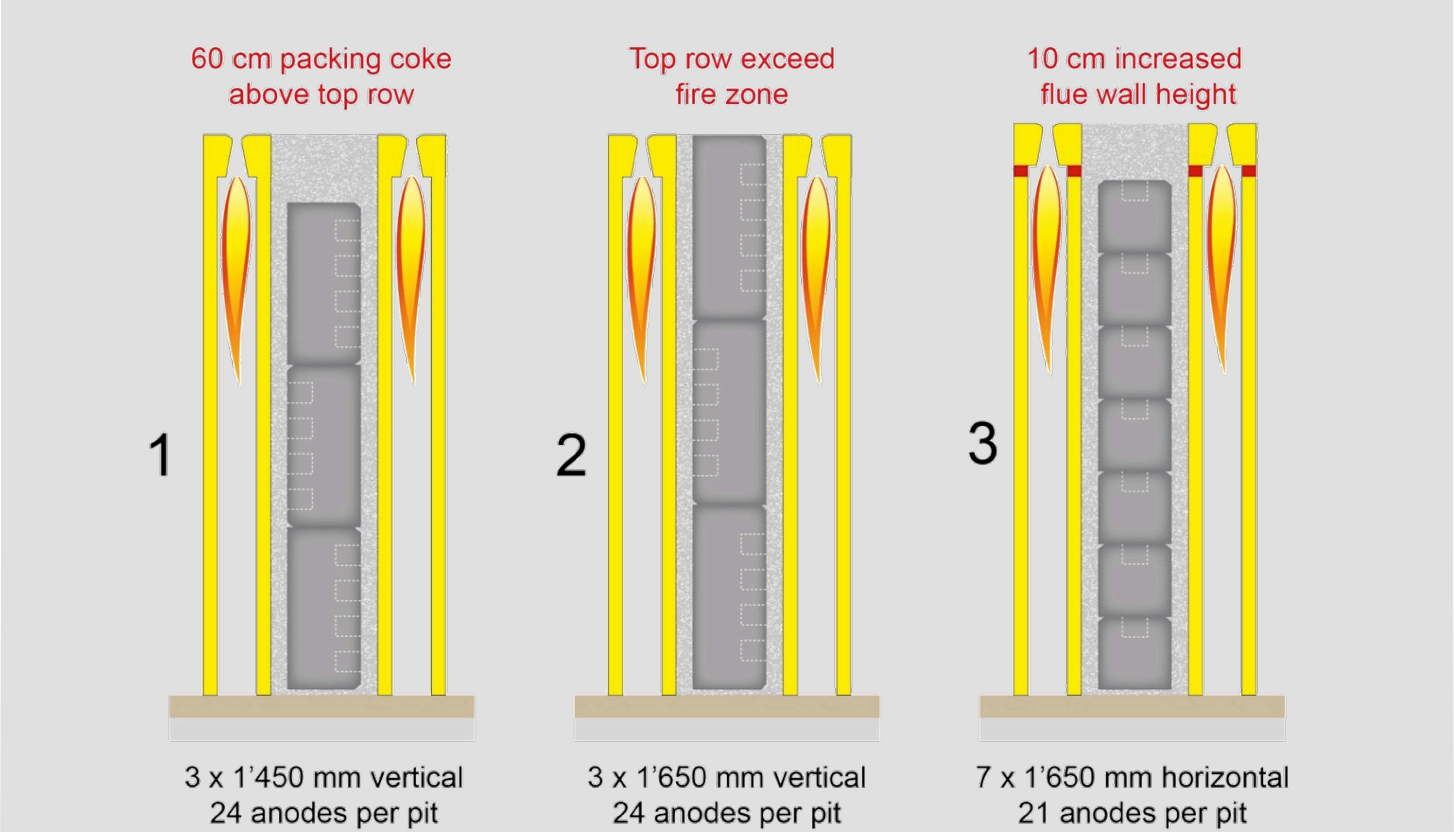


R&D Carbon

KAN-NAK

Baking Furnace
Anode Arrangement in Pit

- **Anode arrangement in pit**



Long anodes must be placed horizontally

R&D Carbon

KAN-NAK

Baking Furnace
Production and Quality

- **Baking furnace operation parameters**

Baking Furnace	Unit	Start-up	Actual	Future 6 fires	Solution: Future + 1 fire
Line current	kA	**300**	**360**	**410**	**410**
Baked anodes requirement	t/year	280'000	335'000	380'000	380'000
Production per fire and year	t	46'700	55'800	63'300	54'300
Tons per section	t	167	188	180	180
Fire cycle time	h	31.4	29.5	24.9	29
Total heat up time	h	**188**	**177**	**149**	**174**

With the existing 6 fire furnace, the production of 380'000 t/year of BENCHMARK quality anodes **is impossible**

- **Reasons**

- Top row anodes exceed pit height
- Total heat up time 149 hours does not allow a homogeneous anode heat treatment
- Increased waste gas volume of 38 % doubles the pressure drop in the flues
- Higher pressure drop in the flues leads to a lack of oxygen in the fire zone (soot)

R&D Carbon

KAN-NAK

Baking Furnace
Production increase

Investments for in house baking of 380’000 t/year of BENCHMARK anodes

- Addition of one fire (54’300 t/year)
- Increase flue height in existing 6 fire furnaces
- Adaption of handling system to horizontal anode setting for 7 fires
- Expansion of waste gas cleaning installation
- Update of anode cleaning and slotting facilities
- Improved process and quality control

Estimated cost 50 to 70 Mio $

Prior to a substantial line current creep, the availability of BENCHMARK anodes must be guaranteed.

Merchant BENCHMARK Anodes

Investment of 70 to 100 Mio $ in paste plant and baking furnace can be avoided by purchasing merchant BENCHMARK anodes

To be considered

- **Availability** Long term contracts with optimum lot sizes
- **Price** Raw material or LME related
- **Quality**
  - BENCHMARK anode specification
  - Determination by third party laboratory before shipping
  - Defined actions for anode lots out of specifications

R&D Carbon

KAN-NAK

Aminco Anodes

A Merchant Anode supplier in partnership with R&D Carbon since 1997

AMINCO ANODES
SWISS ENGINEERING MADE IN CHINA

More than 2.0 million tons of anodes delivered to smelters around the world

Highest anode quality – through limitation of variability is Aminco's competitive advantage

Merchant BENCHMARK Anodes

Impact of merchant anodes on in house production

Paste plant

Decreased throughput and higher mixing energy allows production of green anodes with the required values and consistency without further investment.

		Merchant anodes	
Paste plant	**Unit**	**Without**	**With**
Line current	kA	**410**	**410**
Green paste production	t/year	420'000	357'000
Green mill throughput	t/h	2 x 36	2 x 31
Specific mixing energy	kWh/t	7.8	9.1

Baking furnace

A heat up time of 174 h and horizontal loading of the anodes allows the production of BENCHMARK anodes in the existing 6 fires baking furnace with refurbishment cost below 10 Mio $.

Baking Furnace	Unit	In house production	Merchant anodes
Baked anodes requirement	t/year	325'000	55'000
Production per fire and year	t	54'200	
Fire cycle time	h	29	
Total heat up time	h	174	

Summary

- Variable anode properties influences the cell stability by
  - Non uniform anode current distribution
  - Disturbed cell thermal equilibrium
  - Carbon dust in the bath
- TE and MHD computations have shown an over-proportional influence of anode quality variations on cell stability by increased current density.
- **Smelter improving their profitability by line current creep need more and better anodes**
- **Entire in house production of more and better anodes require substantial investments in paste plant and baking furnaces.**
- **Purchase of merchant anodes allows the production of BENCHMARK anodes in the existing carbon plant without further investments**

R&D Carbon

KAN-NAK

AMINCO RESOURCES

Your partners for total carbon solutions