IBAAS 2024
Technical Lecture Series

BAUXITE ONLINE ANALYSER AND A/C RATIO CONTROL IN ALUMINA REFINERY

1. György (George) Bánvölgyi
Senior Process Consultant (Alumina)

2. Ashok Nandi
President, IBAAS

Personal Data

NAME: György (George) Bánvölgyi

BIRTH: 23 April, 1948. Budapest, Hungary

EDUCATION, PRACTICE:

- **1992. Patent Attorney, Postgraduate Institute of Budapest University of Economics**
- **1972. MSc. in Chemical Engineering, Veszprém University of Chemical Engineering, Hungary. Specialized in process automation.**
- **Has been working in the aluminium industry since graduation.**

AFFILIATION: Senior Process Consultant, Alumina

LANGUAGES:

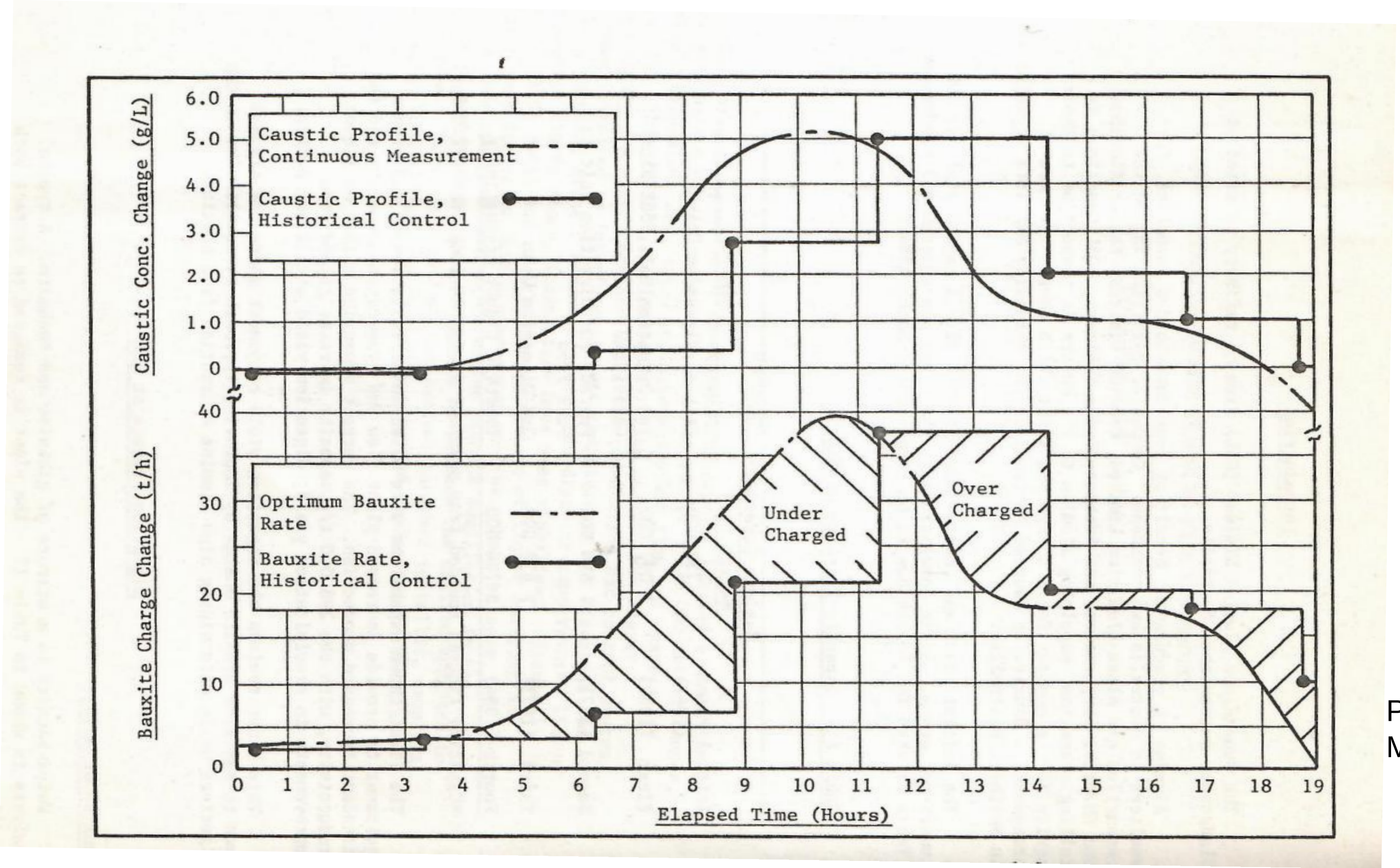
- **Good English command**
- **Russian, fair**

E-mail: gbanvolgyi@gmail.com

Introduction

- **Bauxite is highly heterogeneous in nature and despite efforts for thorough blending, it is not always feasible to get uniform grade of ore.**
- **The process bauxite moving on the conveyor belt is hourly sampled and the analysis of day composite is normally available after 2 days.**
- **Consequently, a critical decision, i.e. the test tank liquor/solid ratio is based on the average ore quality, which leads to suboptimal digestion efficiency.**
- **Installation of online analyzer on the conveyor belt provides real-time alumina and silica measurements, enabling precise adjustments for optimal solid to liquor ratios and digestion efficiency.**
- **The under- and overcharge of bauxite in the desilication-digestion process step can be avoided, if available alumina and reactive silica of bauxite are known.**

Historical vs optimum bauxite charge



P. McIntosh, Light Metals 1984, 27-38

Drawbacks of Bauxite Undercharge and Overcharge

Bauxite under-charge

- part of the digestion capacity of the Test Tank Liquor is not utilized
- more bauxite could be charged into the Test Tank Liquor, the production rate of the digestion and therefore the refinery could be higher
- part of the Test Tank Liquor is heated to the digestion temperature unnecessarily.

Bauxite over-charge

- part of soluble alumina does not dissolve and is lost with the bauxite residue
- this part of gibbsite comprises seed for prematured formation of precipitated gibbsite during the decantation of bauxite residue and is also lost with the bauxite residue
- may cause scalings on the control filtration cloth.

Choice of technology – Near Infrared Technology (NIR) – Option 1

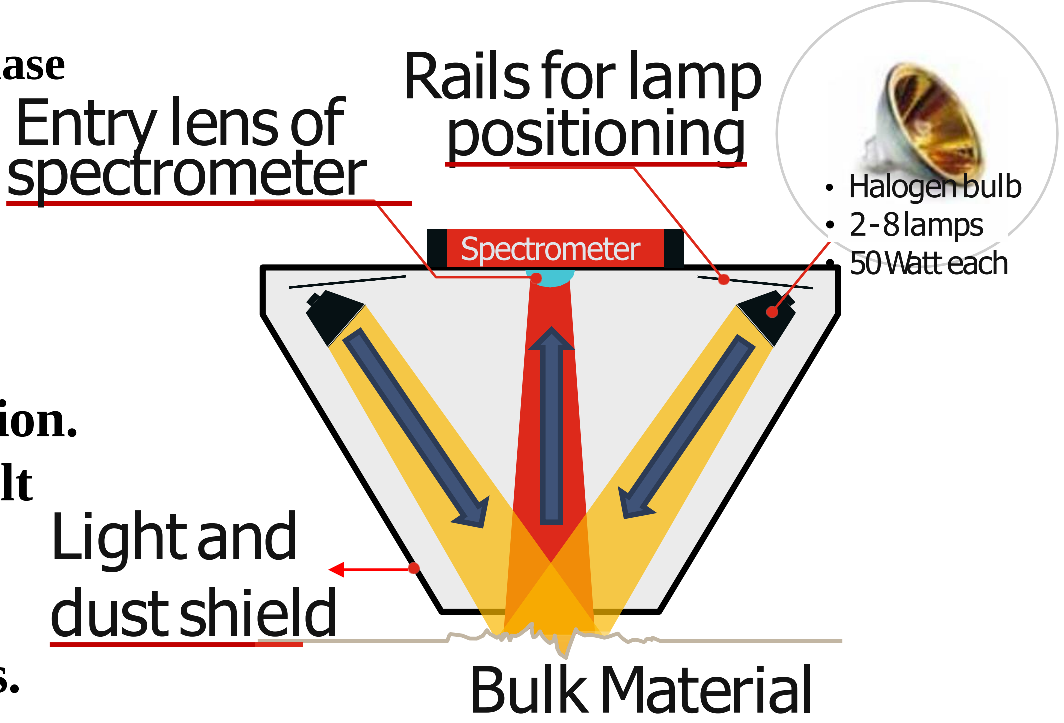
Near Infrared Technology (NIR), Spectraflow

- ✓ **Provides elemental and mineral phase analyses.**
- ✓ **Large measurement area and 150 scans per minute.**
- ✓ **Online minute-by-minute analysis.**

Advantages

- ❖ **Independent of belt load variation.**
- ❖ **No requirement for variable belt speed drives to compensate for belt load variations.**
- ❖ **Actual 1-minute analysis values.**

Working principle of SpectraFlow Analyzer



Entry lens of spectrometer

Rails for lamp positioning

- Halogen bulb
- 2-8 lamps
- 50 Watt each

Spectrometer

Light and dust shield

Bulk Material

Choice of technology – Controlled Neutron Activation (CNA) – Option 2

CNA Cross- Belt Analyzer
Malvern Panalytical

- ✓ Utilizing Advanced PFTNA (Pulsed Fast and Thermal. Neutron Activation) Technology
- ✓ No Radiation Hazard.
- ✓ Electrically Controlled Neutron Source.

Advantages

- ❖ High Penetration Capacity, led to Excellent Output.
- ❖ Measure H,C,O and moisture.
- ❖ Al2O3, SiO2, Fe2O3 and Moisture contents in bauxite can be accurately measured.

Choice of Technology – LIBS - Option 3

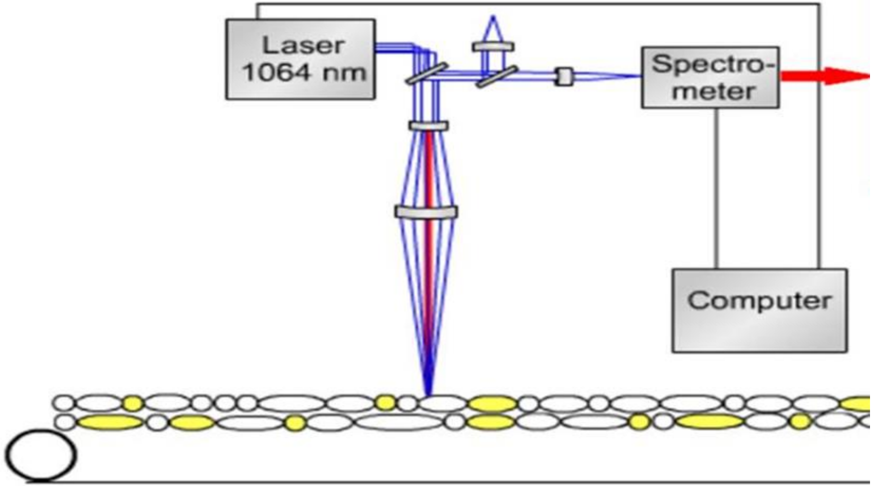
Laser based analytical technology *MAYA* of Lyncis company

- ✓ **Utilized Laser Induced Breakdown Spectroscopy (LIBS).**
- ✓ **Source of Energy is Solid-state pulsed Nd:YAG (Neodymium-doped Yttrium Aluminum Garnet) laser.**
- ✓ **Simultaneous quantitative elemental analysis of bulk material.**

Advantages

- ❖ **Completely safe, no radioactive emission.**
- ❖ **Low maintenance expenses (i.e. $500k for PGNAA vs $20k for LIBS over 10 years).**
- ❖ **Measuring rate 1 to 20 times per second.**

Working Principle of LIBS



Why to Choose Controlled Neutron Activation Cross- Belt Analyzer of Malvern Panalytical?

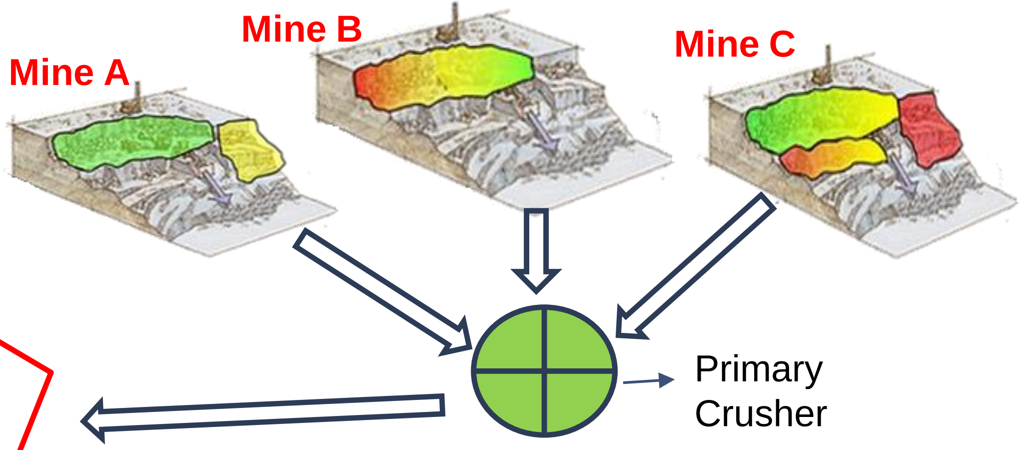
CNA Analyzer of Malvern Panalytical

- Uses neutron having high penetration capacity.
- Direct elements measuring potential, without mineralogical data.
- Effective in analyzing non-homogenous material, due to high penetration capacity.
- Accuracy in measuring material with high moisture content.
- Easy installation and maintenance.

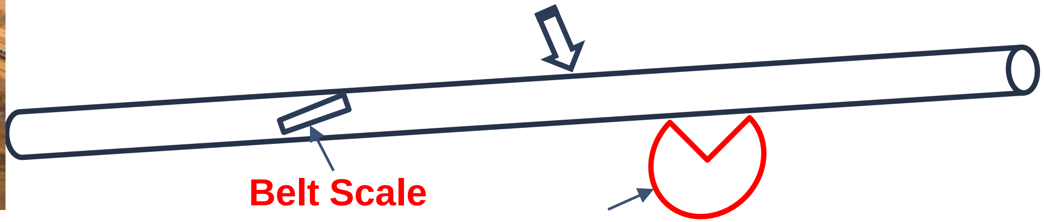
NIR and LIBS Technology

- Both are Surface Technique penetrating few micron, missing internal composition.
- Focuses on mineral phases, not on elemental composition led to low accuracy.
- Due to surface technique cannot handle non- homogenous material.
- NIR require regular cleaning of halogen light source.
- LIBS needs periodic calibration, due to laser induced technology.

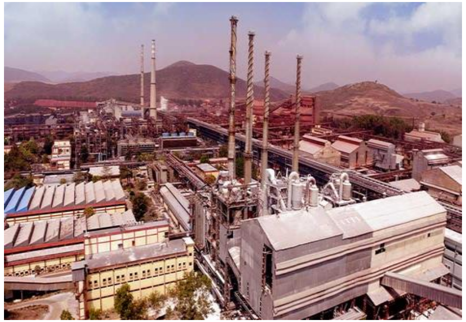
Bauxite Online Analyser for Alumina Plant



Plant
Stock Pile
-100mm



Stacker Reclaimer



Ion Composition of the Industrial NaOH – Na-aluminate Solutions

The industrial NaOH - sodium aluminate solutions consist of

Na^+, OH^-, $[Al(OH)_4]^-$, $[SiO_2(OH)_2]^{2-}$ CO_3^{2-}, Cl^-, SO_4^{2-}, $(C_2O_4)^{2-}$, $(C_5O_7)^{2-}$, etc. ions in various concentrations.

The conductivity measures the total consentration of ions, therefore it is not specific for any ions. However, the concentration of most of the ions in the liquid phase of the digestion effluent does not alter rapidly, whilst formation of aluminate anions ($[Al(OH)_4]^-$) at the expense of hydroxide ions (OH^-) by the dissolution of gibbsite causes rapid changes in the OH^- concentration and can be monitored by a conductivity sensor if properly selected and applied.

Formation of aluminate anion

$$Al(OH)_3 + \color{red}{OH^-} \rightleftharpoons [Al(OH)_4]^-$$

Types of Conductivity Measurements

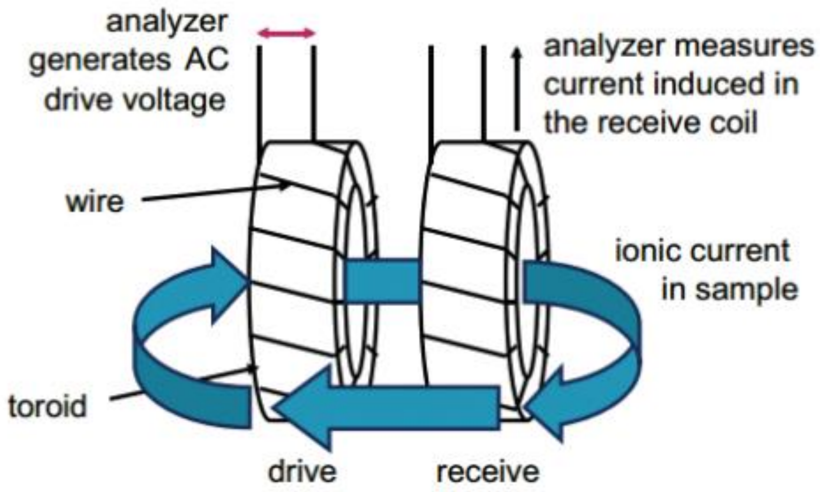
1. Contacting conductivity

Contacting measurements are restricted to applications where the conductvity is fairly low, the sample is non-corrosive and free of suspended solids.

2. Inductive Conductivity

Inductive conductivity sometimes called toroidal or electrodeless conductivity. An inductive sensor consists of two wire-wound metal toroids encased in a corrosion resistant plastic body. One toroid is the drive coil, the other is the receiver coil. The sensor is immersed in the conductive liquid. The analyzer applies an alternating voltage to the drive coil, which induces a voltage in the liquid surrounding the coil. The voltage causes an ionic current to proportional to the conductance of the liquid. The ionic current induces an electronic current in the receiving coil, which is measured by the analyzer. The indiced current is directly proportional to the conductance of the solution. The toroids do not need to touch the sample. They can be encased in plastic, allowing the sensors to be used in solutions that would corrode metal electrode sensors. Inductive sensors tolerate high levels of suspended solids. These sensors are ideal for solutions of high conductivity.

Schematics of an Inductive or Toroidal or Electrodeless Conductivity Sensor

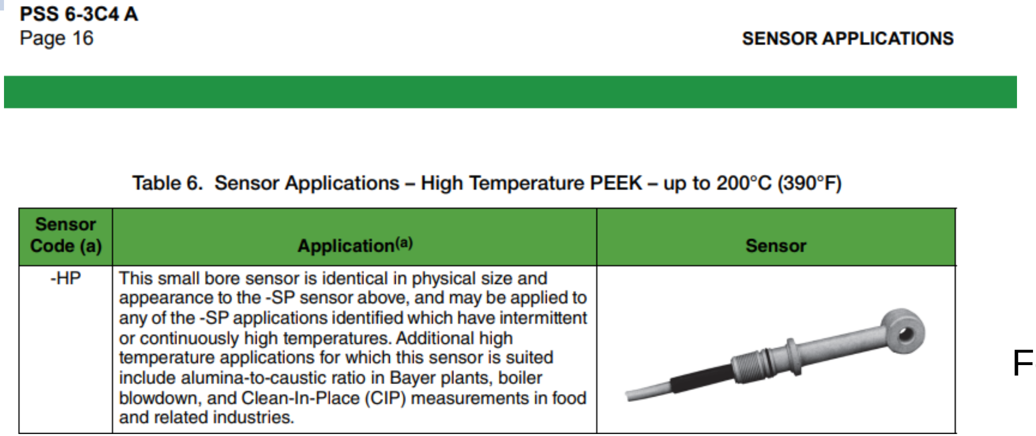


Both coils are encased in a single sensor body and overmolded with plastic. The coils must be completely submerged in the process liquid.

Improved Conductvtivity Analysis
in Desalination Processes
Rosemount Analytical

Two types of toroidal Conductivity sensors are in the market

Rosemount 228 Toroidal Conductivity Sensor



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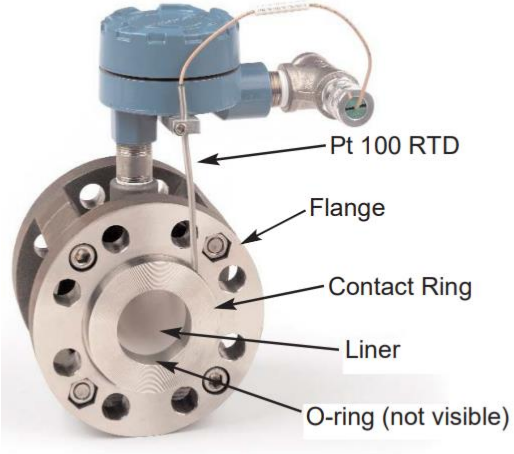
SENSOR APPLICATIONS

Table 6. Sensor Applications – High Temperature PEEK – up to 200°C (390°F)

Sensor Code (a)	Application(a)	Sensor
-HP	This small bore sensor is identical in physical size and appearance to the -SP sensor above, and may be applied to any of the -SP applications identified which have intermittent or continuously high temperatures. Additional high temperature applications for which this sensor is suited include alumina-to-caustic ratio in Bayer plants, boiler blowdown, and Clean-In-Place (CIP) measurements in food and related industries.	

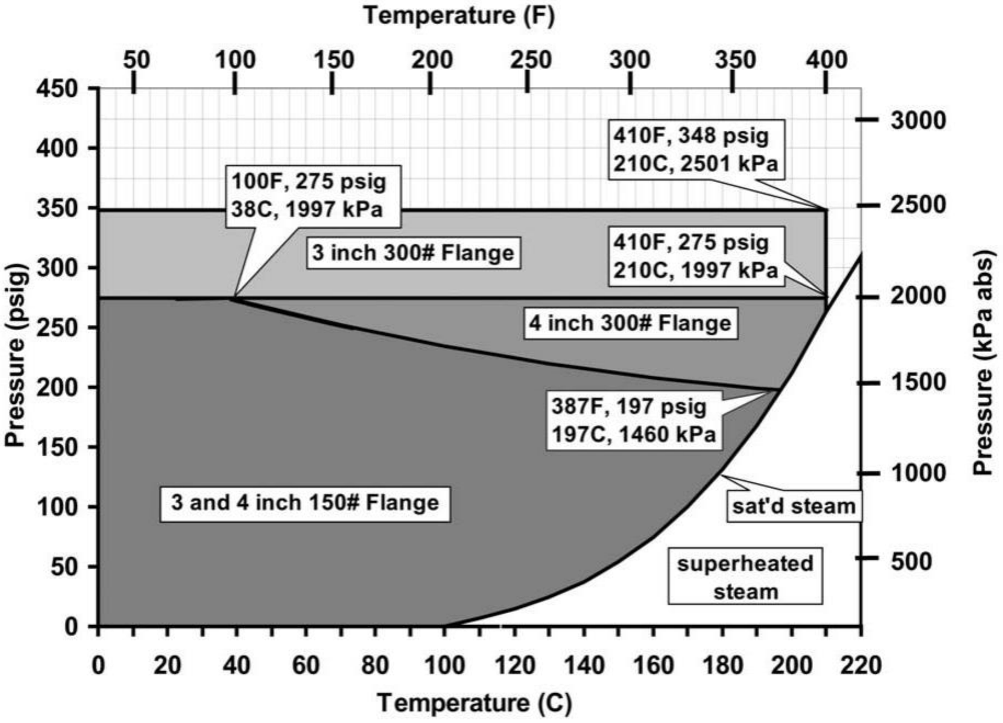
Foxboro



Rosemount Model 242 Flow Through Toroidal Conductivity Sensor

Liners are available in Teflon, glass-filled Polyetheretherketone (PEEK), and alumina. These materials provide excellent chemical resistance. PEEK is recommended for high pressure or high temperature applications. Teflon is recommended when the process solution contains hydrofluoric acid or other strong oxidizing agents. Alumina is recommended if the process solution is abrasive, such as in alumina/caustic ratio applications.

Pressure – Temperature Specifications for 3” and 4” Sensors, Rosemount Model 242



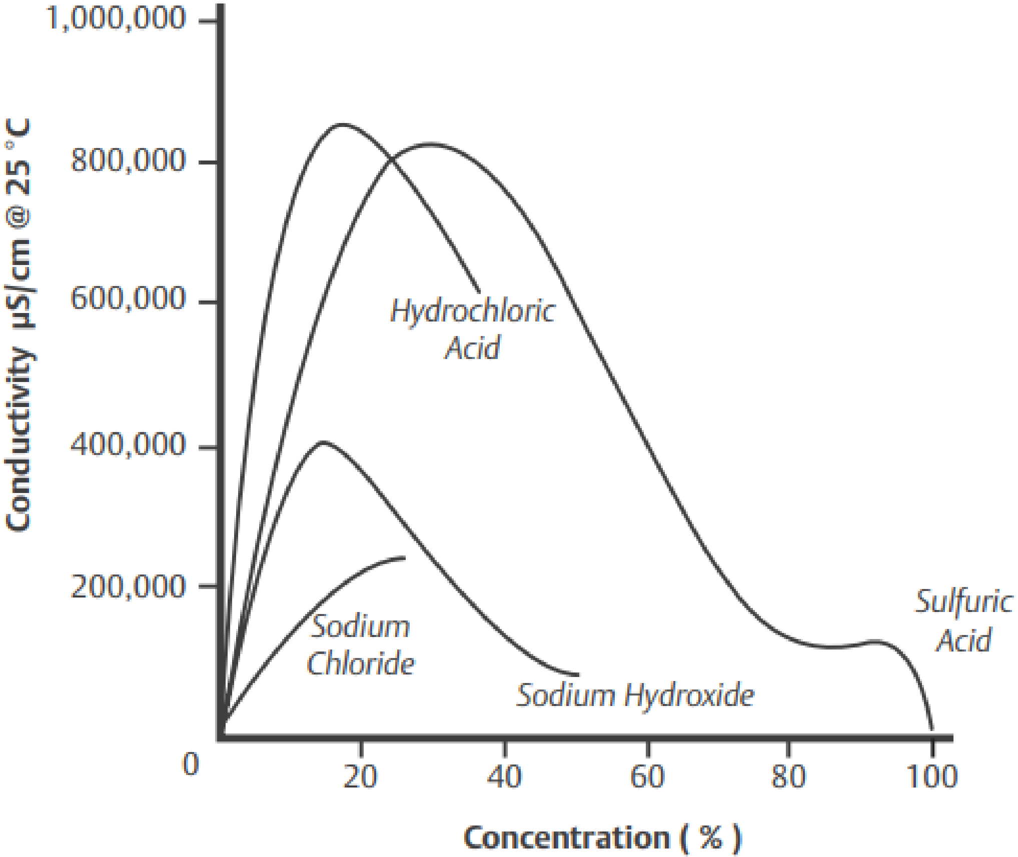
Pressure - Temperature Specifications for 3” and 4” Sensors: Alumina Liner

Free caustic concentration (equivalent NaOH), wt%.

Blow-off slurry of an Alumina Refinery C 285 g/L as Na_2CO_3, A/C 0.757

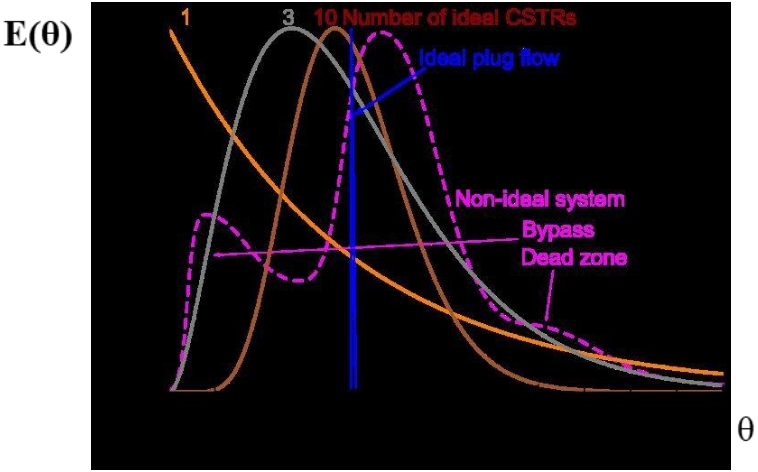
Free caustic concentration as equivalent NaOH: 3.300%

Conductivity of Some Common Solutions

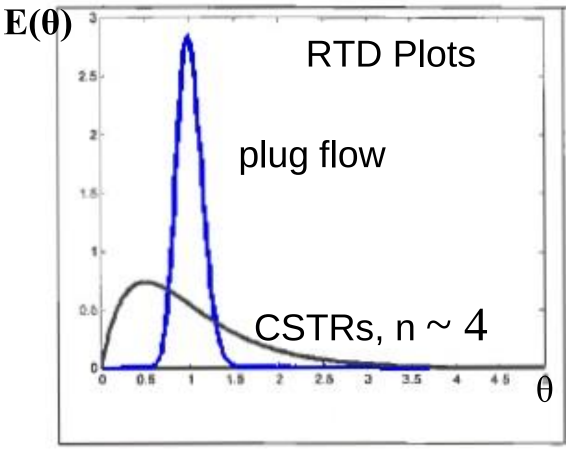


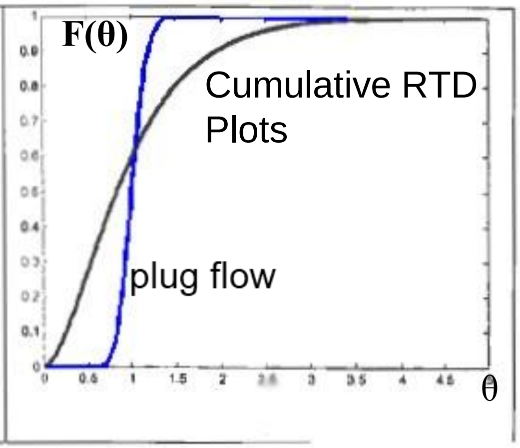
Conductivity Measurement in Chemical Concentration Control, Application Note, Emerson - Rosemount

Residence Time Distribution Curves for CSTRs and Tube Reactor



Residence Time Distribution Plots of Continously Stirred Tank Reactors (CSTRs), ideal case and plug flow





Benefits and Drawbacks of Feed-forward and Feedback A/C Ratio Control

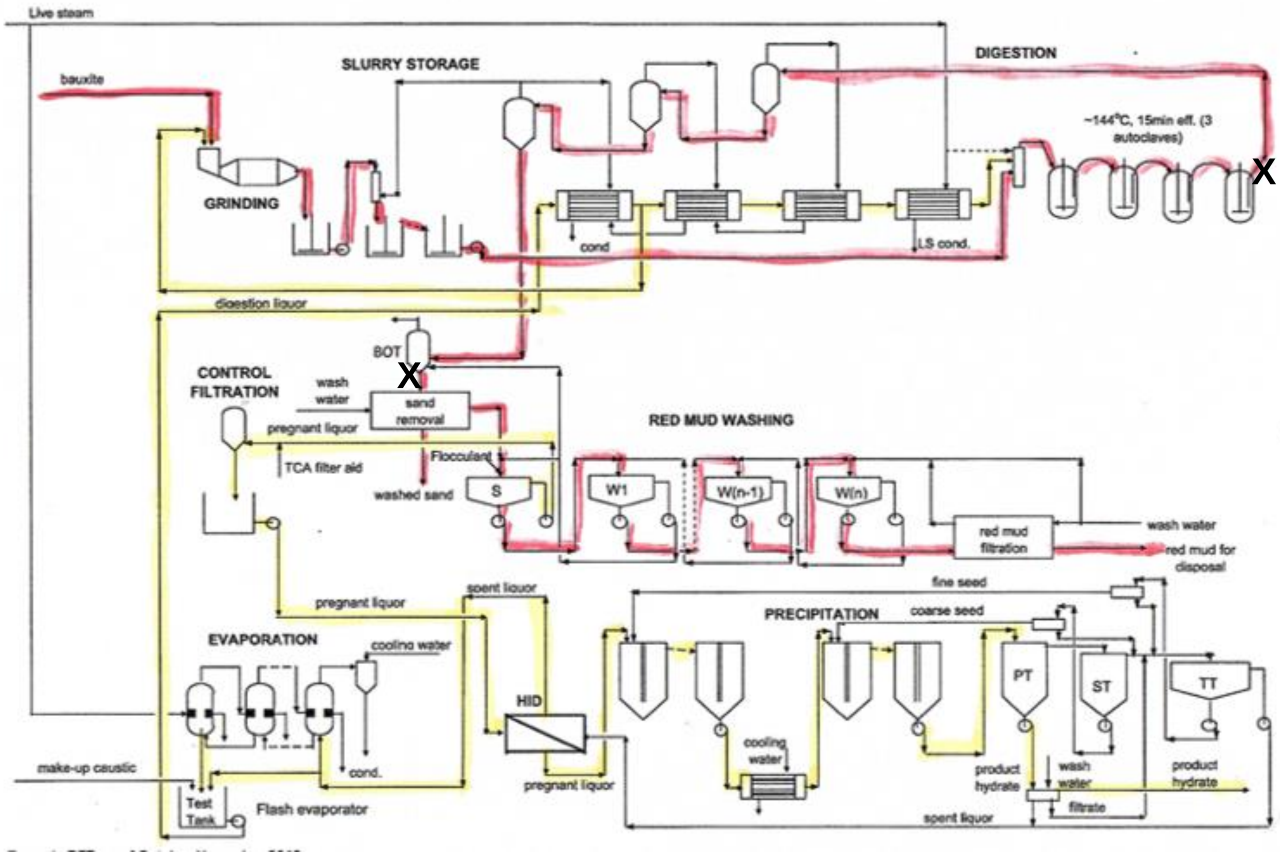
The fundamental process control strategies are the feed-forward and the feed-back controls.

The feed-forward control is associated with difficulties with the measurement of the precise mineralogical composition of the solids and concentrations of the liquid phases, also with the solid content of the dense slurry.

In case of the feedback control, ideally the A/C ratio of the liquid phase exiting the digestion reactor should be measured and controlled. There are refineries where the A/C ratio of the digester effluent is measured by a conductivity sensor. However, in most of the refineries the A/C ratio of the blow-off slurry is measured since its lower temperature and pressure that is close to the atmospheric boiling point and it is more convenient to operate. On the other hand the blow-off slurry is subject to more disturbances. The optional locations of a conductivity sensor are indicated on the Flowsheet.

The feed-forward and the feed-back controls can be combined; generally this combination provide the most accurate control.

Typical LT Digestion, Conceptual Process Flow Diagram



Legend

Red line: bauxite, bauxite slurry, bauxite residue slurry

Yellow line: pregnant liquor, spent liquor, digestion iquor

X optional location of the conductvity sensor

Where should the Setup Point (Target A/C Ratio) be?

In the conventional process control design several alumina refineries have used a safety margin of 0.05 A/C ratio (with other words, 50 points of safety margin). The safety margin is defined as the difference between the target A/C ratio (setup point) and the equilibrium A/C ratio.

Several alumina refineries use the formula of the landmark paper of Rosenberg and Healey (R&H) for the calculation of the equilibrium solubility of gibbsite.

It is deemed that the A/C ratio points follow the normal distribution around the average. Looking at the curve of the normal distribution where the standard deviation is indicated it can be seen that 99.7% of the points is within a range of ± 3σ (where σ is the symbol of the standard deviation), meanwhile 99.98% of the points is in the range of ± 4 σ. It is believed 3σ or 4σ from the true equilibrium solubility of gibbsite should provide sufficient safety margin. The safety margin might be about 0.015 from the equilibrium in case of a precise A/C ratio control.

The Equilibrium A/C Ratios vs Temperature and Process Parameters of a Refinery

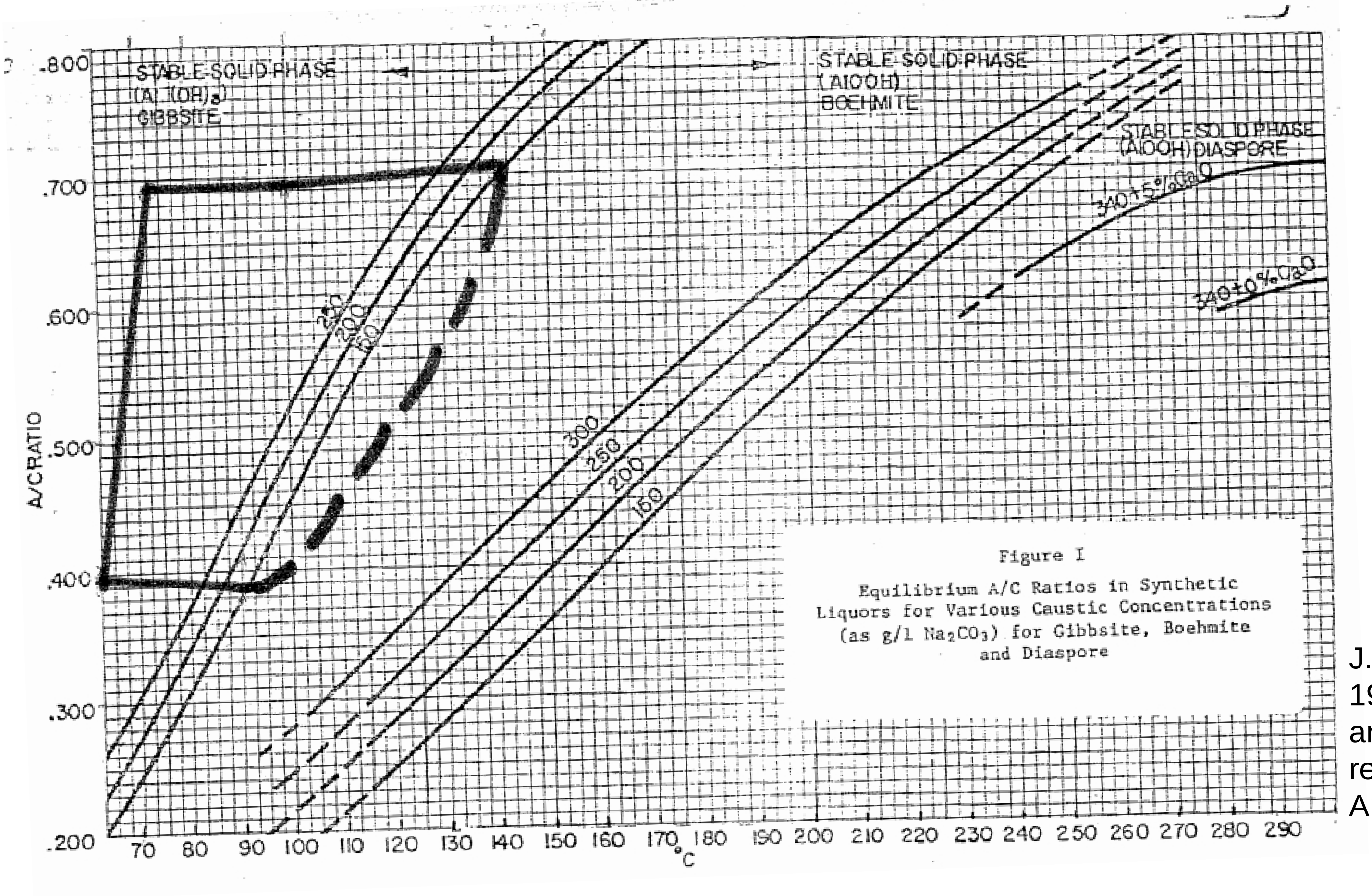
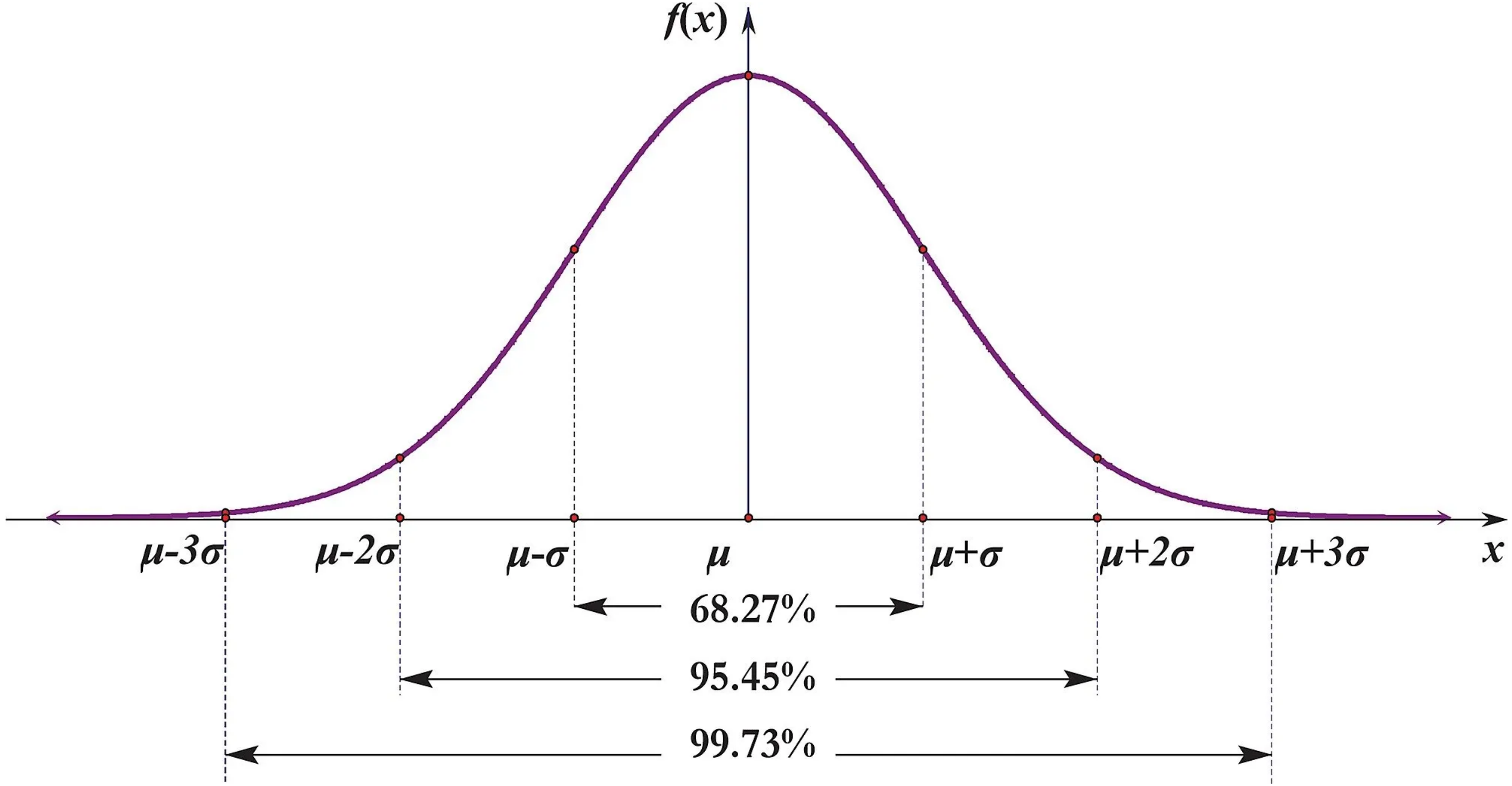


Figure I

Equilibrium A/C Ratios in Synthetic Liquors for Various Caustic Concentrations (as g/l Na_2CO_3) for Gibbsite, Boehmite and Diaspore

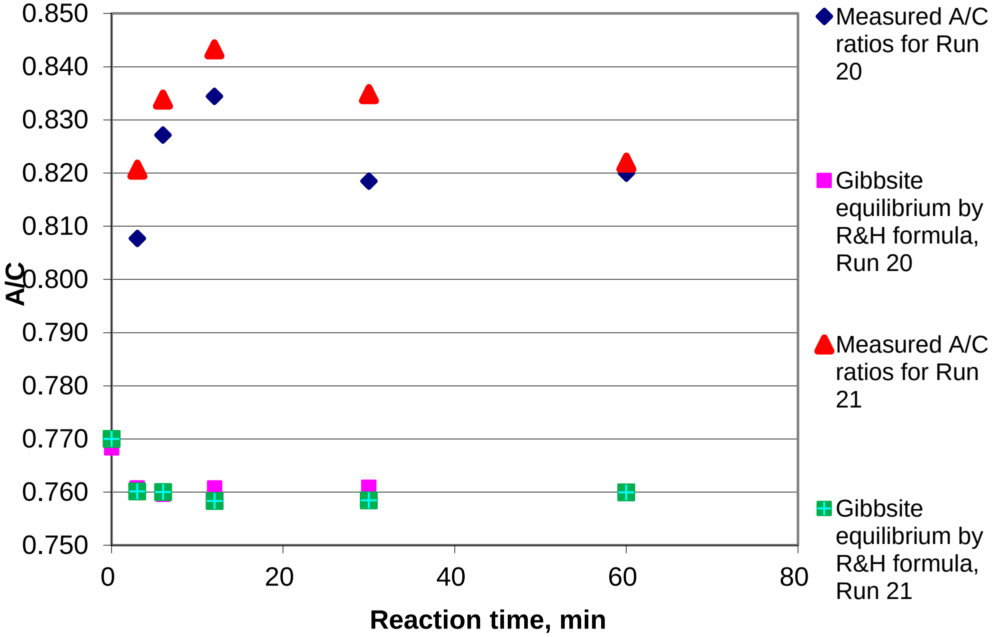
J. Kotte, Light Metals 1981, 45-81
and the A/C ratios of a refinery in Latin America

Probablity of Observations Within the Range of Standard Deviations



Measured by Repeated Kinetic Test and the Calculated A/C Ratios

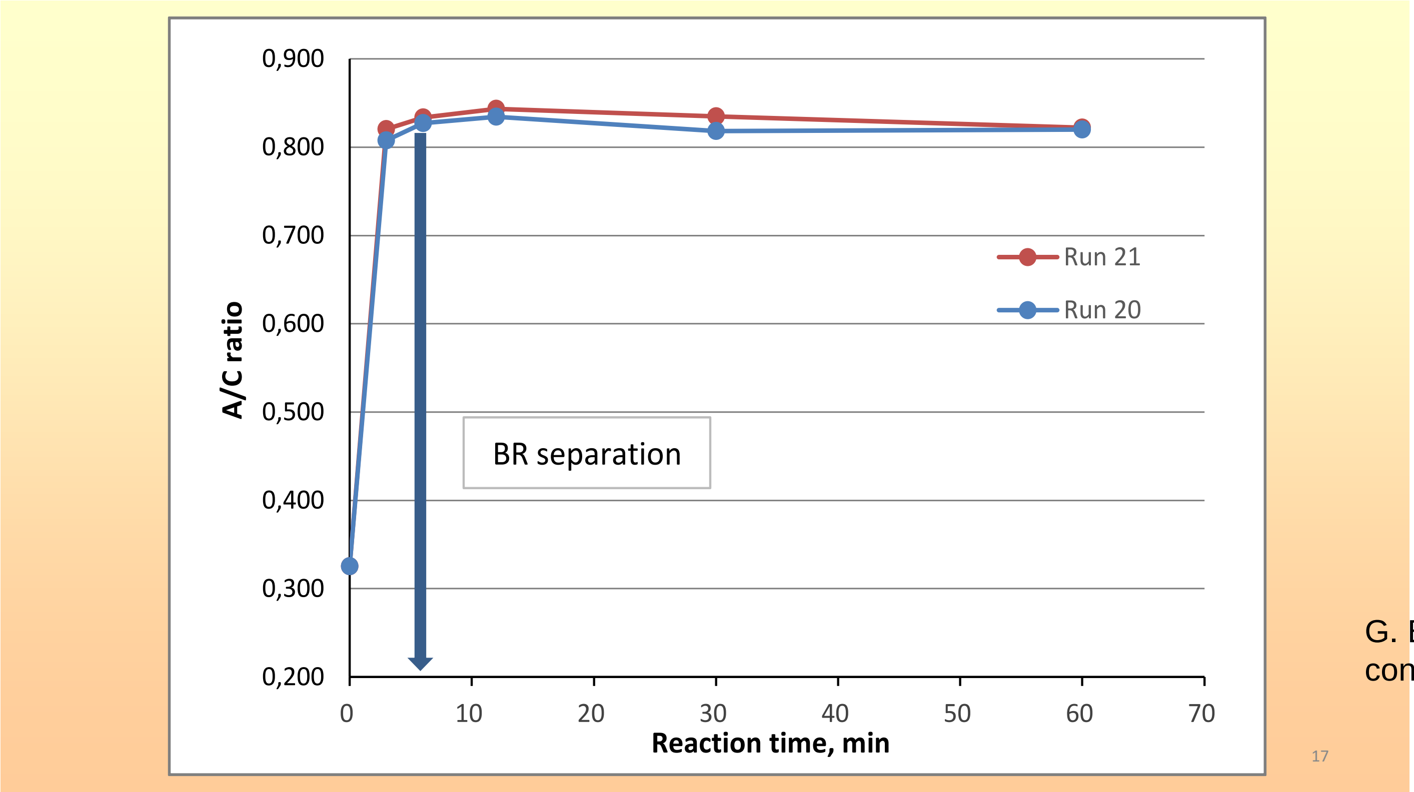
Kinetic studies of digestion of a gibbsitic bauxite at 150°C showed that the actually achieved A/C ratios is higher by about 8-10% than it is suggested by the Rosenberg and Healey (R&H) formula. A comparison of the observed A/C ratios with the calculated equilibrium by the R&H formula is shown here.



G. Bánvölgyi, Alumina 2024 conference, #45 paper

A/C Ratio vs Reaction Time for a LT Digestion

The measured A/C ratios of a kinetic test. The dissolution of gibbsite is completed in about 6 minutes.



G. Bánvölgyi, Alumina 2024 conference, #45 paper

Summary of the A/C Control and a Tentative Analysis of the Benefit

As per the Authors view, the most advanced A/C ratio control is based on a conductivity meter that is placed for the effluent of the digester reactor, let it be a tank reactor cascade or a tube reactor. The conductivity meter should preferably be calibrated to the A/C ratio. Two conductivity meters are preferred for a digestion train.

The flowrate of the predesilicated slurry should be adjusted by the controller so that the A/C ratio be kept constant.

A tentative calculation has been arrived at about USD 3-5 / ton of alumina product for the benefits of an up-to-date A/C ratio control. A moderate estimation of 1% increase in the digestion extraction efficiency and an estimated saving of 5% in the process steam consumption due to the higher setup (average) A/C ratio have been calulated with. For a given refinery a targeted process audit should be carried out for a better estimate. In case of a 1.5 MTPA refinery the annual savings is estimated to be USD 4.5-7.5 million. The costs and benefits are to be elaborated as next stage.

Closing slide

Thank you for your attention.

The Authors are looking forward to your questions or comments.