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SGA REQUIREMENTS IN COMING YEARS

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Abstract

Refineries report various physical and chemical properties of Smelting Grade Alumina, SGA, on Certificate of Analysis data sheets. Without strong understanding of customer needs this data may fall short of meeting the true needs of smelters and downstream customers. For example, improving excess fluoride control with no specification or target for the variability of Na_2O content may be a challenge. Downstream customers for aluminum conductor products require excellent conductivity, but this does not always translate itself into alumina shipping limits for Cr_2O_3, MnO or V_2O_5. The author presents these and other examples for consideration during the joint sessions between Alumina & Bauxite and Aluminum Reduction Technology.

Introduction

Shipping specifications for SGA tend to focus on those physical and chemical properties that have or have had relevance to typical smelting clients. In many cases the properties that are routinely reported act as surrogates for other items of customer interest. For example a customer who desires rapid solubility may focus on content of +325 mesh or alpha alumina. Interest in the ability of alumina to scrub fluorides from pot off-gas with no standard test of the sorptive capacity of SGA may have to be satisfied by surface area data. A smelter with metal customers that are interested in electrical conductivity may have to defer to the content of chromium, vanadium or other metallic impurities.

Some properties are straightforward. The soda content of the alumina may be used as a direct input to bath chemistry control and calculations of bath generation or consumption. The iron oxide content of the alumina will be a direct input to the mass balance for iron in the pot room metal.

The connections between alumina properties, smelter needs and metal customer requirements are not always obvious and these may not be fully understood by all parties involved. In some cases the customer needs may also not be completely satisfied by the alumina properties that are routinely measured.

The connections between refineries, smelters and metal customers are often incomplete. Closing these gaps will require improved understanding and communication. The technical community can function as a key contributor in this area. Joint sessions between Alumina and Bauxite and Aluminum Reduction Technology at the Annual TMS meeting provide a good forum for such interaction.

Discussion – Metal Customer Requirements

The interaction between refineries and smelters may begin and end with parameters that lower costs, make alumina more process friendly, or address environmental concerns. The connection to the customer may only include discussions of iron, silicon or other

metallic oxides. Interaction may not include what the smelter can do about these issues or their customer needs and thus may not identify what is truly needed from the refinery. Comments that attempt to capture these future requirements are offered below.

Iron Oxide

Iron negatively impacts ductility, conductivity, fracture toughness and high speed extrudability of metal. It generally does not add desirable properties to aluminum. Iron can be tolerated at some level in harder alloys and is desirable in limited quantities in a few alloys. For example iron helps to provide a uniform matte finish to anodized products made from extrusion billets. Iron is also specified at low levels in other products such as conductor wire.

With the exception of purity products that require less than 850 ppm of Fe in the metal or high purity products that have less than 350 ppm of Fe, the Fe_2O_3 content of the alumina is often not a great concern. The reason for this is that 35% to 85% of the iron in aluminum is from corrosion of iron and steel pot components, anode assemblies and gas manifolds or studs. There is often much that a smelter can do to reduce iron contamination before having to rely heavily upon the refinery for assistance.

This does not leave the refinery with nothing to be concerned about. Refineries will often have multiple smelting clients and typically one-half of these have metal customers with moderate to tight demands upon the iron content of ingot. The many clients who have limits of 850 ppm Fe or less will prefer alumina that is 0.015% Fe_2O_3 or less. Fe_2O_3 at 0.015% contributes about 200 ppm of Fe to the metal. Those clients that produce high purity products will look for alumina that has 0.010% Fe_2O_3 or less.

Even though few clients need iron oxide below 0.010% refineries should be aware that as Fe_2O_3 content increases above this level that the potential customer base begins to diminish.

That which is acceptable today to make par metal grades may not be acceptable tomorrow. P-1020 grade metal (99.7%), currently the LME par metal grade, requires <2050 ppm of iron. P-0610 metal (99.84%) still may command a small premium, but is soon expected to become the LME par grade as customer expectations increase. This will require producers to have <1050 ppm of iron in metal to avoid market penalties. Many smelters currently can not meet this challenge. The market shift is already happening. Premiums for P-0610 have diminished in North America and the market has effectively shifted to a 1300 ppm Fe maximum for par grade in Australasian markets. The pressure for smelters to reduce iron content will eventually involve the refineries.

Silica

Silicon negatively impacts ductility, formability and conductivity. The iron and silicon content generally determine the value of

common metal grades in the marketplace. Some silicon can be tolerated in many alloys. Si is desirable in great quantity in certain alloys such as those of aluminium wheel makers.

With the exception of a few products that require <550 ppm Si or high purity products that can require <350 ppm Si, the SiO_2 content of the alumina is typically not of significant concern. Generally less than 25% of smelters are constrained by Si limits.

Unlike iron, more than half of the silicon in the metal may come from raw materials. Alumina and coke usually contribute the greatest amounts of Si, often in near equal quantity. Aluminum fluoride may also contribute a noteworthy fraction of Si to metal.

As with iron there often are things that smelters can and should do to control Si content in metal before requesting help from the refinery. The balance of Si to the pot comes from contamination such as from pot lining, bricks, insulating materials or from items such as floor sweepings. These factors often can be controlled.

An SGA content of 0.015% SiO_2 will contribute about 135 ppm of Si to the metal. As with iron, the potential customer base for SGA begins to diminish with increasing silica levels. Customers that produce high purity metal will generally look for SGA with 0.009% SiO_2 or less. Customers that produce conductor products may have limits on Si in metal as it detracts from electrical conductivity. The limit for Si in metal varies since many elements detract from conductivity. In general SGA over 0.017% SiO_2 may be rejected by some potential clients.

As with iron, what is acceptable today will not be acceptable tomorrow. The expected shift from the P-1020 standard metal grade to P-0610 will reduce maximum acceptable Si from <1050 ppm to <650 ppm. This does not pose as steep a hurdle as iron requirements, but tighter limits on Si will trickle back to refineries as markets shift and expectations rise.

Conductivity

Manganese, Chromium, Vanadium and Titanium are some of the elements that detract from electrical conductivity, much more so than iron or silicon per ppm of oxide in alumina. [1]

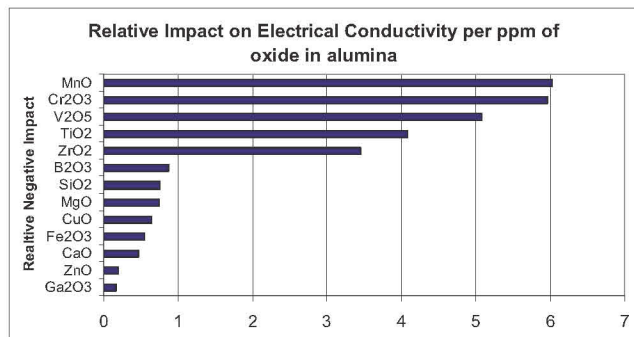Relative Impact on Electrical Conductivity per ppm of oxide in alumina

Figure 1 – Metallic Impurity impact upon conductivity converted to metallic oxide equivalents

Small increases of these metallic impurities can make large differences to some customers. Ingot plants have some ability to control some metal impurities by precipitating them out as borides. Boron treatment is not desirable since the cycle time of the holding furnace must be extended to let the borides settle out.

This reduces net furnace capacity. Boron additions are also not a universal treatment. They do not reduce Mn or Si in the metal.

MnO at 0.0010% in SGA contributes 15 ppm of Mn to metal. Manganese may also enter aluminum from attack on collector bars, anode stubs or studs on pots with problems. While Mn is not an issue at every smelter it is worth noting that smelting clients that serve the conductor products market may not consider SGA with more than 0.0015% MnO.

Cr_2O_3 at 0.0010% contributes 13 ppm of Cr to metal. Alumina is generally the only source of chromium in aluminum except for locations that use some cast iron components with small amounts of Cr included. Even in these cases most of the Cr in metal will come from the alumina. Smelting clients may avoid SGA with more than 0.0007% Cr_2O_3.

V_2O5_5 at 0.0010% contributes 11 ppm of V to metal. Vanadium in SGA is often associated with refineries that use fuel oil for calcination, but bauxite can be a major contributor as well. In the smelters anode coke is often a large source of vanadium and the greatest contributor to %V in the metal. Some smelting clients may not consider SGA with more than 0.0015% V_2O5_5.

TiO_2 at 0.0010% in SGA will contribute about 12 ppm of Ti to metal. Alumina is a major contributor of Ti to pot metal. A level of 0.0040% TiO_2, or less, is reasonable for SGA.

Zinc Oxide

Zinc can be particularly problematic for smelters that serve extrusion billet customers. It causes spangling which is an undesirable, grainy, surface finish.
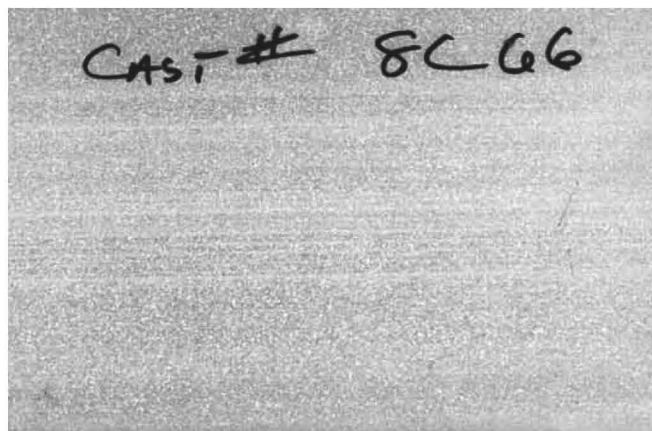

Figure 2 - Example of spangling

While zinc may also be found in anodes the majority comes from the alumina. ZnO at levels as low as 0.006% in SGA may not be considered by smelting clients that produce much extrusion billet.

Gallium

Gallium will reduce corrosion resistance and create loss of mechanical properties. It also is known to interfere with silicon modification in foundry alloys and with etching or brightness response of other alloys. The primary source of Ga in metal is alumina and some producers may find levels of 0.012% Ga_2O_3 in SGA or more to be unacceptable.

Beryllium

Beryllium is a worker exposure concern at some locations and in some metal producing regions such as Québec, Canada. Be in metal is limited to 1 ppm in the products of some producers. The source of Be is bauxite from various deposits in the world. Beryllium accumulates in pot bath at levels of 30X to 60X the concentration in SGA. In the future this metallic impurity is quite likely to come under more scrutiny and governmental regulation.

Phosphate

Phosphorus can create concerns for a few customers as it makes metal more porous and brittle. As an example wheel products may have limits on phosphorus content.

Phosphorus concentration in SGA can be extremely difficult to measure with accuracy and precision. Most refineries report only that the typical level of P_2O_5 in SGA is less than 10 ppm due to the measurement issues involved.

Phosphorus is not only a metal customer concern. It is a smelting process concern as well. It has been widely reported upon in the literature for negative impact on current efficiency especially in pre-baked cells. In the range of 15 to 40 ppm of P_2O_5 in SGA it is well documented that each 1 ppm increase in phosphate will decrease current efficiency by 0.1%.[2] The multivalent nature of phosphorus robs current as it changes valence states in the bath. This lowers current efficiency. The phenomenon is projected to be linear down to the individual ppm levels of P_2O_5 in SGA.

Phosphorus in aluminum may also come from coke, cast iron and phosphate bonded refractory or mortar. Since P can cause such significant problems smelters must minimize contributions from all sources. As smelters continue to drive for higher current efficiency, more demand is anticipated for accurate measurement of P_2O_5 in SGA down to the individual ppm level with interest to reduce phosphate content in SGA to essentially zero.

Discussion – Smelter Process Requirements

Process requirements of smelters go beyond the need for low phosphate. There are other properties that can cause process related inefficiencies, lead to environmental issues or increase costs. As with the connection between electrical conductivity and certain metallic impurities the link between a customer need and reported physical or chemical properties is not always clear. In some cases a desired test, such as for solubility may not be available. In other cases, the data may be available but not gathered or reported in such a way that direct comparisons may be made between refineries. The following topics comment upon such present and future requirements of smelting customers.

Soda Content

The sodium oxide, or soda, content of alumina is common topic between refineries and smelters. At the refinery control of the soda level in hydrate and calcined alumina helps to control costs through the recovery of soluble soda. On the other hand some improvements to refinery yield may drive soda content in SGA upwards. At the smelter the interest in soda level has to do with bath balance, bath chemistry control and cost.

The bath of molten salt in the pot contains NaF and AlF_3. The mass balance around sodium is dynamic. Some sodium leaves with the metal. Much will be intercalated into cathodes. The rate of absorption into cathodes depends upon the types of cathode blocks used and the age of the cell. Young pots soak up sodium rapidly and old pots have few sites left for intercalation. There are other sodium losses in the equation and other net inputs such as sodium carbonate, or soda ash, additions.

All of the forms of Na that enter or leave the cells determine the total amount of bath in a smelter. Generally two factors predominate. Sodium absorption into the cathode is the large sink for Na and soda in the alumina is the primary source of Na.

Smelters with low pot life tend to lose more Na than they gain so they purchase and consume bath. These smelters generally prefer soda content of >0.40% in alumina to reduce the amount of bath that must be purchased and handled. Some smelters are bath neutral neither consuming or producing significant quantities of bath. These generally have long pot life and lower Na_2O content (e.g. 0.35%). Many smelters produce more bath than they consume leading to market excesses except when new smelters are under construction. These plants generally have long pot life and moderate or high levels of soda. The balance point for these customers may be below 0.30% Na_2O in SGA.

Excess bath costs much more to make in materials, energy and labor than it can be sold for. This causes smelters that make much excess bath to call for reductions in soda content. As pot life continues to increase more smelters will find themselves in a position of being concerned about the costs that come with having Na_2O content above their bath neutral point. The call for lower soda in SGA is also expected to continue as more smelters convert to graphitized cathodes. Unfortunately not all customers have the same bath neutral point and the target for soda content can at best be a weighted average for any refinery.

Variation of Soda Content

Bath Ratio, or excess fluoride, control is another matter related to sodium oxide content of alumina. Smelters generally drive to operate with as high an excess fluoride or AlF_3 content as possible to keep pot temperatures low. The solubility of aluminum in bath is temperature dependant and is the main factor in current efficiency control according to much of the published literature. The lower the temperature is, the lower the likelihood will be for re-oxidation of metal and current efficiency loss.

However if the excess fluoride content becomes too high the cell can become too cold and suffer operational problems. It's a tightrope that requires consistent Na inputs to control the NaF content and AlF_3 input to keep bath chemistry on target.

When Na input in alumina varies it affects bath chemistry and the ability of the pot to operate at peak efficiency. Thus smelting clients need low variation of Na_2O in SGA. In many cases this exceeds the benefit of having soda content at the bath neutral point. There is often more money in lost current efficiency than the losses that come from making excess bath.

Unfortunately there is no uniform method or industry standard for measuring and reporting the variation of Na2O content in alumina. A standard lot size for a sample and the method for

gathering samples from each lot are needed to establish such a standard. The best available information is range of shipments data which can be very misleading when making comparisons between refineries. Alumina shipment sizes vary from a few hundred tons to more than 50,000 mt. The largest shipments tend to have the smallest ranges of Na_2O content between shipments.

Calcia

Calcium Oxide, or calcia, content also affects bath chemistry. Calcium accumulates in bath as CaF_2, or spar. Some spar content is desirable. It can help to reduce the melting point of the bath and improve the workability of the crust. Too much spar in the bath reduces alumina solubility. It will also change the density of the liquid bath reducing its ability to separate itself from liquid aluminum thus posing another real threat to current efficiency.

Calcium content in metal is important for a few products. However, since CaO accumulates primarily in the bath and the concentration of CaF_2 affects transfer rates to metal the customer focus will primarily be upon the spar content of the bath.

While the CaO level in the SGA is important, the ratio of CaO to Na_2O is the primary driver of spar content in pot bath. Excess soda makes bath that dilutes spar. A ratio of CaO to Na_2O of 8% or less in SGA will all but assure that smelting clients will not have increasing spar levels in their bath. At ratios much greater than 10% most smelters will tend to see increases in spar levels.

If spar levels go too low, smelters can add relatively inexpensive fluorspar to the pots. However, if spar levels go too high the only remedy is to dilute the bath at a cost of hundreds of thousands of dollars per year at a typical smelter.

CaO in alumina is not the only source of calcium to the metal. Anode coke also has Ca in it, but this often is not reported on the certificate of analysis for coke. Coke may account for as much as 30% of the Ca input from raw materials.

Alpha Alumina

Alpha alumina is more thermodynamically stable than gamma phase alumina. It also has more problems than gamma alumina going into solution during the short time that it is exposed to liquid bath after being discharged from a point feeder. It thus tends to settle underneath the metal pad of the pots and form "sludge" or "muck". Alpha is only one of multiple potential sources for sludge formation or problems with solubility.

An SGA with an alpha content of 10% or more may also affect the integrity of the pot crust making it weaker and more difficult to keep the pot sealed. Generally alpha content of less than 10% is preferred by most smelting clients.

Loss On Ignition

%LOI is often referred to as the chemically combined water that is Lost on Ignition between 300 C and 1000 C. More accurately it is a measure of the combined hydroxyl units [3] that remain on the various phases of alumina that have not been fully calcined to alpha alumina. SGA is a mixture of many phases of alumina ranging from a very small amount of alumina tri-hydrate to a

percentage of alpha phase alumina. Typical LOI content will be 0.8% in SGA.

Some customers wish to have low %LOI to avoid paying for "water". However some LOI content is necessary as it is linked with other important properties, surface area and alpha content. As more LOI is driven off of the intermediate phases of alumina, the surface area needed for efficient removal of fluorides is reduced and the alpha content increases. Alumina with almost no LOI would have almost none of the surface are needed for scrubbing fumes and would not dissolve well in pot bath.

Søderberg customers may prefer low LOI more than pre-bake customers since less fluoride is evolved and captured by the dry scrubbing system per ton of metal produced. Pre-bake customers may prefer to accept a little more LOI and surface area to have more efficient scrubbing of fluoride gases from the pot.

An interesting twist on this is that LOI is one of the significant contributors to total fluoride evolution for pot off-gas.[4] Unlike physical moisture that flashes off when the alumina contacts the pot bath the chemically combined hydroxyl units come off relatively slowly. This places hydrogen in contact with bath and allows the HF to form that the surface area on the alumina will be used to remove. The end result is that a mid-point is required for LOI content that balances HF evolution with fluoride capture.

Hydrate Content

In the literature hydrate, or gibbsite, has been linked with the formation of volcano like features around point feeders. It is thought that the very high -OH content of gibbsite causes bath to splatter during feed forming volcanoes that can choke off the ability to feed the pot. Claims have also been made in Søderberg operations that gibbsite content contributes to excessive dusting during side-break and causes problems with pot operations. This has not been substantiated or countered in the published literature.

Gibbsite content often parallels the superfines fines content of the alumina. Gibbsite in SGA has by-passed calcination as fine particles that have passed with hydrate cyclone exhaust to the electro-static precipitators, or ESP units.

Moisture Content

%MOI is the Moisture on Ignition that comes off between room temperature and 300 C. Calcined alumina is hydrophilic and draws moisture out of the air that it comes into contact with. SGA leaving the refinery can vary from a few tenths of a percent moisture to more than 1% depending upon exposure to sources such as fluidization air used for conveyance. At the smelter the SGA may be over 2% moisture at unloading.

Fortunately the MOI flashes off rapidly and is reported to be only 5% as effective at making HF in the pot as LOI.[4] Moisture either is driven off in the storage bins or on the pot crust. This is fortunate since aside from keeping SGA out of the rain there is not much that a refinery or the smelter can do to control MOI content.

B.E.T. Surface Area

Surface Area needs have grown to match changes in the industry. Modern pre-bake smelters evolve more fluoride than previous

generations of technology such as side-break pots that work alumina in from the crust. Thus, pre-bake pots generally evolve more fluoride than Søderberg pots. With the most demanding class of customer in mind the industry has settled in at 60 to 80 m^2/gm of surface area as the norm.

High surface area is required to remove higher levels of fluoride. Dry scrubber manufacturers base performance guarantees near 85% of the theoretical saturation level of alumina, 0.275 mgF/m2, calculated using B.E.T. (Brunauer-Emmett-Teller) surface area. Above 85% saturation, removal efficiencies for HF in pot off-gas begin to drop off.

There are other factors beyond surface area that define the ability of alumina to remove HF from pot gas. The soda content of the alumina can play a role in sorptive capacity of alumina.[5] As with surface area higher soda content aids scrubbing ability.

There have been some calls to reduce fluoride evolution via reductions in LOI but to do so will require a penalty in surface area. When the call to do so comes from a Søderberg customer it can place the refinery squarely between the needs of Søderberg and Pre-bake technology. In the near term SGA surface area requirements are expected to remain in the 60 to 80 m^2/gm range.

Loose Bulk Density

Loose Bulk Density in and of itself is usually not of great importance, but variation of L.B.D. can cause problems with pot feeding and anode effect rates. Most pot feed systems are volumetric in nature, either using a specific volume point feeder or using target heights for additions of alumina to side-worked pots. When density shifts it also shifts the feed rate of alumina to the pots and it may take systems a few days or more to catch up. Modern feed systems are less sensitive to changes than older systems or ones that rely solely upon operators and practices. The greatest impact of a shift in loose bulk density often is seen at those locations that use more than one alumina source. Just after a change in alumina source the customer may report that the anode effect rate suddenly increased or decreased.

Fines And Superfines Content

Fines and superfines are the focal points of many complaints about alumina. Alumina fines can impact many smelting parameters including anode effects that make potent greenhouse gases, solubility, flowability, particle segregation, emissions of dust and fluorides, pot instability, shifts in thermal balance, loss of efficiency, energy loss and formation of gray scale. The impacts are not uniform. They vary with pot technology and alumina handling system design. In some cases fines content may explain a large fraction of the variability of such impacts. It should also be noted that factors other than the fines content of SGA can contribute to each of these negative potential outcomes.

Often the content of fines, -325 mesh, and superfines, -20 micron, at the pot are more than twice the amount reported with the shipment. Alumina particles suffer attrition and secondary alumina contains fine alumina and bath dust from the pot exhaust. These facts are often over-looked since smelters may not measure this or if measured it may be thought that there is little that can be done about it. Therefore most complaints about fine ore are directed at the refineries.

Some pot types and technologies are more sensitive to fines and particle attrition than others. Among the most sensitive are side-worked Søderberg pots. These pots may be fed more than 100 kg of alumina at a time. No controls exist to capture the fumes and dust that escape during side-break feeding. By contrast Søderberg pots that have been fitted with point feeders have fewer problems with alumina fines. Søderberg pots are still fairly common and will face difficult challenges as environmental regulations for dust emissions become more common. Currently dust emissions from this type of pot may be 5 to 10 kg/mt Al produced or more. Proposed regulations such as those of OSPARCOM for much of Europe limit total dust emissions to 2 kg/mt Al at the beginning of 2007 and 1 kg/mt Al by 2012. Regulatory challenges such as these will lead many smelters to call for lower fines content in SGA and also for the ability of particles to resist attrition.

Older technology pre-bake pots have many problems in dealing with fines as well. The material handling systems may not keep the alumina contained. Some pot types in this class have open overhead bins that are filled from crane mounted buckets. Other forms of handling equipment, especially high velocity dense phase systems can cause a lot of the attrition that modern systems try to avoid. The pots themselves have often been pushed for amperage and have relatively few feeding points that replenish the pot frequently. Such designs give relatively little time for alumina to go into solution before the next feed shot discharges. These pots can accumulate un-dissolved alumina under the metal pad rather easily and then may suffer process upsets to the thermal balance and operation of the pot.

The newest pre-bake technology pots have taken these factors into consideration during design and when these are coupled with a low impact handling system and anti-segregation storage there may be minimal impact of alumina fines upon pot operations.

Smelters that do have significant issues with alumina fines at the pot can do some things before looking to their supplier for relief. Efforts to control particle segregation can take the form of capital improvements to storage tank inlets and discharges. Tank filling and unloading strategies assisted by routine measurements of fines content or alumina flowability help to reduce segregation. These measures can be particularly important with large storage tanks that hold more than 30,000 mt, but can also be effective strategies to use with storage tanks that hold 5,000 mt or less.

Smelters may also be able to control the attrition of particles to some extent. With capital improvements alumina transport systems and dry scrubber equipment can often be improved upon especially in older locations. A few things can be done with little or no capital as well. Eliminating points of air inleakage on fluidized alumina transport systems also eliminates point sources of high velocity that can break down particles. Balancing these systems and lowering fluidization air to design targets not only helps to reduce attrition, it can reduce the carry-over of fines to the secondary alumina at any point where the transport equipment vents directly to the main pot exhaust ducts.

The dry scrubber system can be a focal point for reducing the attrition of alumina as well. In some cases the recirculation rate of alumina may be able to be reduced with minimal impact on emissions of gaseous fluoride and some positive impact upon the generation of fines. It may also be possible to by-pass a fraction of the fresh alumina around the dry scrubber if the fluoride

evolution rates are low enough to permit this. The fresh alumina is then recombined with the secondary alumina for pot feed.

The refineries also have a large role to play in control of fines. Dust from the ESP units that follow calcination is divided between additions to SGA and to re-digestion for capture of the residual hydrate. To increase output refineries may reduce the ESP fraction sent to re-digestion if the product remains within shipment specifications. Not adding ESP dust to product sends a large fraction of this material to the mud lakes as residue, wasting the resources used to mine and refine it.

ESP additions easily become a contentious issue that trades off potential gains for one party for the potential losses of the other. Economic factors for both parties may be considerable, especially if the refinery makes a large amount of ESP dust. Also there is the net environmental impact that must be considered. A decision to increase dust additions to SGA contributes to greater dust emissions and a higher generation rate of greenhouse gases with most clients. These gases are estimated to last for thousands of years in the atmosphere, well beyond the next seven generations. The best position for a refinery is to make a particle that generates little ESP dust. This is easier to say than to do.

Refineries can also help to improve customer satisfaction by reducing shipment to shipment variation in fines content. Product consistency is a key to many pathways of process stabilization for smelting clients. At this time the variation in fines content has no uniform method or industry standard for measurement. As with soda content a standard lot size for a sample and the method for gathering samples from each lot would again be needed to create a standard. Currently the best available information is to use range of shipments data. This is misleading when making comparisons between refineries. Alumina shipment sizes can vary by orders of magnitude. The largest shipments will naturally tend to have the smallest ranges of ship to ship fines or superfines content.

Refineries also have some ability to affect the attrition rate of the product. Particle morphology is emerging at the center of studies on precipitation on how to make particles that do not easily break down. Success in this area can help to provide a Win-Win solution to many of the fines at the pot issue. If the alumina does not break down very easily there is less incentive for smelters to call for reduced fines and superfines in alumina shipments.

Conclusions

Metal customer demands and the requirements of smelters upon refineries will continue to tighten in the years to come. The expected shift from P-1020 to P-0610 as the par metal grade of the LME will place new pressures on ingot mills, smelters and refineries alike. Certain metallic contaminants currently exclude some alumina sources from some customers and expectations will only be higher in the years to come. Other particular properties of SGA detract from customer satisfaction of smelting clients due to cost, quality or environmental concerns.

Cost pressures on smelters will continue to drive issues that surround phosphate content, soda content and its variability, calcia content, the content of fine or superfine material, its variability and the potential to generate more fines through attrition of particles. Environmental regulations will continue to require a balance between surface area and LOI content and will pose true challenges as more restrictive regulations in dust emissions are applied in Europe and in other regions of the world.

Cost pressures on refineries will continue to drive for more yield that may risk degradation of product quality with regard to fines content, attrition index or soda content.

In the discussion of individual physical and chemical properties it has been shown that there are few properties for which the refineries or the smelters have sole responsibility. Many of the issues that have been discussed can be addressed jointly with combined efforts of refineries and smelters and in some cases with the cooperation of the ingot mills.

While the predictions and the timeframes offered in this paper may not prove to be accurate as the future unfolds it is certain that future requirements for alumina will be more challenging as customer demands and market conditions change.

The foundation for making combined improvement needs to be strengthened. In many cases key personnel at refineries and client smelters may not know one another. Technical forums such as this joint session between Alumina & Bauxite and Aluminum Reduction Technology provide a venue to begin bridging this gap and forging combined pathways to improvement.

References

1. %IACS Conductivity Data

2. Tabereaux, A.T., "Phosphorus Impurity in Aluminum Electrolysis Cells", TMS Short Course on Alumina, Charlotte, N.C., February, 2004.

3. Metson, J.B., "Making and Analysing Smelter Grade Alumina", TMS Short Course on Alumina, Charlotte, N.C., February, 2004.

4. Hyland, M., "Alumina Properties and Dry Scrubber Performance", TMS Short Course on Alumina, Charlotte, N.C., February, 2004.

5. Wong, J.F., Wainwright, P.J., Brungs, M.S., Coyne, M.P, "Factors influencing Hydrogen Fluoride Adsorption on Alumina", Light Metals, 1989, pp 113– 118.

Acknowledgements

Recommended Reading

Archer, A.M. Considerations in the selection of alumina for smelter operation (1983, pp. 231–239).

Bertaud, Y., and A. Lectard. Aluminum pechiney specifications for optimizing the aluminas used in sidebreak and point feeding reduction pots (1984, pp. 667–686).

Braun, D.J. Attrition of aluminas (1984, pp. 257–268).

Clerin, P., and V. Laurent. Alumina particle breakage in attrition test (2001, pp. 41–47).

Coque, P.G., et al. Porosity of industrial aluminas (1992, pp. 259–265).

Coque, P.G., et al. Superficial properties of industrial aluminas (1991, pp. 193–201).

Derdacka-Grzymek, A., et al. The influence of calcination conditions on the physicochemical properties of obtained alumina (1991, pp. 213–218).

Elrefaie, F.A., et al. Alpha alumina segregation in metallurgical alumina (1991, pp. 203–211).

Fortier, F., et al. A new method for selection of sodium and calcium specifications in alumina (1995, pp. 435–440).

Gu, S., et al. Influence of alumina morphology and microstructure on its strength (2006, pp. 145–148).

Hamano, S., et al. Properties of smelting grade and specialty aluminas (1991, pp. 125–131).

Hill, V.J. Factors influencing angle of repose of calcined alumina for electrolytic reduction (1963, pp. 219–228).

Hsieh, H.P. Measurement of flowability and dustiness of alumina (1987, pp. 139–149).

Hsieh, H.P. Study of alumina behavior in smelting plant storage tanks (1984, pp. 287–304).

Johnston, T.J., and R.D White. Electrical charge on metallurgical alumina (1985, pp. 315–329).

Li, W., et al. Review on the quality of alumina (2008, pp. 173–177).

Lima, J., et al. The influence of moisture in the attrition index of alumina (2009, pp. 219–222).

Lindsay, S. Attrition of alumina in smelter handling and scrubbing systems (2011, pp. 163–168).

Llavona, M.A., and R. Zapico. Effect of residual hydrate on properties of metallurgical grade aluminas (2005, pp. 93–96).

Martineni-Catalot, V., et al. A new method for smelting grade alumina (SGA) characterization (2004, pp. 87–92).

Matocha, C.K., Sr., et al. Alumina properties characterization - the flow funnel test incorporating angle of repose and loose bulk density determinations (1991, pp. 179–185).

Matocha, C.K., Sr., J.H. Crooks, and P.P. Plazio. Alumina attrition and dustiness--an extension of the attrition index method (1987, pp. 129–137).

Metson, J., et al. Evolution of microstructure and properties of SGA with calcination of Bayer gibbsite (2006, pp. 89–93).

Metson, J.B., M. Hyland, and T. Groutso. Alumina phase distribution, structural hydroxyl and performance of smelter grade aluminas in the reduction cell (2005, pp. 127–131).

Perander, L.M., et al. Short- and long-range order in smelter grade alumina – development of nano- and microstructure during the calcination of Bayer gibbsite (2008, pp. 29–35).

Saatci, A., et al. Attrition behavior of laboratory calcined alumina from various hydrates and its influence on SG alumina quality and calcination design (2004, pp. 81–86).

Shmorgunenko, N.S., G.V. Telyatnikov, and T.A. Arlyuk. An investigation on how the equipment flow sheet for the calcination processes influences the physicochemical properties of alumina used for electrolysis (1985, pp. 331–337).

Stahlin, W., J. Bachmann, and S. Molnar. Alumina morphology and particle strength (1985, pp. 423–432).

Wahl, B.J. Automatic sampling systems at Alcan smelters and chemicals (1979, pp. 31–43).

Wai-Poi, N., and B.J. Welch. Comparing alumina quality specifications and smelter expectations in cells (1994, pp. 345–350).

Williams, F.S. Improving customer/supplier relationships between alumina refining and smelting (1992, pp. 241–247).

Yanly, X., et al. Effect of precipitating condition and additives on the attrition-resistance property of hydroxide alumina (2002, pp. 149–152).