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FOREWORD

Greetings from the ICSOBA Secretariat. We have great pleasure in bringing out the second issue of the ICSOBA News Letter. Since the last time we were in touch with you, we have made considerable progress in our activities pertaining to enrolment of Corporate members, discussing and in many cases finalizing the details of the next ICSOBA Meet in Zhengzhou China in association with CHALCO R & Center. Dr. Ashok Nandi , the Executive Secretary spent sometime in China in October 2009 to make the necessary arrangements. A report on his visit is included in the present issue of the News Letter. Mr. Roelof Den Hond, one of our Vice Presidents, has finalized the programme for the Special Session on Future of Alumina Production; the details are given in this issue. We are also trying to get a special session organized on Red Mud; cooperation of our members and readers is earnestly requested for contribution of technical papers. We have contacted a number of organizations for technical presentations in the areas of aluminium smelting and down stream areas. Here again your support and help will be warmly welcomed. The next issue of the News Letter is due in June 2010 where we will include the abstracts of all the papers scheduled for presentation in the Zhengzhou Meet.

There are two technical presentations in this issue; one dealing with red mud and the other with the LARS melt treatment system for quality control of the metal. We would like to include at least one article in future issues, dealing with equipment used in various areas of bauxite / alumina/ aluminium industry, their technical specifications, operating parameters and feedback from the users. We welcome contributions from our readers and members in this regard.

We would like to reemphasize what we have stated in the foreword to the last issue; to sustain our activities, we need to enroll as many members as possible; application form for membership can be found in the ICSOBA website, www.icsoba.org. We need technical contributions as well as information on various mines and plants. We warmly welcome suggestions on how to improve the contents of the News Letter.

Wishing you all a very happy and prosperous 2010.

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The Almex LARS™ HF Series Degassing and Metal Purification System

a Novel Approach to Vessel Design

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Keywords: Degassing, Tilting, Heat Free, Refining.

The requirement from batch type billet casthouses for a low cost, flexible, and user friendly degassing unit has prompted the development of the Almex LARS™ HF Series Degassing System. Frequent alloy changes and minimal set-up times have forced billet producers to demand a system which will keep pace with required production cycles. The HF Series of degassing units was developed to meet this demand and has been designed from the floor up to provide the optimum combination of performance and operating simplicity.

These criteria demanded a fresh review of molten aluminum reaction vessel design and have prompted a unique and revolutionary approach to vessel construction. This paper describes the characteristics and demands placed on the design of these systems and the engineering, materials and construction solutions implemented to meet these requirements.

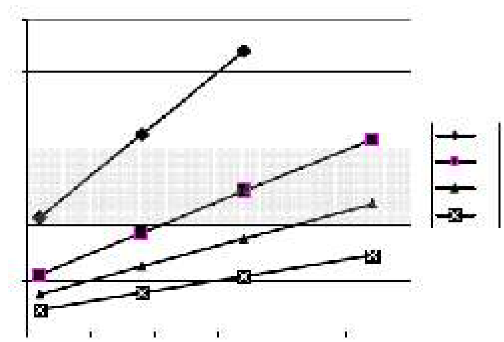

Figure 1 Linear relationship of degassing process time and reactor volume for various metal flow rates.

Introduction : Conventional Degassing System Design

Conventional degassing systems, including the Almex LARS™ RL series degassing system, are configured with stationary reaction vessels with a total molten metal holding volume specific to the molten aluminum flow rate during casting. As flow rate increases, the metal holding volume must also increase to permit sufficient residence time of the metal in the chamber to fully react with the process gas used to achieve optimum hydrogen desorbance. A typical rule of thumb is to maintain a 4 to 7 minute residence time of metal in the reaction chamber(s) for optimum hydrogen removal. (see Figure 1) The metal in the reaction chamber is held between casting drops, requiring a heating system to maintain a temperature suitable for subsequent drops. As an example, the LARS™ RL series degassing system can add heat to the metal both prior to a cast and during a cast in order to optimize casthouse efficiency and process optimization. Between drops, the system must also maintain a flow of inert gas to prevent failure of the graphite components used in the process gas disperser units and flow of cover gas to prevent reabsorption of hydrogen into the aluminum and to minimize oxidation of the graphite components. (See Figure 2)

Figure 2 Stationary type molten aluminum degassing system. LARS™ RL Series

The resulting system construction inhibits the ability to have an automated, end-of-cast emptying of metal into the path of metal being cast. Instead the systems are stationary units with drain ports at the base of the unit which allow draining of the molten aluminum into pre-positioned sow molds. This system draining is generally limited to extended casthouse maintenance shutdowns or when alloy changes are made. These stationary systems when correctly selected, sized, operated and maintained provide effective degassing and purification of molten aluminum and are the most efficient system configurations for locations which have planned and extended production runs using similar alloys. The Case for Draining Conventional degassing system configurations are not ideally suited to batch type operations where production demands require frequent alloy changes. In these instances, the critical demand for holding the metal between drops is replaced by the need to empty the reaction vessel of aluminum at the end of each drop. This brings about a whole new set of unique characteristics required by the system. ***(See Figure 3)***

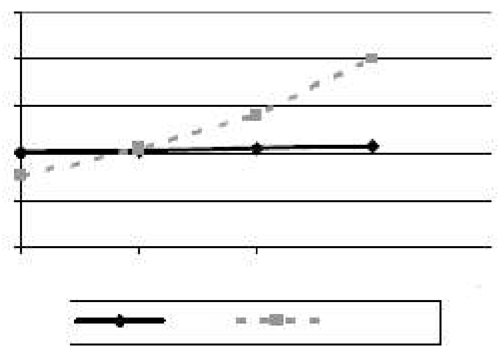

Figure 3 Tilting degassing systems offer lower operating costs when frequent alloy change drains are required. Data shown for demonstration only.

Figure 4 Almex LARS™ HF degassing system in end of cast tilting mode.

Because of frequent draining required for many systems, a need was identified for draining the volume of metal from the reaction vessel to complete a cast. To achieve this a new system was developed that tilts in the direction of the metal transfer launders and pivots to an angle to allow complete emptying of the reaction vessel. At the end of the drop, the metal flows from the degassing system into the downstream trough providing molten metal to the casting system. ***(See Figure 4)***

The exact requirements of this new configuration were identified and a new system was configured from the ground up, specifically designed to meet the demands of this mode of operation. The key requirements for the operation of the system and Almex' solution in the development of the LARS™ HF Series of degassing units is explained below.

Process and Equipment Description Draining Method

The reaction vessel is pivot mounted on a heavy duty structural steel framework which is foundation mounted to the casthouse floor. The frame is designed so that the center of gravity of the assembly remains within the limits of the frame throughout the tilting range of the reaction vessel. This ensures total stability of the structure at all times. ***(See Figure 5)***

To ensure integrity of the metal transfer system, the pivot point of the reaction vessel is in line with the metal entry and exit ports in the reaction vessel. Use of a flexible launder section permits simple connection to the remainder of the metal transfer system. The flexible joint provides excellent integrity against leaking and at the end of its usable life can be replaced in less than a five minute operation. An automatic leak detection alarm is also provided to warn the operator of any discontinuity of the flexible joint which has affected the integrity of the seal.

Operating Modes

Throughout start-up and the steady state operation of a cast the reaction vessel remains in the declined position and the operation is typical of a conventional, non-tilting system. At the end of a cast when the metal flow from furnace is stopped, the degassing system is automatically gradually tilted to maintain the desired metal level in the runner. The normal operating mode is fully automatic for all flow rates where the tilting operation is conducted via closed loop PLC control, yet it can be controlled accurately in a manual mode via a position sensitive joystick. Prior to start-up, the reaction vessel is preheated via roof mounted electrical heating elements. These heaters are provided to remove entrapped moisture in the refractory lining and to limit the thermal shock on the refractory components when molten aluminum is introduced. Typical atmospheric temperatures achieved within the reaction vessel when in the preheating regime are between 430 to 540ºC. During the period between casts, a continual supply of nitrogen cover gas is provided to the reaction vessel to prevent oxidization of the graphite gas dispersion components and to provide a positive pressure to ensure air and moisture is prevented from entering the system. This nitrogen is introduced through the heater housings. Thereby the electrical junctions and heater terminals are also maintained in the inert atmosphere. The steady state stage of the casting process is conducted with attention to scheduled skimming practices and checks on casting and degassing operating parameters. As the cast reaches its conclusion, a number of automatic triggers can be used to initiate the end of cast sequence. These triggers can be in the form of any of the following:

A time signal or cast length signal identifying a preset cast length has been reached

- A non-contact or contact launder level sensor identifies that a preset drop in metal level has been reached
- For tilting furnaces, an inclinometer signal can identify a tilt angle setpoint has been reached.

In all instances, applicable logic is provided to prevent against actions being taken as a result of false or abnormal process generated field signals. The configuration of the reaction vessel permits flow of metal during LARS tilting either upstream and back into the furnace or downstream to the casting system. This flexibility accommodates any process, maintenance, or emergency metal flow direction to be achieved. Once the desired metal flow direction is selected, simple dam placement achieves the desired flow path. Upon either manual or automatic energizing of the tilt mode, the system can either react to a preset launder metal level or use the actual metal level for the setpoint. The angle of tilt of the degassing system is then controlled by a PID control loop. The preset setpoint is achieved and maintained through tuned PID loops which send the necessary demand signals to the motor drives. Tilting continues until the metal in the reaction vessel is completely emptied and the unit reaches a preset tilt angle where it is held. To assure process safety, manual intervention by the operator is required to allow the system to tilt back at a controlled rate. At this time the process gas disperser drives have stopped and the process gas supply switches to a low idle level to assist in the cooling of the graphite components and in the prevention of clogging of the gas flow path near disperser. Once the degassing unit has returned to the home (non-tilted) position, the metal transfer system is cleaned and the standard plant preparation practices are implemented to ready for the next cast. During the casting process, the heater setpoints are unchanged and, as the metal temperature exceeds the setpoint temperature, the heaters do not draw any energy. However, following a cast, the heaters automatically energize once the system cools to the setpoint and to maintain temperature in the system in preparation for the subsequent cast. Reaction Vessel Configuration The reaction vessel is a refractory lined welded and reinforced steel chamber. The vessel geometry is configured to provide complete emptying of the vessel at maximum tilt angle of 37º. This arc of motion provides inherent stability of the system throughout the range of motion and also a sufficiently large movement range to enable precise control of the metal level during the tilting operation. The internal configuration of the vessel is such that it creates three separate chambers for the metal to pass through.Metal Path

The main objective of designing a “special metal path” as fully described below is to prevent any “carryover” of gas bubbles and to maintain clear separation between untreated metal and purified metal. The first chamber receives the initial fill of metal from the furnace and has a single gas dispersion assembly located in it and so acts as the initial reaction chamber. Although centrally located in the chamber, generation of vortex in the reaction chamber is prevented as a result of the change in chamber volume from the front to the rear of the unit. The first and second chambers are separated by a baffle which extends from the floor of the reaction vessel to above the operating molten metal level line. Two metal transfer ports located at either end at floor level allow the passage of treated metal to pass from the first to the second chamber. During the degassing of the metal, the cleanest metal is resident in the lower region of the reaction chamber, so allowing transfer at this point permits only well treated and clean metal to pass from the initial reaction chamber. Once the metal enters the second chamber, it is again processed by a centrally located gas dispersion system. Residence time in this reaction chamber is similar to the first chamber so metal is fully treated in advance of entering the exit chamber. The baffle between the second chamber and final chamber is of similar configuration to the first baffle, but the transfer port is offset to prevent bypassing of metal from the first directly to the exit chamber and thus reducing the degassing effectiveness of the system. The final chamber is provided purely for supply of fully processed metal to the casting system so no further metal treatment is carried out in this chamber. During casting, dross accumulation in the reaction chambers is removed by horizontal skimming via two chamber width skimming doors. During operation, dross is skimmed into bins located on platforms at the rear of the reaction vessel for simple handling prior to the end of the cast. End of cast When the end of cast tilting operation is initiated, the metal flow passes through the un-dammed port either to complete the cast or return the metal to the furnace. As the tilt angle increases, the configuration of the ports in the baffles within the reaction vessel allow metal to pass through. This unrestricted metal flow between the reaction chambers assures that the reaction vessel is completely devoid of metal close to reaching maximum tilt angle. Equipment Heating The roof of the reaction vessel houses the electric heating elements and provides the interface for the gas dispersion assembly. The roof is sealed against the reaction vessel using refractory blanket. The two assemblies are bolted together to form an integral unit. The welded steel roof is refractory lined on the inside and facility for installation and replacement of all process components is provided from the outer face. ***(See Figure 7)***

Figure 7 Reactor chamber of degassing system viewed with skim door open.

There are two sets of heating elements mounted in the roof to provide heat to both of the reaction chambers. The heating elements are preassembled in a refractory lined steel housing which bolts to the roof of the reaction vessel for simple replacement and maintenance. Nitrogen cover gas is introduced through the heater housing to provide an inert cover gas in the reaction vessel and also provide a continued shielding to the coil type heating elements. A control thermocouple is positioned in each of the heater housings for control and monitoring of the heating elements. A third bath thermocouple can be installed for accurate measurement of metal temperature within the vessel. Refractory Selection Key to the successful operation of the LARS™ HF series is the selection and configuration of the refractory liner within the reaction vessel. The reaction vessel is a modular construction consisting of carefully selected refractories to obtain the optimum combination of wear resistance, thermal insulating properties, strength and thermal shock resistance. The reaction vessel is comprised of a three chamber design. The first chamber is constructed of two refractory materials. The entry port and floor of the chamber and intermediate baffle are constructed from high wear resistant refractory with high thermal shock resistance. These properties are critical as these are the faces exposed to high metal flow rates, especially at the start of each cast during the initial fill. The remainder of the chamber is constructed using a cast refractory with excellent thermal resistance properties. This forms the main portion of the chamber and is selected primarily to minimize heat loss during first fill and in steady state operation. Process Gas Dispersion The gas dispersion assemblies are flange mounted to manifolds located on the lid of the reaction vessel and remain in place throughout the entire operating cycle.

This ensures the graphite parts of the assemblies are maintained in oxygen free environment at all times preventing oxidation of the parts at elevated temperatures. Maintaining the sealing integrity of the vessel also prevents oxygen and moisture from entering the vessel between drops and minimizes the idle cover gas consumption by limiting the evacuation of the gas from the vessel when empty. (See Figure 8) Figure The metal parts of the gas dispersion assembly contain bearings and seals which must be maintained at a controlled temperature. Insulation is provided between the molten metal face of the assembly and the metal parts to limit heat transfer. A dedicated air blower provides continuous flow of cooling air through internal passageways within the assembly. To enable full utilization of the system during the tilting operation, all gas utilities are connected to the vessel by braided steel hose and electrical connections run through protected flexible conduit. Gas Dispersion Assembly As a result of the specific operating characteristics of the LARS™ HF series of degassing units, it was necessary to develop a completely new gas dispersion assembly for this application. The patented configuration used in the LARS™ RL series of degassing systems provides in situ preheating of the process gas prior to release into the molten metal. This combined with optimum gas bubble shearing provides an excellent gas bubble size, bubble residence time and associated molten metal purification. However, following evaluation, it became clear that, although this configuration is ideally suited to the operation requirements of the LARS™ RL series, it would introduce limitations in operation and expected life of the graphite parts if utilized in the LARS™ HF system.

Figure 8 Process gas dispersers shown on two rotor tilting degassing system. LARS™ HF Series.

The key limitations identified during this evaluation were:

- Potential for molten metal freezing between the stationary and rotating parts of the assembly, leading to risk of premature failure of the graphite parts.
- Elevated risk of solid inclusions becoming lodged between the stationary and rotating parts during the tilting operation, again leading to premature failure of the graphite parts.
- Overall height of the drive motors and metal parts of the assembly producing high bending load on the mounting flange and fastening system during the tilting operation.
- Potential impact on the integrity of the close dimensional tolerances in the graphite parts during the tilting operation which would have detrimental effects on the system performance. Hence an entirely new gas delivery and dispersion mechanism was designed which still provides for in-situ heating of the process gas yet avoids the use of rotating graphite parts moving in close tolerance with stationary graphite parts.
- The design uses multiple internal channels machined inside the graphite shaft which increases the flow path and residence time of process gas inside the graphite shaft by as much as 10 times. This allows in-line preheating of the gas to near molten metal temperature through heat transfer from the metal via the graphite shaft.
- A more compact drive assembly was also created by selection of compact gear motors and redesigning the gas passages through the metal parts of the assembly. This reconfiguration greatly reduced the loading characteristics on the mounting flange and maintained the simplicity of design associated with the original LARS system. Automated Process Control The automation platform for the LARS™ HF series degassing unit provides total control, monitoring, diagnostic and alarm indication for the system. Both the reaction vessel tilt actuation and the gas dispersion assembly are controlled by independent variable frequency drives. The tilt control operates by precise speed control with high resolution motor encoders providing the exact feedback of the motor speed.

A PLC platform provides the interface to the drives and executes the necessary signal processing for total system control and monitoring. Human interface is via a control panel and touch screen monitor. Intuitive icon driven screens provide the operator with all of the necessary information for safe and repeatable control of the system. Additional functionality including process trending, audible and visual alarm status, diagnostics and password protected tuning screen are incorporated to provide fault finding and process control data. ***(See Figures 9 and 10)***

Key benefits of the design include:

• Synchronization of actuators through Variable Frequency Drive (VFD) control which provides excellent control accuracy & reliability.

• Compact design as actuators are located within the bounds of the equipment, so additional foundation work is not required.

A separate hydraulic power unit is not required and hydraulic piping is avoided. Furthermore, oil actuated components are avoided in an area of high temperature and molten aluminum presence.

Performance

The first LARS™ HF series degassing system entered operation during the last quarter of 2006 for the production of DC cast billet in the 6000 series. Furnace charge comprises primarily clean, heavy scrap with casting rates up to 460 Kg per minute. To achieve optimum hydrogen removal, a metal residence time in the reaction chamber of 6.5 minutes was achieved by designing the vessel with a 3000 Kg metal holding capacity. The system shows the degassing efficiency consistently in excess of 64% in absence of chlorine and inclusion removal to the extent of guaranteeing no head level difference across the filter box with 40 PPI CFF. The treatment gas used is Argon and rotor speed of 420 rpm (225 mm dia rotor) is selected as optimal for reactor depth of 1.1 meters. Temperature losses have been recorded over two flow rates and are tabulated below. ***(See Table 1)***

30 MT/Hr Flow Rate	2° C drop across inlet & outlet
18 MT/Hr Flow Rate	5° C drop across inlet & outlet

Table 1 Temperature change from entry to exit of LARS™ HF

Metal level control during the tilting of the reaction vessel at the end of a cast is extremely repeatable and the level control accurately maintains the metal level in the trough to within ±3 mm during the ending cycle of the drop. Conclusions The new generation of LARS™ degassing system, the HF series, was developed from the ground up to provide a degassing system specifically designed for the demands of multiple alloy and batch type casthouses. By starting with a fresh sheet of paper and utilizing the process advantages of the existing Almex technologies, a truly “built for the application” solution has been created providing:

I. Complete in-line draining at the end of each cast.

ii. No need to raise gas dispersers when tilting & draining.

iii. No heat input necessary during casting, minimal power consumption in between the casts.

iv. Complete freedom to change alloy on cast to cast basis.

v. Isolated metal path for purified metal

vi. 64% Degassing efficiency References

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De-watering, disposal and utilization of red mud: state of the art and emerging technologies

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Abstract

Bauxite residue, commonly called red mud after its color, is the main by-product of making alumina by the Bayer process. The amount, chemical composition and physical characteristics of red mud vary depending on the quality of the bauxite feedstock and the processing conditions. Single-chamber decanter type washers, high rate deep cone washers, rotary vacuum filters comprise the last stage of the counter-current washing system in the Bayer process. Dewatering of red mud sometime takes places with pressure filters and it is easy to transport or to tip the cake. Traditionally red mud is disposed of in non-sealed and later in sealed ponds. Dry mud stacking, the most advanced disposal method, was introduced about 25 years ago. This is cost-effective and provides several environmental benefits as well. Extensive and successful research and development activities have been carried out aimed at the utilization of red mud. The large amount generated and chemically combined and soluble soda content pose problems for several uses.

The present paper reviews the state of the art of washing, transportation and storage of red mud, the related emerging technologies and the principal applications in use in pilot or commercial scale. While disposal requires special attention, red mud can now be disposed of in an environmentally sustainable way.

1. Introduction

Bauxite residue, commonly called red mud after its color, is the main by-product of making alumina by the Bayer process. The quantity and quality of red mud, the amount and the caustic content of the adherent liquor differ widely in various refineries. The amount of red mud (as dry matter) varies from 0.4 ton to 2 ton per ton of alumina product, depending first of all on the quality of the bauxite feedstock. Considerable progress has been made in the last 40 years in the washing, dewatering and disposal of red mud and in developing applications. Some of these aspects are reviewed in this presentation.

2. What is red mud?

Red mud or bauxite residue is the denomination of the residual material obtained from the dissolution of the hydrated alumina minerals of bauxite in the caustic Bayer liquor. Beside the essentially non-soluble constituents of bauxite such as iron and titania minerals, the red mud contains some un-digested soluble alumina minerals and other compounds such as sodium aluminium hydrosilicates formed in the course of processing. When the washed and possibly de-watered red mud leaves the alumina refinery for disposal, it is frequently called bauxite tailings.

Caustic-soluble hydrated alumina minerals in bauxite are gibbsite, boehmite and diaspore. Gibbsitic type bauxites are usually digested at temperatures of about 140-150oC (low temperature digestion). Boehmitic bauxites are digested at temperatures of 230-270oC, while diasporic bauxites are processed at 240-280oC. Lime used at different stages of the Bayer process ultimately becomes a constituent of the red mud.

Bauxite residue containing coarse particles (>106μm or >150μm), is called sand. The amount of sand ranges from < 1 % to as high as 50 % in different digestion residues; the normal value is about 5%.

In several cases the sand is separated before the clarification and is submitted to washing in a separate system. The sand may contain much of quartz, but not necessarily. There are ambiguities whether the term red mud (bauxite residue) is referred to the dry matter only or to the adherent liquor/moisture as well. The authors use the term red mud (bauxite residue) only for the dry matter.

2.1. Chemical composition of red mud

The chemical and mineralogical composition of bauxites varies greatly, so do the digestion and other process parameters. Consequently the chemical and mineralogical composition and also the physical characteristics of the red muds are different in various alumina refineries [1], ***see Tables 1 and 2.***

Table 1. Chemical composition of different digestion residues

	Weipa (Australia)	Trombetas (Brasil)	South Manchester (Jamaica)	Darling Range (Australia)	Iszka (Hungary)	Parnasse (Greece)
Digestion temperature	240°C	143°C	245 °C	143 °C	240 °C	260 °C
Components, %						
Al_2O_3	17.2	13.0	10.7	14.9	14.4	13.0
SiO_2	15.0	12.9	3.0	42.6	12.5	12.0
Fe_2O_3	36.0	52.1	61.9	28.0	38.0	41.0
TiO_2	12.0	4.2	8.1	2.0	5.5	6.2
L.O.I.	7.3	6.4	8.4	6.5	9.6	7.1
Na_2O	9.0	9.0	2.3	1.2	7.5	7.5
CaO	-	1.4	2.8	2.4	7.6	10.9
Others	3.5	1.0	2.8	2.4	4.9	2.3

The vast majority of soda is in chemically combined form (sodium-aluminiumhydrosolicates) and is a hurdle for several uses. The soluble soda content is directly coupled with the adherent liqour content and its caustic concentration.

2.2 Mineralogical composition of red mud

The following mineralogical constituents can be found in red muds: gibbsite, boehmite, diaspore, hematite, (alumo-)goethite, magnetite, maghemite, kaolinite, quartz, sodiumaluminium-hydrosilicates (sodalite, cancrinite, etc.), anatase, rutile, calcium carbonate, Ca(Mg,Al,Fe) titanates, calcium-alumo-silicates, etc. The last two are characteristic of the residues obtained from the high temperature digestion processes. Red muds may also contain some amounts of amorphous (non-crystalline) constituents.

2.3. Physical characteristics of red muds

Some important physical characteristics of red mud are density, 2.6-3.5t/m3, pH: 12-13.5 (sometimes up to 14), settling rate 0.014-35.9 cm/ks (the higher value relates most likely to sand) [2].

Typical particle size distribution of red mud (fine fraction) and of the coarse fraction of a bauxite residue [3] (sand) are shown in Fig. 1.

Table 2. Mineralogical composition of different digestion residues

Components, (%)	Weipa	Trombetas	South Manchester	Darling Range	Iszka	Parnasse
Gibbsite	33.0	-	33.0	5.6	-	-
Hematite	3.5	38.0	3.5	14.5	33.0	38.0
Goethite	18.0	19.0	10.0	14.5	6.0	1.0
SAHS	27.0	27.0	27.0	5.4	32.0	26.0
Illite	2.0	-	-	4.7	-	-
Boehmite	2.0	0.6	2.0	3.5	0.8	0.6
Diaspore	-	1.2	2.0	2.5	0.7	0.6
Ca-Al-silicate	-	-	-	1.7	12.5	10.0
$CaTiO_3$	-	1.5	-	-	7.0	10.5
Calcite	0.5	1.4	-	2.3	3.0	3.6
Quartz	6.0	2.2	0.5	37.1	-	-
Anatase	2.0	2.5	6.0	1.0	-	-
Rutile	6.0	0.8	2.0	-	-	-
Na-titanates	-	-	6.0	0.6	-	-
Magnetite	-	-	-	1.3	-	-
Chamosite	-	-	-	-	-	6.0
Ilmenite	-	-	-	1.0	-	-
Others	-	5.8	-	3.4	5.0	3.7

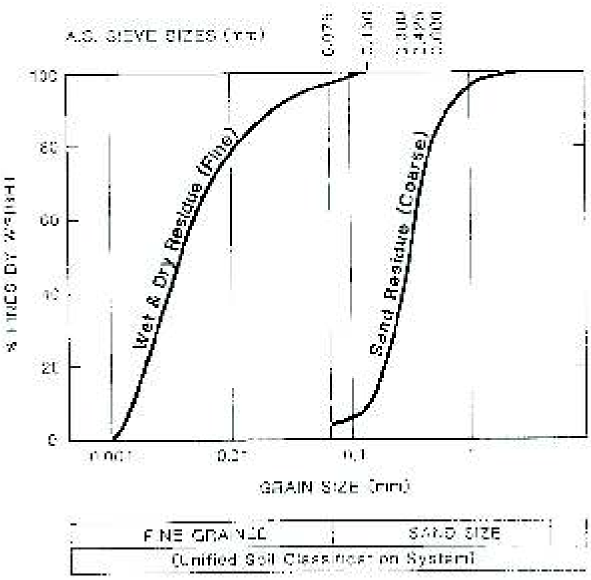

Fig. 1 Typical particle size distribution for fine and coarse fractions of bauxite residue

As can be seen, about 80% of the particles in red mud are less than 10µm, therefore the settling rate is expected to be extremely low. However, flocculation helps in speeding up settling; over the last few decades synthetic flocculants have been developed and these have replaced the outdated starch-based settling aids. Red mud containing more than 28% moisture is thixotropic in nature, i.e. viscosity greatly decreases when it is submitted to mechanical effects, namely shear stress. It has a tendency to develop fissures and cracks on drying, thereby leading to dust problems during drying in windy weather conditons. If the filter cake is disposed of as it is, virtually no dusting of the dried cake is experienced. Rain penetrates the dried filter cake only to a minimum extent. If underflow of deep washer or super-thickener with high solids content is disposed, their dusting behavior is close to that of the filter cake.

3. Ultimate stage of red mud washing/dewatering

The objective of this operation is to obtain red mud with the lowest amount of adherent liquor, and containing the lowest concentration of solutes. Equipment such as multichamber (Dorrtype) washers or Kelly filters are outdated and those like High rate/Deep cone thickeners, vacuum and pressure filters are being widely used in modern refineries. A brief outline of the equipment in use is given in this section.

3.1. Single chamber washers

3.1.1. Conventional single chamber washers

The single chamber decanter washers have typically a diameter up to 45m and height about 6m. The bottom can be flat (underflow discharge at the perimeter) or conical (underflow discharge at the centre). These type of equipment have been installed since about 1960. The underflow solids content is typically between 22-35%, depending on the type of bauxite, flocculant and the fine details of flocculation. Higher underflow solids content can be attained with the washers having conical bottom.

3.1.2. Super-thickeners

These washers have a diameter up to about 90m, as installed in the 1980s. The Superthickeners have a conical bottom and are typically located adjacent to the red mud disposal site. The underflow solids content is typically about 48% for Western Australian red muds. A disadvantage of these washers is the high rake torque, requiring an expensive solution.

3.1.3. High rate (deep cone) washer

The first deep washers were installed in the 1980s by modification of outdated multi-chamber washers [4]. The L/D ratio of the deep thickeners/washers is 1 or 1.2. This type of washer, due to its design, sophisticated flocculation and process control, can reach a mud throughput of 10-20 t/m2,day. The typical solids content of the underflow is 50-55% in case of last washers [5]. The high rate deep washers can be installed with or without an internal rake and do not necessarily require removal of the sand prior to its use, contrary to the other one-chamber settlers and washers. The maximum diameter of this type of equipment now is 24m [6].

3.2. Vacuum drum filter

The first generation commercial size vacuum drum filters were developed and put into operation in Germany in the middle of the 1960s for washing and dewatering red mud. Introduction of the stripping rolls made it possible to remove the thin mud cake. Drawbacks of these filters is the 20-40 g/l solids content in the filtrate, and the need for re-heating the filtrate [7]. Several vacuum drum filters have been upgraded over the years, thereby achieving significantly higher throughputs and more effective washing [8].

Typical operational data for the vacuum drum filtration of red muds are as follows [9]:

- Solids throughput: 150-250 kg/m2h
- Solids content of the cake: 50-65% (moisture content: 35-50%)
- Soluble soda content: 0.6-1.2%
- Filter cake consistency: sticky mud.

3.3. Pressure filter, plate and frame press filter

The counter-current red mud washing system was closed with filter presses before the 1930s. Operation of pressure filters required excessive amount of workforce [10]. Automated plate and frame pressure filters were installed recently in the Gardanne Alumina Refinery in France and the Alumina Refinery of Aluminium de Greece (AdG). The mud cake can not be washed in the course of filtration. Another drawback is the discontinuous operation and the low throughput. A low moisture content of 28%, and mud cake with good handling properties have been reached [11]. Such red mud filter cake of AdG [12] is shown in ***Fig. 2.***

Fig. 2. Red mud filter cake obtained by plate and frame filter press

3.4. Hyper Baric Filter (Hi-Bar Filtration)

Some details of the Hyper Baric Filtration are given in the Section 8.1. A comparison of filter cake from vacuum filtration and Hi-Bar Filtration is shown in Fig. 3. The relationship between fluidity (rigidity) of red mud and separation pressure is shown in ***Fig. 4.***

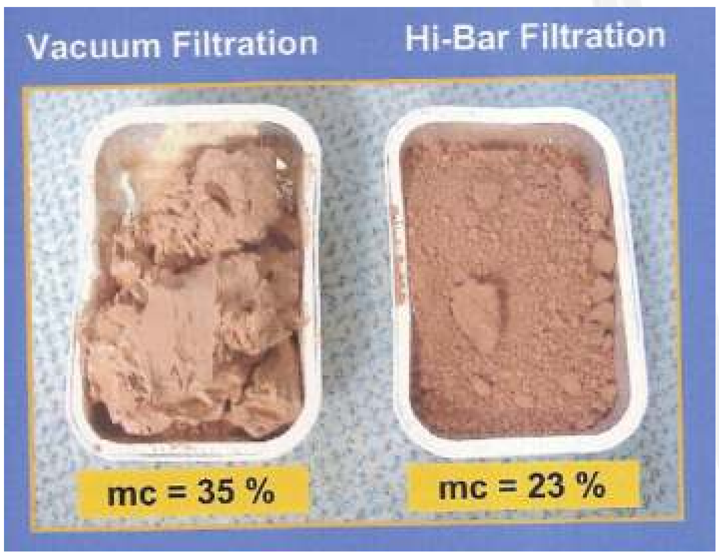

Fig. 3. Filter cake from a vacuum filter and a Hi-Bar filter [13]

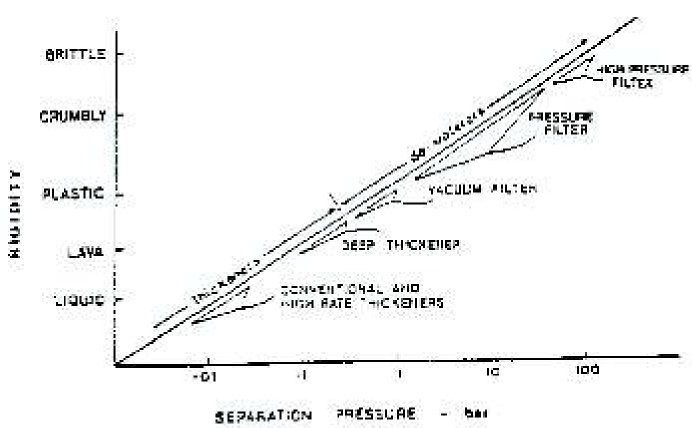

Fig. 4. Relationship between fluidity (rigidity) of red mud and Separation Pressure [14]

A crumbly red mud can be easily transported, stored and recalimed. This requires a moistrue content of less than about 28%. Such a red mud is not thixotropic any more.

4. Transportation of red mud to the disposal site

Transportation of red mud to the disposal site can be carried out by using centrifugal pumps, positive displacement pumps, trucking of the filter cake and thorugh conveyer belt. Centrifugal pumps have been widely used to transport the underflow slurry of the last washers or slurried filter cake from vacuum filters. A disadvantage of the centrifugal pumps is the limited delivery head of about 100 m water, though they can be serially connected. Positive displacement pumps are frequently used for the transportation the underflow of high rate (deep cone) decanters or for somewhat thinned cake of vacuum drum filters especially if the distance (pressure loss) justifies that. They are expensive and require high level of maintenance. Trucking of the filter cake involves relatively low investment costs and has the advantage of being easily adapted to fluctuations in the production rate. The trucks need to be of special type if the filter cake originates from vacuum drum filters. Conveyor belt is another obvious option for the transportation of the non-sticky filter cakes.

5. Red mud disposal, types

5.1. Lagoon type disposal (red mud pond)

Lagoon type disposal is traditionally employed to dispose red mud. The lagoon disposal has a typical height of 6-10m, but dimensions of 20-25m are also reported [15,16]. Prior to 1960, no special sealing was applied at the bottom with the mud itself providing the seal in many cases. This led to contamination of underground water table, thereby posing health hazard. The problem is minimized by using clay beds of up to 300-400 mm thickness (Alcoa refinery in Western Australia). Recent detailed investigations revealed that the caustic soda content of the liquor phase reacts with the clay over decades, amorphous sodium-aluminium-hydrosilicates and finally zeolites form through a complex reaction mechanism [17]. This reaction is very similar to the reaction of the clay minerals in the Bayer liquor [18], but obviously much slower. These changes ultimately increase the hydraulic conductivity of the clay bed, causing risks of contamination of the aquasystem after several decades. Another problem is the dusting of the dry surface of such disposal sites. A typical red mud disposal lagoon while drying is shown in ***Fig. 5.***

Fig.5. Lagoon type red mud disposal

5.2. Disposal in the sea, sea water neutralization

Red mud has been disposed of in the sea in France, Greece and Japan for several years. Sea water neutralizes the causticity of red mud. No bioaccumulation of chemicals was found on fish and sandworm using a diet containing 10% bauxite residue. Meio-bethos was observed at both a reference point and the centre of the bauxite residue disposal in the sea close to Japan.

The number of meio-bethos was found to be smaller at the centre of disposal [20]. Seawater neutralization of red mud of QAL [21] and Gove Alumina Refinery [22] (both in Australia) are described in the technical literature. Disposal of red mud in the sea has been appreciably reduced over the last decade.

5.3. Dry mud stacking

The precursor of the dry mud stacking was developed in the Burntisland Alumina Plant, Scotland in 1941. The washed cake obtained from plate and frame filter presses was delivered by trucks to a nearby tipping site. The mud consolidated fairly rapidly, so this was considered to be cost effective and created negligible environmental problems [23]. In early 1970s Giulini GmbH in Germany was the other pioneer of the dry mud stacking of rotary vacuum filter cake [24]. The third milestone was the achievement of Robinsky [25,26]. Alcan reported the introduction of dry mud stacking [27,28]. Alcoa adopted the dry mud stacking in 1985. The dry mud stacking of high solids content underflow of high rate deep cone or Superthickeners or of vacuum filter cake makes it possible to attain a solids content of about 72% in the consolidated muds in contrast to the 58-60% of the dried red mud ponds. As a consequence much smaller footprints are needed for dry mud stacking. The highest dry mud disposal facility reported is 50m [29]. A careful design of the impurity balance of the process is very important if dry mud stacking is applied [30].

In the up-to-date disposal sites using dry mud stacking system, two layers of sealing are applied. A compacted clay liner (CCL) of at least 600mm thickness is placed at the bottom followed by the upper layer of a plastic membrane, made of e.g. high-density polyethylene (HPDE), that has a good record of protection in a relatively high soda, high pH environment. The bottom layer can be replaced by a so-called geosynthetic clay liner (GSL). All these measures should make sure that the hydraulic conductivity of the sealing is less than 10-7 cm/sec. This parameter complies with the requirements of the hazardous waste landfill of the European Union Best Available Technique, or that of the US Environmental Protection Agency.

Provided that filter cake (without slurrying with water) or high solid underflow is disposed of by the dry mud stacking technology, the red mud is hardly permeable even for heavy rainfalls.

A schematics of the dry mud stacking of Alcoa is shown in Fig. 6.

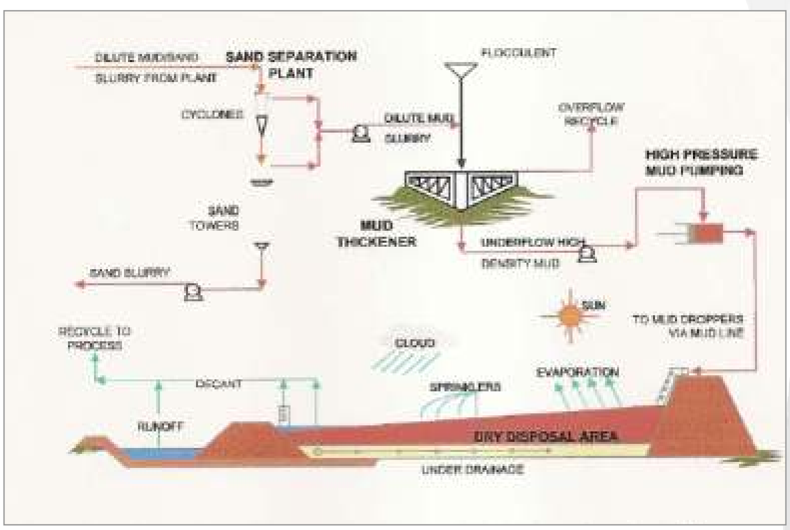

Fig. 6. Schematic of a dry mud stacking system[31]

In the 1970s, 70-80% of the red mud was disposed by the wet (lagoon type) method, the rest in the sea in 10 major alumina refineries in USA, Australia and Europe. By 2008 the lagoon type disposal was reduced to 25%, disposal in the sea to 15% and the share of the thickened tailings (dry mud disposal) was 60% [32].

5.4. Tipping of cake of pressure filtration or Hi-Bar filters

Disposal of crumbly cake of Pressure Filtration or Hi-Bar filters with good handling properties is considered tipping. There is no dusting and virtually no rainwater enters if this type of red mud is disposed of. The appearance of such a cake, as already referred to, is shown in ***Fig 3.***

6. Red mud: hazardous or non-hazardous waste?

There are different opinions in the literature and also in the legislation of different countries. The causticity that mainly originates from the adherent liquor makes the red mud hazardous. The recent review of the Basel Convention, which controls the transboundary movement of wastes, has adopted pH 11.5 for bauxite residue as hazardous waste criterion [33].

7. Environmental aspects

7.1. Seepage

The prevention of seepage by sealing has been discussed in Section 5. In case a well washed red mud is disposed of by the dry mud disposal method, especially after partial neutralization, a balance is to be struck betweeen the investment and operational costs and avoiding the long term risks of seepage. In any case observation wells are needed to monitor the surrounding underground water table [34] over the operation and afterwards.

7.2. Collection of runoff water and precipitation, their use and/or treatment

When the red mud disposal method is optimized, the red mud washing (possibly filtration) system and the water balance of the process and that of the red mud disposal should be considered and optimized simultaneously. The water balance is greatly affected by the meteorological circumstances (drying of the disposed mud, recovered water from the storage site, rainfall, etc.). Extreme seasonal variations may occur during rainfall and drying. The runoff water should be directed to the alumina refinery. In extreme meteorological circumstances the surplus water (e.g. once in 25-50 years) may need to be released after its treatment (neutralization).

7.3. Dusting

Recent model experiments confirmed that there are white and red dust, consisting of sodium carbonates (originating mainly from the adherent liquor) and red mud particles, respectively [35].

7.3.1. Spraying the drying surface

Spraying the surface that has dried out is the most widespread measure to prevent dusting, though even distribution of the spray water can be a challenge.

7.3.2. Mud farming

In case of thick layers of deposits, the surface becomes dry while the lower parts of the layer are still completely wet. Therefore a proper thickness of the deposited layer should be selected, taking into consideration the anticipated meteorological circumstances (e.g. dry or wet season). Mud farming is a measure by which the dried out surface being most prone to dusting is replaced with a wet layer, by an operation similar to ploughing [36,37].

It is imperative to minimize the bone dry mud surface by spraying and/or by mud farming and finally by closure of the surface as soon as possible.

7.4. Rehabilitation of the surface

A well managed surface rehabilitation programme is the ultimate measure to minimize the dry mud surface. Succesful revegetation programmes have been reported by various companies [38-43]. Rehabilitation results of a dry stacking disposal site are shown in Fig. 7.

Fig 7. Rehabilitation of a dry mud stacking disposal site

7.5. Radiation

There are sharp differences among different red mud as far as concentration of various radioactive elements is concerned. The extent of usage varies with applications, ~ 14% in bricks, no restriction in floor tiles and roof tiles, 61% in ceramics for exterior applications in the case of a Greek bauxite residue, using the activity index method [44]. Radioactivity should always be checked for each bauxite residue when its utilization is targeted.

8. Uses of red mud/bauxite residue/bauxite tailings

Technically successful research and development activities have been carried out aiming at the utilization of red mud. The applications which have been in use either in pilot or commercial scale are shortly reviewed here:

- for amendment of acidic soils, for immobilization of heavy metals [45] and/or for retaining of certain nutrients, such as phosphorus in agriculture [46]
- for making crude and fine ceramics, such as tiles, floor tiles, [47,48]
- for making bricks [49,50],
- in road contruction, first of all the coarse fraction [51]
- as a component in making cement, OPC [52-55] and special cements [56], cement mortar [57]
- an an additive in ferrous metallurgy [58-60]
- as a filler in rubber [61] and plastic industry
- as pigment in production of paints [62]
- as a material used for trapping carbon dioxide [63,64] and/or sulfur dioxide [65] from flue gases
- as a feedstock for manufacturing adsorbents and catalysts [66]
- as a feedstock for making water and sewage treatment agents [67]

8. Emerging technologies/solutions

8.1. Hyper-Baric Filtration (Hi-Bar Filtration, Continuous Pressure Filtration)

Hyper Baric Filter with possible steam enhancement is an option to obtain bauxite tailings cake with about 75-77% solids content (moisture content 23-25%). The cake is crumbly in nature and can be handled easily. This feature is important if the bauxite residue is utilized instead of being disposed of. Pilot scale and field trials have been carried out in Bauxilum, Venezuela [68,69] and in Aluminium Oxid Stade GmbH, Germany [70]. It should be pointed out that over 30% of the chemically combined soda was released by the DSP when a hot wash water was used. This type of filter generates cake that allows minimum rain water entry. Hi-Bar Filtration has been implemented so far in the alumina industry for dewatering of the beneficiated bauxite after its transportation in a slurry form for a 240 km distance [71,72].

8.2.Partly neutralized red mud

As a result of developments in the last twenty years, it has been proved that red mud can be partly neutralized with various agents, including sea water or gypsum (can also be obtained as a waste). The resulting material has several favourable features, among others:

- high acid neutralising capacity
- high cyanide and toxic heavy metal trapping capacity
- not hazardous any more.

Several applications have been found in commercial or trial scale:

- treatment of acid mine drainage (AMD), acid rock drainage (ARD)
- treatment of sulphidic mine tailings and waste rock and acid sulphate soils
- production of portable barriers for controlling acidic or metal rich spills
- treatment of sulphidic marine sediments used as land fill
- removal of phosphate from water or sewage
- use as soil conditioner to increase the phosporus and water retention capacity, thereby reducing the need for fertilizer
- removal of arsenic and other toxic metals from drinking water or sewage
- treatment of leachates from domestic and industrial waste disposal facilities
- treatment of chromium rich tannery effluents
- treatment of electroplating plant effluents.

Most of the phosphate that have been removed from watery effluent proved to be accessible for plants [73]. Consquently the material obtained from a phosphate removal by partly neutralized red mud can be re-used as a soil conditioner [74]. The toxic metals are bonded to the treated red mud, and not available for plants in realistic circumstances. There are several case studies about a wide range of applications listed above [75].

8.3. ILTD Process

The Improved Low Temperature Digestion (ILTD) Process [76] provides the following advantages compared with the Conventional Low Temperature Digestion (CLTD) Process:

- No predesilication is needed
- 50% or even more savings in the chemically combined NaOH losses
- 5-10% savings in bauxite consumption
- 10-20% higher digestion production rate at the same volumetric throughput
- 10-20% savings in the process heat consumption
- 10-20% higher liquor productivity in precipitation; practically the theoretical maximum alumina content can be attained in the Liquor to Precipitation (LTP)
- Significantly less silica and certain other contaminants in the product (estimated reduction of 20-40%)
- Significantly less scaling in the liquor preheaters of the evaporation (estimated reduction of 40-60%)
- 70-90% less chemically bound soda content in the bauxite residue
- option of at least partial utilization of the low soda bauxite residue
- option of making desilication product (Bayer-sodalite) as a new by-product for sale, and/or converting it to value-added products such as zeolites at a competitive cost
- more cost effective pressure decantation instead of relatively large settlers
- processing of bauxite bodies with relatively high silica and/or high boehmite and/or high goethite content do not pose a processing problem.

The ILTD Process makes possible to obtain such a bauxite residue with a chemically combined soda content of as low as 1-1.5% Na_2O, opposite to the 8-9% Na_2O content of the red mud of the conventional process. The iron content of the low soda bauxite residue of the ILTD Process can be as high as 60-70% Fe_2O_3 instead of the 50% Fe_2O_3 of the red mud of the CLTD Process. These figures are based on tests with a typical Trombetas bauxite, Brazil [77]. Therefore the ILTD Process has benefits both from the point view of the usage of the residue and its environmentally sustainable disposal. The ILTD Process has been further developed since its patenting.

9. Waste paradox

There is a paradox regarding the utilization of wastes:

- There are cheap competitive materials and the transportation costs hinder its transportation to a large distance, therefore the price in large quantities should be cheap enough to be competitve
- there are high value added applications, but these are marginal in quantites compared with the amount of production of bauxite residue by-product.

10. Conclusions

Consideration of red mud disposal should be based on alumina process technology and with weather and socio-economical circumstances.

When the method for the transportation and the disposal of the bauxite residue is selected, the red mud washing system and the overall water balance should be considered at the same time. Special attention should be paid for preventing dusting and the progressive rehabilitation of the filled red mud disposal areas.

The most up-to-date solution is the dry mud stacking system, provides a technical solution what satifies the environmental regulations in a cost-effective manner. In such a case the disposal of the red mud is safe. The bauxite residue can be obtained with characteristics which make possible disposal as a non-hazardous material.

Due to the research and development achievements so far and the ongoing activities, the bauxite residue has several useful and environmentally sustainable applications.

Though there has been continuous progress, utilization of the red mud has not been solved in great quantities. It can be reasonably expected that using the proven and emerging technologies the amount of bauxite residue that are used in an economic and environmentally sustainable way will considerably increase.

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Dr Ashok Nandi, Executive Secretary of ICSOBA visited the Zhengzhou Research Institute (ZZRI), CHALCO from October 12 to 15, 2009 to have the first round of detailed discussion regarding organization of the 2010 symposium. ZZRI have agreed to host this symposium in Zhengzhou city and provide all the support to ICSOBA Secretariat. A full team of ZZRI participated in the start up meeting of ICSOBA; this showed their earnestness in pursuing the program. The meeting was attended by the following:

Zhengzhou Research Institute (ZZRI), CHALCO

1. Dr. Li Wangxing, Professor, President of R&D Centre of CHALCO
2. Dr. Yin Zhonglin, Professor, Director of Alumina Research Department
3. Dr. Yang Jianhong, Director of Green Metallurgy Division
4. Mr. Liu Bin, Information Department Director
5. Mr. Fan Dalian, Assistant President, Director of Pilot Refinery
6. Mr. Zhang Yongjun, Deputy Manager, Technologies Transfer Department
7. Ms. Chen Shouhui, Secretary

ICSOBA Secretariat

Dr. Ashok Nandi , Executive Secretary and Convenor ICSOBA-2010

ZZRI organized visits to their laboratory, bauxite beneficiation pilot plant and alumina production facilities. A team of ZZRI and ICSOBA also visited Crowne Plaza hotel in the city as proposed venue of ICSOBA-2010 symposium and exhibition. During two days of active discussion, both sides agreed on the following points:

- It is decided to open a bank account in the name ICSOBA in the China Industrial & Commercial Bank (ICBC) in the branch near to the Institute. Delegates and companies from China will be allowed to pay in RMB equivalent to US$ mentioned in the circular. The ICSOBA corporate and individual membership fee can also be paid in RMB by Chinese companies and individuals. ICSOBA members have special rates in symposium registration fee, sponsorship and exhibition.
- ICSOBA Secretariat will be responsible for coordinating with companies / delegates mainly outside China, printing brochures, advertisement material, collecting and reviewing all technical papers in English, preparing and editing conference proceedings (TRAVAUX volumes), souvenirs, list of delegates and other conference material. Zhengzhou Research Institute, CHALCO will be

Meeting of Dr. Ashok Nandi with Dr. Li Wangxing, Professor, President of R&D Centre of CHALCO

mainly responsible for coordinating with Chinese companies, inviting technical papers, reviewing them and forwarding to ICSOBA secretariat for final editing and formatting. ZZRI will vigorously pursue for symposium sponsorships, exhibition, advertisements and sponsorships. They will provide all the logistic support to ICSOBA Secretariat such as invitation letters for visa, translate circulars in Chinese and organization of symposium in Zhengzhou.

● A team of ZZRI and ICSOBA visited the Crowne Plaza Hotel in the city centre of Zhengzhou and held detailed discussion with the management. There are good (e.g. Holiday Inn) and budget (e.g. Express Holiday Inn) hotels belonging to the same group as Crowne Plaza, located near by, and these can be booked for delegates. After visiting the proposed exhibition sites in Hotel Crowne Plaza, it is decided to use the outside area for the ICSOBA exhibition (about 400 sq. meter). It is planned to contact a company to erect pre-fabricated stalls (Three sizes 2m x 2m; 3m x 2m and 4m x 2m) and provide details to ICSOBA secretariat. This team also visited Zhongyou Garden Hotel as an alternative for the Conference venue.

● ZZRI is working on details of post symposium visit of ICSOBA delegates to CHALCO bauxite beneficiation facility, alumina and aluminium plants.

Photograph with ZZRI team in front of new CHALCO research institute

● ICSOBA and ZZRI jointly planned preliminary symposium program (Chief guests, invited guests and other dignitaries of China for Inaugural function and key note addresses) and availability of consecutive English / Chinese translation particularly for the inaugural function.

● ICSOBA Secretariat has supplied 1000 copies of first circulars for distribution in China. ZZRI translated this circular in Chinese and they are in the process of circulating the same to all the bauxite mines, special bauxites producers, alumina refineries, smelter and downstream facilities and related organizations in China.

● It is decided to provide wide publicity of ICSOBA-2010 in China through CHALCO web site, Chinese technical journals and e-mailing to all concerned people of Chinese bauxite-alumina and aluminium industry.

● A CHALCO Coordinator is nominated to send invitation and visa letters to all foreigners in consultation with ICSOBA Secretariat and coordinate activities related to visa, flights and hotel booking.

● Discussions were held on the possibility of bringing out a booklet on Chinese bauxite-alumina-aluminium industry in English during the ICSOBA symposium. ZZRI would collect the data and send to ICSOBA Secretariat for editing, compiling and publishing booklet.

● ZZRI assured to mobilise several technical papers on Chinese bauxite, alumina and aluminium industry for this symposium. According to ZZRI, there may be about 200 delegates from China only and several companies may come forward to exhibit their products during the symposium.

XVIII International Symposium
ICSOBA-2010

Special Session on "THE FUTURE OF ALUMINA PRODUCTION"

Roelof Den Hond, Director ALCOR, President ICSOBA.
Oegstgeest, The Netherlands.

The recent closure of high cost alumina plants has increased the future requirement for new, low cost bauxite mines and alumina refineries. Alcor is organizing a special session, "The future of alumina production", to review structural developments that impact on these greenfield projects. The session reviews how recent technologies impact on bauxite deposit selection and on refinery operating and capital costs. Also structural changes in technology supply and project financing will be reviewed. The session will demonstrate how these structural changes facilitate the formation of new alumina producers.

1. **BAUXITE UPGRADING PRACTICES IN BRAZIL**
   Arthur Pinto Chaves, Full Professor, Mineral Processing Department of Mining and Petroleum Engineering.
   Escola Politécnica, University of Sao Paulo, Brazil.

2. **CROSS-COUNTRY BAUXITE SLURRY TRANSPORTATION**
   Yueguang Che and Jay Chapman,
   Pipeline Systems Incorporated, Concord, California, USA.

3. **BAUXITE, RED MUD AND TAILINGS DEWATERING BY HI-BAR FILTRATION**
   Dr.-Ing. Reinhard Bott, Dr.-Ing. Thomas Langeloh, Dipl.-Ing. Jürgen Hahn
   BOKELA, Karlsruhe, Germany.

4. **RESEARCH ON LOCAL FLOW VELOCITIES AND SOLIDS CONCENTRATION FLUCTUATION IN SUSPENSION VESSELS, USING DIFFERENT IMPELLER SYSTEMS**
   Detlef Klatt, Managing Director,
   STC-ENGINEERING, Waldenburg, Germany.

5. **BARRIQUAND INTERSTAGE PRECIPITATION COOLERS – LAST DEVELOPMENTS FOR TROUBLE FREE OPEARTIONS**
   Daniel Martin, Export Manager.
   BARRIQUAND TECHNOLOGIES THERMIQUES.

6. **ENGINEERING, PROCUREMENT, CONSTRUCTION AND PROJECT FINANCING**
   Speaker(s) to be announced.