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CONSIDERATIONS IN THE SELECTION OF ALUMINA FOR SMELTER OPERATION

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The widespread introduction of new technology such as alumina pot gas scrubbing systems and stationary calciners has created an increased interest in understanding alumina properties so that overall costs can be reduced. There are a number of critical smelter operations and indices including: dry gas scrubbing, material handling, dust losses, anode oxidation, pot crust strength, heat loss through the cover, electrolyte composition and mass balance, alumina feeding and dissolution, and metal purity, that are significantly affected by alumina properties. Consistent alumina quality, or the knowledge to cope with changes in it are essential requirements for meeting the high process control standards of a modern smelter. A metholodogy for preparing realistic alumina specifications and highlighting promising areas for development is presented.

Introduction

Quantum increases in oil and energy prices and heavy pressure for reduced smelter emissions and improved working conditions have resulted in technological and other developments, in the aluminaplants and smelter, that have in turn significantly influenced the property requirements for commercial alumina (1).

The reason for the shift away from floury alumina to a lower calcined, coarse, free-flowing, strong, sandy alumina with narrower particle sizing and lower chemical impurity values can best be illustrated by examining the major developments involved.

Developments Affecting Alumina Quality Requirements

Alumina Pot Gas Scrubbing

The development of dry scrubber systems using the pot feed alumina as adsorbent for the fluorides in the pot gas effluents has, perhaps, been the most significant event affecting smelter alumina quality requirements.

The excellent environmental performance and attractive fluoride recovery economics have resulted in the technique being adopted for new smelters as well as for the retrofitting of many existing smelters.

The various systems developed have all required similar changes in alumina properties to a greater or lesser degree, primarily depending on the available gas-alumina contact time, the pretreatment of the gas before scrubbing, and the degree of particle attrition characteristic of each system (2, 3, 4, 5). These alumina requirements are:

- highly adsorbent to fluoride gasses.
- strong attrition-resistant particles.
- free flowing properties.
- Low chemical impurity levels to compensate for the recovery of certain elements in the dry scrubber with their attendant adverse effects on metal purity (iron, vanadium) and/or pot operation (calcium, sodium, phosphorus).

This impurity problem (6) is illustrated by recent data from a V.S. pot-type dry scrubber (2) installation, as shown in Table I.

Table I. Some Typical Impurity Levels in Feed & Recycled Alumina in a V.S. Dry Scrubber

Impurity	Feed Alumina	Recycled Alumina	Change	Operation Affected
$\%Fe_2O_3$	.014	.041	+.027	
$\%SiO_2$	.013	.018	+.005	Metal Purity
$\%TiO_2$	.002	.004	+.002	
$\%V_2O_5$	.002	.006	+.004	
$\%CaO$	.016	.024	+.008	Bath Composition
$\%Na_2O$	.31	.58	+.27	Cryolite Balance
$\%P_2O_5$	.0004	.0030	+.0026	Current Efficiency

It should be noted that the increases shown in Table I while illustrative of the problem cannot be used to directly relate impurity levels in virgin alumina to those in metal (or recycled alumina).

A system for removing or reducing many of these impurities has been described (5), however, the solution is costly and some problems still remain for many operators.

The oxides of sulphur which are adsorbed can also be a problem because of its effect on the working conditions on the potroom floor.

New Pot Designs

New pot designs in the 1980's were tailored to meet the pressures of escalating energy and labour costs and increased environmental and working condition demands.

The resulting long lived, hooded, high energy efficiency prebaked anode cells with automatic centre feed systems using electrolyte with high aluminum fluoride and/or other additive levels require unique and often conflicting properties in the alumina.

The major requirements were:

- good handling properties and consistency for conveying and volumetric metering from the central feeder (7).
- low thermal conductivity to reduce heat losses from the top of the cell
- low sodium levels to compensate for the decreased losses of sodium in the dry scrubber system and for the lower sodium absorption in the carbon potlinings. The latter is due to both the longer life of the cathode linings and the higher total production rate per unit weight of cathode carbon.
- low calcium levels to permit the use of higher levels of additives such as AlF_3 and LiF.
- low phosphorus levels to minimize current efficiency losses (6).
- good anode - carbon covering properties to reduce oxidation (8).

and - a stable crust to prevent over-feeding and aid the overall gas collection efficiency (12).

It is interesting to note that one response to these sometimes conflicting requirements was a proposal to use two different types of alumina on a cell - one for feeding and the other for covering the anode carbons (10).

In general, however, most operators of these cells have tended to specify a free-flowing moderately calcined alumina with relatively coarse, strong, narrow size distribution particles (1).

Environment, Working Conditions and Economic Pressures in Existing Smelters

In the 1970s, in response to demands for improved environmental and working conditions, it was discovered that the use of low-calcined alumina resulted in both improved fluoride removal in the scrubbers and in the gases permeating through the crust and, in a strong stable crust (11) with associated good gas collection.

In at least one instance (12), this was the primary reason for conversion from floury to moderately calcined sandy alumina. It is also probably one of the major factors for the substantial improvement in gas collection in older Soderberg lines.

Another item of concern has been the alumina dustiness both on an environmental and economic basis. An investigation of the factors affecting alumina dusting showed that it was necessary to compensate for extra dusting which occurs as the degree of calcination is reduced, by simultaneously reducing the proportion of fines (% -44 micron) fraction in the alumina (13). Confirmation of the effect of the percentage of fines in the alumina on dust losses in H.S. Soderberg pots has also been reported (14).

Experience in an Alcan V.S. smelter, as shown in Table II, however, indicates that the presence of gibbsitic material can also have a profound effect on dusting during the alumina crustbreak-feeding operation, while on dry scrubbing of the alumina gibbsite appears to have an insignificant effect. It is important to note that the higher dust concentrations observed with alumina "A" occurred in spite of significantly greater amounts of fine particles in alumina "B".

Table II. The Effect of Alumina Type and Treatment on Dust Loss During Alumina Feeding

	Size (microns)		Specific Surface	Gibbsite	Dust Concentrations in Working Area
	% -44	% -20	Area m^2/g	%	During Feeding - mg/m^3
Alumina "A"					
- fresh	8.3	1.2	74	1.2	400
- scrubbed	-	-	-	1.2	450
Alumina "B"					
- fresh	12.0	1.9	62	ND	250
- scrubbed	-	-	-	ND	220

ND - None Detected

Stationary Alumina Calciners

In the alumina production sphere, the development and implementation of a number of different stationary calciners has significantly reduced fuel consumption (16, 17). However, the new technology has resulted in a very uniformly calcined product, in which the previous relationships between commonly measured indices of calcination have been radically disturbed. The effect on the relationship between Specific Surface Area and % α, for instance, has been shown by Barrillon (1). This, in turn, has made the interpretation of previous work on the effect of degree of calcination on dry scrubbing, dissolution behaviour and crust strength and thermal conductivity difficult. It also poses problems in the selection of the degree of calcination index when preparing alumina specifications (18).

Material Handling

The strength of the alumina particle has become of concern not only because of the greater breakdown in the new stationary calciners but because of the attrition being experienced in new high speed pneumatic unloading and conveying equipment and fluid bed type dry gas scrubbers.

Example of Problems Associated with Unsuitable Alumina

There are a number of ways that an unsuitable alumina can unfavourably affect conditions in a smelter.

An example of such a problem was the effect on an Alcan V.S. smelter in the early 1970s when the alumina feed was changed from Type "X" to Type "Y", as shown in Table III.

Table III. Physical Parameters of Aluminas Fed to V.S. Smelter

	Alumina "X"	Alumina "Y"
% Alpha α	13	30
Specific Surface Area - m^2/g	68	40
Bulk Density - g/c^3 - Loose	0.90	0.99
- Packed	1.06	1.18
% +105 micron	7	11
% - 44 micron	6	10

In this instance:

- fluoride loss from the dry scrubbers increased by a factor of four.
- fluoride loss from the potroom roofs was 35% higher.

and

- there was severe overfeeding due to weak crust characteristics, which resulted in poor gas collection, heavy sludge and freeze formation in the pots and a very unstable operation.

Similar incidents were encountered in other H.S. and prebake installations during the first half of the 1970s and the difficulties usually arose when switching to highly calcined, dense, fine aluminas.

It is interesting to note that these results could have been predicted today on the basis of subsequent studies reported on the effect of alumina properties on crust formation and dissolution in operating baths (11, 19, 20, 21).

The overall answer appears to be the preparation of realistic specifications which can be used as a guide to those involved in the supply of alumina to the various smelters, and the development of a model that enables the smelter operator to predict the effect of a change of alumina properties on the process and thus react in an appropriate manner.

Specifications

New alumina specifications for the individual smelter systems can thus be prepared and an example of the format used together with a number of illustrative items is shown in Table IV.

The specifications use the following guidelines.

- the alumina should result in acceptable performance and metal purity in the particular smelter.

Table IV. An Example of the Format of an Alumina Specification

Required Specification						
Property		Min.	Typ.	Max.	Analytical Method	Remarks
Moisture	%	-	0.4	0.7	ISO 803	Analysis on sealed sample taken at point of loading. Directly related to alumina consumption factor.
Specific Surface Area	m^2/g	60	65	90	Alcan "A"	Min. & typ values essential to meet gas scrubbing limits. Values greater than Max increase dust loss & sulphur pick-up
Phosphorus	% P_2O_5	-	.0003	.0010	ISO 2829	Current efficiency loss increases by 0.2 % per 0.001% P_2O_5 in alumina
				etc.		
In addition to the above "Required Specifications", excursions outside the limits for the following properties must be signalled to and approved by the local smelter management involved.						
Bulk density						
- loose	kg/m^3	0.92	0.95	0.98	ISO 903	Consistency essential for satisfactory alumina feed control
- packed	kg/m^3	1.08	1.12	1.16	Alcan "B"	
Permeability at loose bulk density	centidarcys	5	7	10	Alcan "C"	Suspected effect on pot crust behaviour

- a typical value together with a maximum and minimum should be shown for each item.
- the analytical and sampling method should be agreed to by both parties.
- the reason for, and if possible the cost/benefit, of a variation should be shown for each item.
- the quality specified should reflect, as far as possible, that currently being received from the major supplier. Notation should however be made of those items requiring future improvement.

and,

- the document should be periodically updated to review progress on improvements requested and changing conditions in the ore plant and smelters.

These specifications are a useful base for controlling the quality of smelter alumina receipts and indicating areas for changes in alumina quality. However it is apparent in preparing such documents that there is insufficient knowledge available, particularly in the case of the physical variables, to make an informed decision in certain items.

Consequently, in order to provide a sound base for preparing specifications, and, also to provide the knowledge to permit a smelter to cope with changes in alumina properties, it is necessary to prepare a model that predicts the effect of changes in alumina on smelter performance.

A Predictive Model Relating Alumina Propeties to Smelter Process Behaviour

A Predictive qualitative model is shown in matrix form in TABLE V.

This model does not include a comprehensive list of all the variables measured on an alumina, but is confined to those properties which can readily be influenced either by the design or operation of the normal Bayer process. It should be noted that in line with recommendations (18) the degree of calcination has been restricted to the specific surface area.

It is believed that there are a number of other properties such as bulk density and permeability which influence the behaviour of alumina in the smelter process. However these are not items that can easily be controlled by the producer and are believed to be related to the three major variables indicated in the model. Attrition index is also a property that is of major concern. This property appears to be related to both precipitator circuit design and operation.

Discussion

Several economic, organizational and technical changes in the past decade have prompted an increased interest in the effect of alumina properties in the overall performance of the ore plant-smelter system. However there is a surprising lack of knowledge in this area which has inhibited the optimization of these properties to improve the overall system performance.

Alumina sizing and degree of calcination are two fields where significant improvements might be made in certain instances if the effect on such critical items as alumina dust loss and crust behaviour were understood and could be quantitatively predicted.

One of the important conclusions in our work has been that in selecting alumina for smelter use there is no one "ideal alumina". The grade of alumina required for each smelter can vary widely depending both on the gas scrubbing system as well as the pot design. As an example, an alumina selected to give a strong stable crust to ensure good gas collection on a V.S. type cell could create severe problems with anode changing if used in a prebake anode type smelter. The specifying of alumina must thus be done with careful consideration of all the logistic, design and operational factors involved in each particular ore plant-smelter system.

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Table V. A Predictive Model Showing Qualitative Relationships Between Changes in Major Alumina Physical Properties and Smelter Process Reactions

Smelter Process Effects / Alumina Properties		Crust			Alumina Dust Loss	HF Loss from:		Ease of Handling	Sludge Formation
		Thickness	Strength	Heat Loss		Pots	Scrubber		
Specific Surface Area m^2/g		?	H↑	M↓	H↑	M↓	H↓	H	L↓
Particle Sizing (μ)	+ 149	HX	HX	HX	HX	HX	HX	H↑	M↑
	- 45	?	M↓	?	H↑	HX	M↓	H↓	?
Particle Size Distribution		?	M↓	M	M↓	L↑	M↓	H↓	L↑
Gibbsite - %		?	?	?	H↑	LX	M↑	L↓	M↓

Notes:

1. The direction (↑) increase, (↓) decrease and (X) no effect on the smelter process reaction of an increase in the value of the alumina property is as indicated, (?) indicates relationships that are unknown.
2. Letters, H, M & L indicate high, medium and low levels of confidence in the prediction of the relationship.

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