

SGA PROPERTIES AND VALUE STREAM REQUIREMENTS

Lindsay, SJ

Alcoa Aluminum, Tennessee, USA

Abstract

The properties that are included on Certificate of Analysis data sheets can fall short of meeting the needs of smelters and downstream customers when there is not a strong understanding of what is required along the value stream. Some requirements are direct. The content of ZnO in SGA can be almost directly translated into metal customer specifications. Other requirements are not so direct such as with conductivity of transmission cable. The combined content of SiO₂, Fe₂O₃, Cr₂O₃, MnO, ZrO₂, TiO₂ and V₂O₅ may rule out some SGA sources at certain smelters that are acceptable at others. The author presents observations upon these and other properties of SGA and what they imply with regard to downstream customer requirements.

1 Introduction

The following is an update of a presentation titled 'SGA Requirements in Coming Years' by Stephen Lindsay that was presented at the 2005 Annual meeting of TMS in San Francisco. [1]

Shipping specifications for SGA are focused on those physical and chemical properties that are relevant to the typical smelting client. In many cases these properties act as surrogates for other items of customer interest. For example, since there is no standard testing method for sorptive capacity of SGA clients rely upon typical surface area data. A smelter with customers who are interested in the electrical conductivity of transmission cable may have to defer to the content of certain metallic impurities in SGA.

Not all properties are complex. The soda content of the alumina is a direct input to bath chemistry control programs and calculations of bath generation or consumption. The iron oxide content of the alumina is a direct input to the mass balance for iron in the pot room metal. Other metallic oxides can be directly translated into impurities in aluminium.

However, the connections between alumina properties, smelter needs and metal customer requirements are not always well defined. In some cases the customer needs may also not be completely satisfied by the alumina properties that are routinely provided on certificates of analysis.

Since connections between refineries, smelters and metal customers are usually incomplete, enhancing the value stream requires improved understanding and communication. Interactions within the technical community are needed in this area to understanding along the value stream and communication of future needs within our respective organizations.

2 Discussion – Metal customer requirements

The interactions between refineries and smelters often begins and ends with parameters that lower cost, make alumina more process friendly, or address environmental concerns. The connection to the metal customer may only include discussions of iron, silicon or other metallic oxides. Interactions often do not include discussion on what the smelter or the ingot plant might do to address issues and customer needs. Thus what is truly needed from the refinery may remain poorly defined. Comments that are aimed at these gaps and requirements are offered below.

2.1 Iron oxide

Iron generally does not add desirable properties to aluminium. It negatively impacts conductivity, ductility, fracture toughness and high speed extrudability of metal. 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 some products such as conductor wire and rolling slab.

With the exception of purity products that require less than 850 ppm of Fe in pot room metal or high purity products with less than 350 ppm of Fe, the average Fe₂O₃ content of the alumina is often not of great concern. Typically 35% to 85% of iron in pot room metal comes from corrosion of iron and steel pot components such as anode assemblies, gas manifolds or studs. With the exception of high purity producers, smelters can do much to reduce iron content before relying heavily upon the refinery.

This does not leave Bayer plants with no need for concern. Refineries usually have multiple smelting clients. 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% Fe₂O₃ or less. Fe₂O₃ 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% Fe₂O₃ or less.

Even though few clients truly need iron oxide below 0.010% refineries should be aware that as Fe₂O₃ content increases above this level that their potential customer base does begin to diminish.

Variability is the other key Fe₂O₃ factor. Smelters often build their product plans around the ability to produce products of certain metal purity. Changes in Fe₂O₃ content in alumina impact the yields of higher purity metal grades and the ability to satisfy metal customer requirements each month. For this reason an SGA with an average Fe₂O₃ content of 0.011% and a maximum of 0.012% may be preferred to an SGA with an average of 0.009% and a maximum of 0.015%. Currently there are no industry standards for measurement of variation for Fe₂O₃ content. Maximums are a starting point, but mean little when comparing a refinery that normally ships in 50,000 mt lot sizes to one that normally ships 2,500 mt lot sizes.

One final note on iron, that which is acceptable today will 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 commands a premium in some global markets, 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 in the world currently can not meet this challenge. The market shift is already underway. Premiums for P-0610 have diminished in North America and Europe 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 refineries, especially those with Fe₂O₃ content greater than 0.010%.

2.2 Silica

The iron and silicon content of aluminium generally determines its value in the marketplace. Silicon negatively impacts ductility, formability and conductivity. Some silicon can be tolerated in many alloys

and 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 less than 550 ppm Si or high purity products that can require less than 350 ppm Si, the SiO₂ content of the alumina is typically not a concern. Generally less than 25% of smelters make products that are constrained by typical levels of Si in metal.

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. Aluminium 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 relying upon the refinery for help. Beyond raw materials, the balance of Si comes from items such as from pot lining, bricks, insulating materials or from materials such as floor sweepings. These factors often can be controlled with some extra attention to detail.

An SGA content of 0.015% SiO₂ 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% SiO₂ or less. Customers that produce conductor products may also have limits on Si since it detracts from electrical conductivity. In general SGA over 0.017% SiO₂ (150 ppm to Al) may be ruled out by some potential clients.

Maximum SiO₂ content will be of great importance to those clients that are focused on high purity production. In order to consistently produce these products and to satisfy the metal customers controlling variability and maxima can be just as important as having a low average SiO₂ content.

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 since typical pot room metal seldom exceeds 450 ppm Si, but tighter limits on Si can be expected to trickle back to refineries as markets shift and expectations rise.

2.3 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. [2]

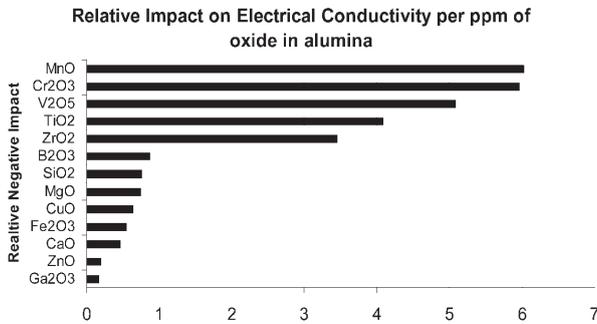


Figure 1 – Metallic Impurity impact upon conductivity converted to metallic oxide equivalents

Small increases of these metallic impurities can make large differences to some metal customers. Ingot plants can control some of these impurities by precipitating them out as borides. However, boron treatment is not desirable since the cycle time of the holding furnace must be extended to allow the borides to settle out. This reduces ingot plant capacity by tying up furnace availability. 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 aluminium from erosion of collector bars, anode stubs, manifolds 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 be wary of an SGA with more than 0.0015% MnO.

Cr₂O₃ at 0.0010% contributes 13 ppm of Cr to metal. Alumina is generally the only source of chromium in aluminium except for those

smelters 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. Some clients may try to avoid SGA with more than 0.0010% Cr₂O₃.

V₂O₅ 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 be dissatisfied by SGA with more than 0.0015% V₂O₅.

TiO₂ at 0.0010% in SGA will contribute about 12 ppm of Ti to metal. Alumina is a major contributor of Ti to pot metal, but Ti is often added in ingot plants as a grain refining agent. A level of less than 0.0040% TiO₂ is reasonable for SGA.

2.4 Gallium

Gallium reduces corrosion resistance and creates losses 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% Ga₂O₃ in SGA or more to be undesirable.

2.5 Zinc Oxide

Zinc can be particularly problematic for smelters that serve extrusion billet customers. It causes an undesirable, grainy, surface finish called spangling. While zinc may also be found in anodes the majority comes from the alumina. ZnO at levels over 0.010% in SGA may not be considered by smelting clients that produce much extrusion billet.

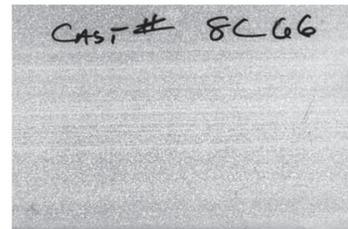


Figure 2 – Example of spangling

2.6 Beryllium

Beryllium is a worker exposure concern at some smelters and geographic regions such as the United States and Québec. Be in metal is limited to 1 ppm in many products. It accumulates in pot bath at levels of 40x to 50x the concentration of Be in SGA. Beryllium is facing greater potential for regulation and is one impurity that is currently a watch list item for alumina producers.

2.7 Phosphate

Phosphorus can create concerns for specific customers as it makes metal more porous and brittle. As an example wheel products can 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 P₂O₅ 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 its negative impact on current efficiency especially in pre-baked cells. In the range of 15 to 40 ppm of P₂O₅ in SGA it is well documented that each 1 ppm increase in phosphate will decrease current efficiency by 0.1%. [3] The multivalent nature of phosphorus robs current as it changes valence states in the pot bath, lowering current efficiency. The phenomenon is projected to be linear down to the individual ppm levels of P₂O₅ in SGA.

Phosphorus in aluminium may also come from coke, cast iron and phosphate bonded refractory or mortar. Since P causes 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.

3 Discussion – smelter process requirements

Process requirements of smelters go beyond the need for low phosphate. 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 one 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 are aimed at addressing present and future requirements of smelting customers.

3.1 Soda content

At the refinery low sodium oxide or soda level in hydrate and calcined alumina can mean lower cost through the recovery of soluble soda. On the other hand improvements to refinery yield may drive soda content in SGA upwards. At the smelter the interest in soda content has to do with bath balance, bath chemistry control as well as cost control. The ideal soda content for a refinery is complex, but generally the trend in customer requirements for soda levels is downward.

The bath of molten salt in the pot contains NaF and AlF_3 making the mass balance around sodium dynamic. Some sodium leaves with the metal. Much is intercalated into cathodes. The rate of cathode uptake 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 have a net loss of Na 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.

It costs much more in materials, energy and labor to make excess bath than it can be sold for. This causes smelters that generate 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 become louder as more smelters convert to graphitized cathodes.

Most SGAs have Na_2O that is over the bath neutral point for the customer base. 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. In general an Na_2O content greater than 0.40% is more than most customers desire and an Na_2O content less than 0.30% will not be satisfactory to all clients.

3.2 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 aluminium in bath is temperature dependant and excess fluoride is the main factor in lowering bath temperature. 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 desire low variation of Na_2O in SGA. In many cases the benefits of low Na_2O variation exceeds the benefit of having soda content at the bath neutral point. There is often more money in lost current efficiency than the costs associated with making excess bath.

As with Fe_2O_3 or SiO_2 content there is no uniform method or industry standard for measuring and reporting the variation of Na_2O 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. This is a key area that forums such as the Alumina Quality Workshop can help address and standardize.

3.3 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 aluminium and can pose a threat to high 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 is primarily 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 very high cost to the smelter.

CaO in SGA is not the only source of calcium. Anode coke also contains Ca, but this may not be reported on the certificate of analysis. Coke may account for 30% of the Ca input from raw materials.

3.4 Alpha alumina

Alpha alumina is more thermodynamically stable than gamma alumina. It also has more problems than gamma going into solution during the short time that it is exposed to liquid bath after being discharged from a point feeder. It tends to settle under the metal pad of the pots and form 'sludge' or 'muck'. Alpha is only one of many 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% in SGA is preferred by most smelting clients.

3.5 Loss on ignition

%LOI is often referred to as the chemically combined water that is Lost on Ignition between $300^\circ C$ and $1000^\circ C$. More accurately it is a measure of the combined hydroxyl units [4] 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 producers measure %LOI from $300^\circ C$ to $1000^\circ C$, while others use peak temperatures of $1100^\circ C$ or $1200^\circ C$. The net difference in the reported values is on the order of a few percentage points, but standardization would benefit potential customers that make comparisons.

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 area needed for scrubbing fumes and would almost not dissolve well in pot bath.

Søderberg customers may prefer low LOI content more than pre-bake customers since side-worked pots generally evolve less fluoride and high surface area is not needed for the dry scrubbing equipment to adequately capture HF. 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.[5] 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.

While %LOI is seldom a determining factor for selection of SGA, customers may be wary of a product with an LOI greater than 0.9%.

3.6 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 feeding forming volcanoes that can choke off the ability to further 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 dust emission levels and pot operations. This has yet to be substantiated or countered in the published literature.

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

The literature indicates that gibbsite content greater than 0.5% is undesirable. Some clients prefer to have it below 0.2% although there are some preferred alumina sources that have gibbsite contents greater than 0.6%. While the jury may still be out on the full technical implications of gibbsite the court of customer preference favors low hydrate content.

3.7 Moisture content

%MOI is the Moisture on Ignition that comes off between room temperature and 300°C. Calcined alumina is hygroscopic 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 depending upon conditions.

Fortunately the MOI flashes off rapidly and is reported to be only 5% as effective at making HF in the pot as LOI.[5] Most 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.

3.8 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. Thus, pre-bakes 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 m²/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. For most pre-bakes this requires that 70% to 90% of the SGA must pass through the dry scrubbers to effectively remove fluoride. The 10% to

30% of sorptive capacity that remains is needed during dry scrubber down-time events.

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.[6] As with surface area higher soda content aids scrubbing ability.

There have been calls to reduce fluoride evolution via reduced LOI but to do so may 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 m²/gm range. With the tendency for higher amperage to existing pots this could easily shift towards a 70 to 85 m²/gm range in the next few years.

3.9 Loose bulk density

Loose bulk density is usually of little 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 can take systems time to catch up. Modern feed systems are less sensitive to changes than older systems or side worked pot technologies. The greatest impact of a shift in loose bulk density often is seen at those locations that use more than one alumina source. Often the customer may report that the anode effect rate suddenly increased or decreased after switching an alumina source.

Providing L.B.D. data to the customer is inexpensive to do and may save the customer some problems or complaints when trying a shipment of an alumina source that is new to them.

3.10 Coarse particles

Some industry studies have indicated that particles of +100 mesh, +150 microns, or greater have a negative effect on solubility [7]. Thus they may tend to promote formation of 'sludge' or 'muck' under the metal pad of the pot. There is still a fair amount of work to be done in this area of study but some customers will be wary of an alumina with more than 5% +100 mesh and may have great difficulty with or try to avoid an alumina that is over 10% +100 mesh.

3.11 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. These 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, such as flowability, 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 overlooked 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.

It is important to clearly understand that 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 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 as high as 5 to 10 kg/mt Al produced. Proposed regulations such as those of OSPARCOM for much of Europe limit total dust emis-

sions 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 lean phase transfer 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 is less 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 ingress 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. 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. Customer preference will be for SGA with 1.0% or less -20 micron content or for product with repeatably good flow characteristics.

Refineries can also help to improve customer satisfaction by reducing shipment to shipment variation in -20 micron 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. 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. Customers desire to see data that indicates that variation in fines content is steady or improving. At the moment they must provide their own from shipment history data.

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. Many smelting customers consider an alumina to be good if the attrition index is less than 10% and bad if it is over 15%.

4 Conclusions

Metal customer demands and the requirements of smelters upon refineries will continue to tighten in the years ahead. 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 refineries from some customers. 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 higher yield that may risk degradation of product quality with regard to fines content, attrition index or soda content.

Product variability particularly in the area of -20 micron content, %Na₂O, %Fe₂O₃ and even %SiO₂ must receive greater attention. These are on the emerging frontier for relationships that can strengthen the value stream of SGA.

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.

The foundation for making combined improvement must be strengthened. In many cases key personnel at refineries and their client smelters may not know one another. This must change and technical forums such as this provide a venue to close the gaps and to begin forging combined pathways to improvement.

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