THE COMALCO BAUXITE ACTIVATION PROCESS

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Abstract

Thermal treatment of bauxite for removal of organic material has been attempted on numerous occasions in the past, but for reasons of deactivation of dehydrated alumina phases under otherwise economically attractive processing conditions there has been no commercial implementation of such processes. In recent work it has been surprisingly found that thermal treatment of bauxite can simultaneously achieve the extinction of crystalline alumina bearing phases, the destruction of extractable organic carbon and the avoidance of deactivation of alumina by water vapour. The thermal processing conditions are such that the process can be conducted with low energy consumption and high intensity. The outcome is a commercially viable process for converting boehmitic high temperature digestible bauxite to low temperature digestible bauxite. The process has been piloted at a scale of one tonne per hour.

The properties of the product are such that in low temperature digestion alumina reversion effects are almost undetectable and very high liquor alumina loadings can be achieved, particularly in double digestion scenarios. Other advantages in the Bayer process include extinction of carbonate and oxalate, very high purity liquors, reduced scaling rates from liquor, improved product purity (especially in relation to soda and silica). Quartz digestion can be almost completely avoided. The liquor productivity that can be achieved with the activated bauxite product is such that a significant expansion of output from existing digestion and precipitation circuits can be expected.

Activated bauxite rehydrates with a heating and liquor dehydrating effect in the Bayer process, and in combination with the enhanced liquor productivity and enabled cogeneration, results in a neutral overall energy effect.

1. Introduction

1.1 *Bauxite in the Bayer Process*

The modern Bayer alumina refinery depends on the reliable supply of large volumes of bauxite feed. The bauxite is produced at low cost, and has predictable properties that suit the refinery design. Blended bauxite is fed to Bayer process mills in its naturally occurring condition, with the exception in some cases of the exclusion of particular size fractions, or partial drying.

The properties of bauxite vary widely, in alumina grade, mineralogy, caustic consumption and impurities content. Table 1 summarises some of the key characteristics of commercially processed bauxites (Boke, Darling Ranges, Gove, Trombetas, Weipa Grades A & D).

The optimum design and operational productivity of a Bayer refinery is specific to its chosen bauxite feed, with particular sensitivities to the following characteristics:
- mineralogy of contained extractable alumina (establishes the optimum digestion temperature, and therefore the size and specification of heater and flash trains, and of the liquor evaporation circuit; also limits power cogeneration opportunities)
- extractable alumina content (determines bauxite to alumina ratio, and mud settling and washing load)
- moisture content (affects digestion productivity, and evaporator size)
- organic and inorganic impurity species that form soluble sodium salts (accumulate to reduce productivity, by caustic displacement and retardation of precipitation, and also contribute to refinery odour)
- organic impurities (oxalate formers and oxalate modifiers) that affect oxalate co-precipitation with alumina, and can therefore promote or modify excessive nucleation of alumina hydrate; these impurities limit productivity to that which does not overload single pass removal of oxalate in acceptable locations
- mineralogy and particle size of mud making components (affects settler and clarification productivity according to mud characteristics)

These bauxite specific influences on design and productivity are sometimes direct, but are often indirect. Some limitations on productivity due to bauxite characteristics are for the purpose of protecting product quality. For example, retardation of precipitation by organic impurities can be accompanied by elevated occlusion of soda into hydrate unless the main controllable productivity driver (liquor supersaturation) is relaxed. Similarly, increased nucleation due to oxalate formers is accompanied by the need to increase the rate of agglomeration relative to nucleation, also achieved by means that can reduce productivity.

1.2 *Bayer Process Modifications*

As productivity limiting effects in bauxite feeds are understood, processes to deal with some of the associated symptoms have entered refinery flowsheets. Some such processes are:
- "sweetening" of liquors exiting from high temperature digestion by injection of low temperature digestible bauxite that boosts liquor alumina loadings
- partially countercurrent double digestion (low temperature digestion, using liquors from higher temperature digestion of residues), for bauxites having moderate boehmite contents

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Table 1 — Typical compositions of commercially available bauxites (dry basis, commercial digestion)

Component	Trombetas	Boké	Darling Rge	Gove	Weipa A	Weipa D
Al_2O_3 %	53.4	56.0	34.0	52.0	53.0	56.4
Fe_2O_3 %	11.0	10.4	21.0	15.5	15.5	6.2
Total SiO_2 %	4.2	1.4	24.0	4.2	2.9	7.1
Quartz %	0.9	0.3	22.5	1.2	0.6	2.3
LOI %	28.4	28.1	20.0	24.5	23.1	26.8
Organic carbon %	0.02	0.12	0.30	0.20	0.23	0.23
Organic C rate (kg/t alumina, excl oxalate)	0.2	1.4	5	3.2	1.9	1.9
Sodium oxalate rate (kg/t alumina)	0.06	1.4	5	4.1	3.5	3.5
Sodium carbonate rate (kg/t alumina)	2	6	15	7	19	19
Ratio monohydrate/trihydrate alumina	0.01	0.14	0.02	0.02	0.32	0.14

- liquor impurity removal processes, e.g. salting out evaporation (with thermal salt cake destruction), wash liquor causticisation and oxalate destruction
- wet oxidation (oxygen injection into high temperature digestion) to convert soluble organic species to oxalate and carbonate that can be removed by the above processes
- thermal oxidation of concentrated liquor/salt slurries ("liquor burning") for side stream removal and destruction of soluble organics, oxalate and carbonate.

These processes have then introduced side effect symptoms (such as elevation of silica in liquor, with consequent heater scaling in the case of sweetening, or increased concerns with odour in the case of liquor burning) that have led to the development of additional process steps. (Examples are post precipitation desilication, hot bypassed spent liquor injection with sweetening bauxite, and thermal decomposition of reactor and vent gases). The consequence is alumina refineries of often complex and specialist design.

1.3 An Alternative Approach: Bauxite Activation

Improved understanding of the Bayer process, and an industry wide commitment to its development, has permitted the Bayer process to be specialised for particular feeds, at progressively higher levels of productivity, while making a product having improved quality at lower cost.

However, there have been notably few successes in modifying feedstocks to better suit the Bayer process so that it can be simplified and made even more productive.

Recently, the international alumina industry participated in an AMIRA managed workshop aimed at identifying strategic technology thrusts for the industry as a whole. The modification of bauxite properties to better suit the Bayer process was identified as one such thrust.

The first recorded thermal treatment of bauxite is contained in a licensing agreement between Karl Josef Bayer and Emanuel Ristori in 1894 (Macfie, 1989), i.e. in the earliest days of the Bayer process. The aim was "to do away with most of the water and organic matter". Since this time there has been a great deal of work aimed at eliminating organic matter by thermal treatment, (including commercial application — Macfie, 1989, Pohland and Tielens, 1983) and it has been recognised that under some quite limited conditions the extraction of the thermally treated product in Bayer digestion is not necessarily impaired (Kobayashi, 1975, Brown, 1989, Russell et al, 1955).

Rijkeboer (1992, 1993) performed ground breaking work in the area of organic carbon removal, identifying both the major incentives and the main issues that prevented economic success. The conditions for the desired effect, of carbon removal without loss of extraction, included almost quantitative exclusion of water vapour, resulting in high energy consumptions in any practical

system in heating the necessary dry diluent air, and requiring indirect heating of the reactor (because of the water vapour content of combustion gases). While no mechanism was given for the loss of extraction when water vapour was not excluded (to below 2 kPa) this effect was clearly demonstrated. It was difficult to justify the process economically while it was hampered by this limitation.

After a century from first suggestion of thermal treatment as a means of removing organic matter from bauxite, and after considerable further work aimed at producing the desired effect and understanding the benefits it had still not proven to be possible to achieve the result by practical and economic means.

It had also been demonstrated that thermal decomposition of boehmite (as a pure phase) could be achieved to produce a variety of alternative products, some of which were amorphous (Abrams and Low, 1969, Ingram-Jones et al, 1996). This led to the additional possibility that low temperature digestible bauxite might be produced by thermal treatment of boehmitic bauxite (although no digestion results from such treatments were available).

However, given experience through to the mid 1990s the possibility that organic carbon removal, decomposition of boehmite, and decomposition of gibbsite could be achieved simultaneously in a simple pre-treatment that could be practically operated and allow productive low temperature digestion at enhanced extractions seemed remote.

As it occurs naturally the largest partition of Comalco's Weipa bauxite has a high level of boehmite, restricting its future use to processing in high temperature refineries. It also has a moderately high loading of altered organic matter, contained within the pores of the pisolitic bauxite, by virtue of its surface location. Comalco has a high incentive to develop more productive and lower temperature means of converting bauxite into refined alumina trihydrate. Commencing with a small amount of testwork in 1996 Comalco therefore began to investigate a possibility having high economic potential but at that time low perceived chance of success.

In work since 1996 (Hollitt et al, 2000) it has been confirmed that a single industrially operable thermal treatment process can have the dual impacts on Weipa bauxite of:
- quantitative destruction of boehmite, and
- elimination of the majority of extractable organic carbon, including all oxalate and most carbonate formers.

The process involves partial thermal dehydration of the bauxite under conditions that are controlled to ensure that digestibility is significantly enhanced while extractable forms of carbon are eliminated. Process conditions that represent a good overall thermal effectiveness, using direct heating and with high water vapour content exit gases, have been identified and tested at large scale.

Under optimised conditions low temperature digestible bauxite that supports a high purity (and highly productive) Bayer process liquor, and a highly simplified Bayer process, has been produced from a range of Weipa bauxites, including highly boehmitic bauxites.

The key to the process is the avoidance of thermal deactivation of dehydrated gibbsite under the influence of water vapour at temperatures that are sufficiently high to decompose boehmite. This poorly understood effect does not result in any distinguishable compositional or physical change, including changes that would normally be detectable by infrared analysis and NMR analysis. Deactivation is detected by impaired digestion response, but has not been detected by any other technique.

2. Digestion Test Methodologies

Three types of digestion tests have been conducted for the purpose of this work (Table 2). "Fast" tests were for the purposes of providing immediate feedback on the digestion characteristics of activated bauxite products made in continuous equipment (i.e. for optimisation and control). A range of test conditions was used over time, as the implications of the treated bauxite compositions for liquor circuit conditions became progressively better understood.

In many cases bauxite was predesilicated in synthetic spent liquor prior to digestion (i.e. held in spent liquor for long enough to convert the majority of dehydrated kaolin to sodalite), with the aim of simulating the impact of slurry tanks on bauxite behaviour in digestion.

Table 2 — Ranges of digestion test conditions for activated bauxite

	"Fast" test	"Extraction" test	Simulation
Start A/C*	0.40	0.40	0.43
Target A/C	0.74	0.73–0.74	0.73
Target CS	280	280	310
C/S** ratio	0.9	0.96	0.96
Temperature, °C	175	175	175–200
Time, mins	15	30	12–30

*A/C expressed as mass ratio of alumina to caustic, with caustic expressed as though present as Na_2CO_3
**C/S is the ratio of caustic to soda present as caustic and carbonate, all expressed as though present as Na_2CO_3

3. Thermal Processing Testwork and Digestion Responses

Figure 1 provides the typical DTA/TGA response, illustrating the thermal dehydration of ground Weipa
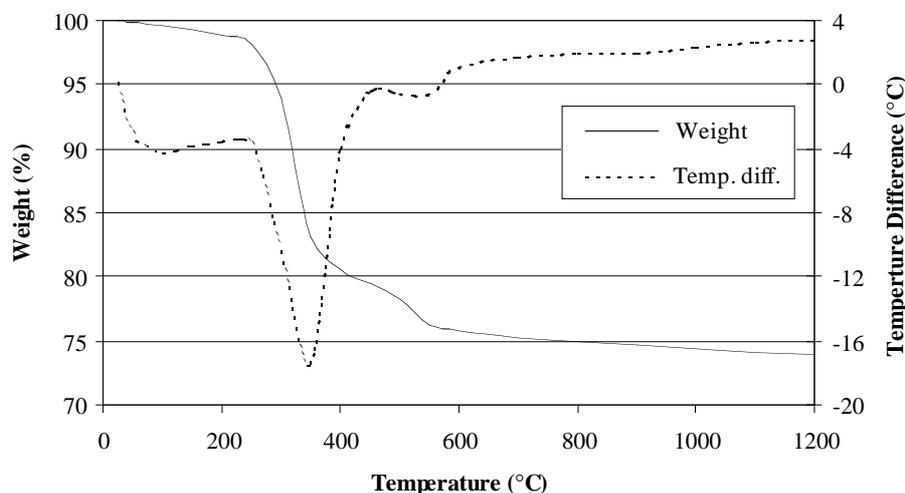
"Grade A" bauxite. Except at slow decomposition rates the thermal dehydration products of gibbsite and boehmite in Weipa bauxites are X-Ray amorphous.

In the process of dehydrating the bauxite, kaolin and any goethite are also thermally dehydrated.

In bauxite activation it is generally advisable to aim at the lowest finishing temperature at which the boehmite and extractable carbon extinction can be achieved, to avoid formation of transition aluminas that are of poor extractability.

Experience is that the DTA/TGA response is shifted to higher temperatures for a given dehydration effect as heating rate increases. Under "flash" heating conditions this shift is approximately 50°C.

Any process aimed at "activating" boehmitic Weipa bauxite for low temperature digestion will therefore ideally operate at bauxite finishing temperatures in the range 520°C to 600°C. This range corresponds to that found by Rijkeboer to be highly effective in the elimination of organic carbon, although at conditions that either were not industrially applicable or produced a loss of extraction through thermal deactivation.

Work by Comalco in muffle furnaces (30 to 180 minutes at 470–500°C), and in fluidised bed and gas suspension heating (see Table 3, including "extraction" test results) confirmed the sensitivity to water vapour, particularly at higher solids temperatures and longer holding times. While there was little sensitivity of the *composition* of finished materials to treatment time or gas purge it was confirmed that water vapour sensitive *deactivation* of thermally treated products was a function of time at temperature.

In the relevant digestion test the original (untreated) bauxite provided initial extractions to liquor of available alumina of well less than 80%, which alumina extraction will not in practice remain supported if the liquor is maintained in contact with the boehmitic bauxite residue.

X-Ray diffraction analysis of residues found no crystalline forms of alumina or hydrated alumina, confirming quantitative extinction of the approximately 15% boehmite in the original sample. This testwork confirmed that the mechanism involved in water vapour dependent thermal deactivation of activated gibbsite was time dependent.

4. Optimum Process Conditions and Thermal Requirements

After establishing the practicality of the proposed process for enhanced extraction (88.7%) and elimination of the extractable component of organic carbon (to 0.01% on an original bauxite basis) by work at 40 kg per hour in a

Figure 1 — Typical DTA/TGA Response Curves for Weipa Grade A Bauxite.

tube furnace (FFEM, Allentown Pa.), work was then conducted in a second stage, aimed at larger scale continuous multistage countercurrent gas/solids contacting, to provide the process with industrial credibility as a scale-up proposition, and to demonstrate a workable and optimised thermal balance. Figure 2 provides the particle size distributions of ground feed and product bauxites in this work.

Process optimisation was not intuitive, requiring the use of a parallel process model to ensure that operating conditions were both pragmatic at full scale and capable of producing the required product characteristics.

In this work the physical arrangement involved three preheating stages and a final finishing stage, with each stage of heating conducted in gas suspension with the exit gases from the later stage. The arrangement was similar to that used in preheating of cement meal, and in alumina calcination, with the exception that product cooling was via a rotary cooler. Between each heating stage gas/solids separation was conducted in a hot cyclone, with gases passing to a prior stage and solids passing via locking valves to the next, higher temperature stage. Preheated air, produced by introduction of combustion gases directly into a flow of compressed air, was forced into the final stage via a throat that prevented back flow of solids. Temperature control of inlet gas was via control of the combustion system, so that gas velocity could be independently set.

In order to control heat introduction to the feed independently of final stage temperature, which was important to optimisation of fuel consumption while avoiding over-burning of the thermally sensitive product, especially the finest fraction (which was used as a "litmus" test), the combustion gases from a second combustion chamber were introduced to the exit gases from the final heating stage. In this manner the heat in the gases passing to earlier stages could be supplemented without compromising control of product characteristics. This modification to conventional multistage countercurrent thermal treatment systems is an important feature for optimisation of the thermal activation of many bauxites.

After some experience it was possible to control the process via DTA/TGA response of the calcined product, but the test involved subtle changes in response rather than phase extinction. The process was successfully operated at up to 1 tph of dry bauxite feed.

Figure 3 is an indicative flowsheet for the commercial process. Note that the cooler is a countercurrent gas suspension cooler train.

In practice the dusts collected by electrostatic separator from the process off gases will be split, with one fraction passing to the third preheating stage and the remaining fraction passing to a small supplementary suspension calciner. In this manner partial direct recapture to product and partial calcination is enabled so that dust reprocessing volume and thermal duty is minimised, while a large recirculating flow of dusts in the preheaters is avoided. At the same time, boehmite extinction and carbon destruction is ensured in all products, including dusts. Exit gases from the dust calciner are diluted with cooling air, dedusted through an electrostatic precipitator and passed to join hot gases entering the throat of the main calciner.

Reprocessing of dusts according to this scheme was successfully tested in the 40 kg per hour entrained flow tube furnace.

Irrespective of the conversion of bauxite to low temperature digestible forms in all cases via extinction of the original bauxite mineralogy the final digestion behaviour

Table 3 — Processing conditions and extraction results achieved: laboratory

Apparatus	Fluidised bed	Fluidised bed	Fluidised bed	Fluidised bed	Suspension
Bauxite passing size, microns	1000	1000	1000	1000	106
Temperature*	510	510	540	540	750
Residence time, mins	5	5	11	11	0.025
Extaction**	83.7	83.5	85.6	81.2	90.4
Final A/C	0.685	0.684	0.691	0.676	0.707
Water vapour pressure, kPa	8	18	<5	18	30

* Gas temperature in the case of suspension
** Net extraction of available alumina to liquor, rather than conversion of hydrated alumina to alternate forms
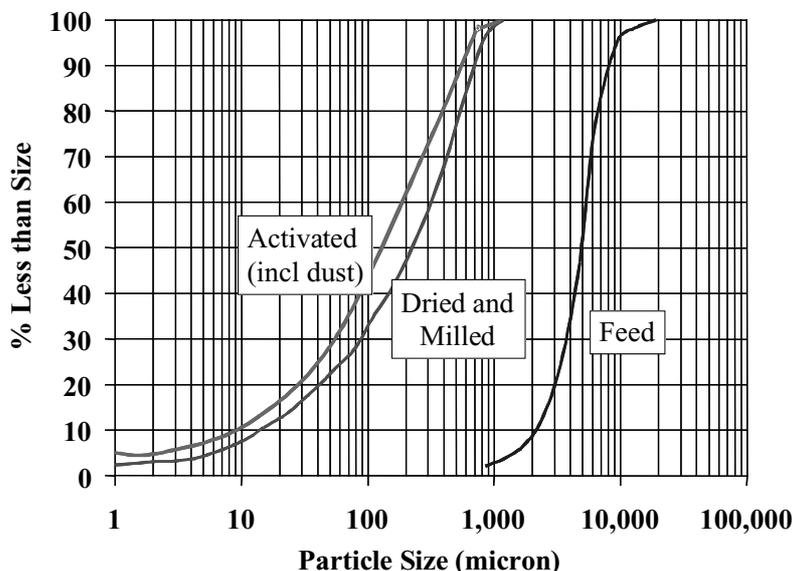

Figure 2 — Typical Particle Size Distributions In Large Scale Activation Work.

was still influenced by the original mineralogy. Activated boehmite was not as quickly digested as activated gibbsite, resulting in digestion of a less quickly digested form of alumina under conditions where the driving force for digestion was also reduced by faster digestion of the more quickly digestible form. In a batch single stage digestion test of *fixed duration* this translates to extraction of alumina from activated bauxite that is dependent on the boehmite content of the *original* bauxite, as shown in Figure 4.

Complete extraction can nevertheless be achieved with longer digestion times, or at lower target liquor loadings. Extractions of 93% have been recorded for the product of the pilot reactor in longer low temperature digestion tests using liquors that optimise the Bayer process for this material.

This type of digestion response provides the incentive for the application of activated boehmitic bauxite in a double digestion flowsheet, having the important distinction from existing double digestion flowsheets that each stage can be conducted at essentially the same pressure, and feeds are not limited to having moderate original boehmite contents. Activated gibbsite is very quickly digested to very high finishing liquor loadings, while activated boehmite can be easily and quickly digested in low temperature digestion at low liquor loadings.

It is important to recognise one of the most important features of activated bauxite muds: the muds have no

crystalline alumina bearing phases that act to seed the precipitation of alumina from supersaturated digestion solutions. The muds also do not react with Bayer liquors to produce crystalline phases in any timeframe of importance to digestion, liquor flashing or mud settling.

This effect is dramatically illustrated in Figure 5, which records the results of holding a highly overcharged digestion liquor (A/C = 0.78) in contact with its poorly extracted muds (65% extraction) at 135°C, following digestion of optimised activated bauxite. Note that the stable liquor loading exceeds even thermodynamically projected gibbsite solubility. In the presence of boehmite this is a highly unstable condition that can normally not be tolerated. However, with activated bauxite there is no measurable autoprecipitation from this highly supersaturated liquor over a timeframe of two hours, nor is there appreciable boehmite formation from residues in this time. In digestion/flash simulations activated bauxite was the only bauxite tested for which the A/C ratio actually increased (slightly) rather than reduced down flash.

5. Optimum Product Properties

The compositions and selected digestion characteristics of the optimally activated product from Grade A bauxite are provided in Table 4, where it may be compared with some of the characteristics of Trombetas bauxite recorded
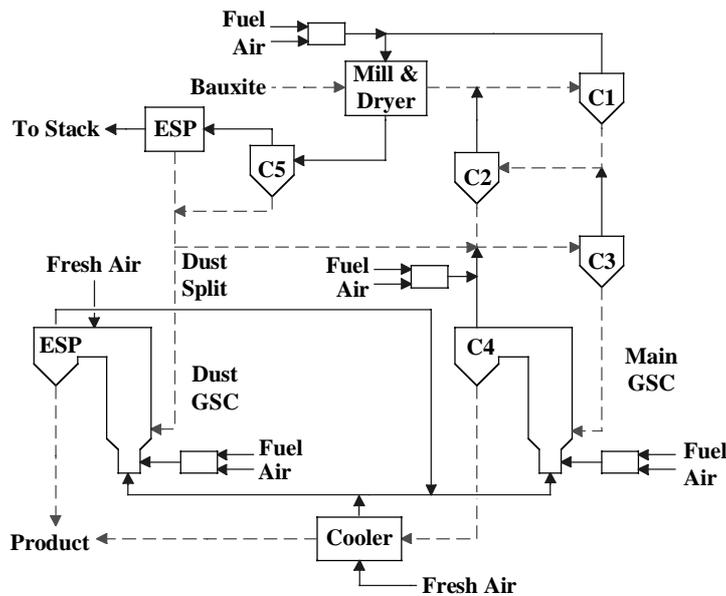

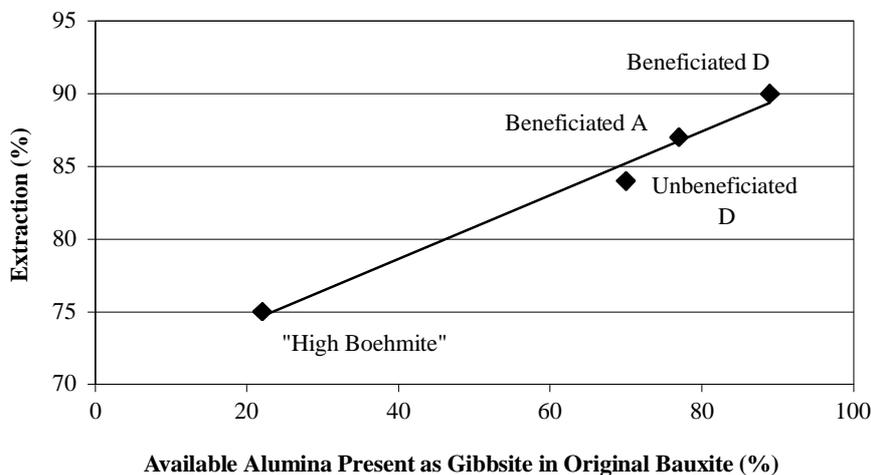Figure 3 — Flowsheet Showing Gas and Solids Streams (solids flows shown as dashed lines).

Figure 4 — Dependence of Extraction on Original Boehmite Content.

in Table 1. The comparison with Trombetas bauxite is for the purposes of demonstrating the similarity of activated bauxite characteristics (with the exception of LOI) to this clean, high alumina, low temperature digestible, easily processed and high value-in-use bauxite.
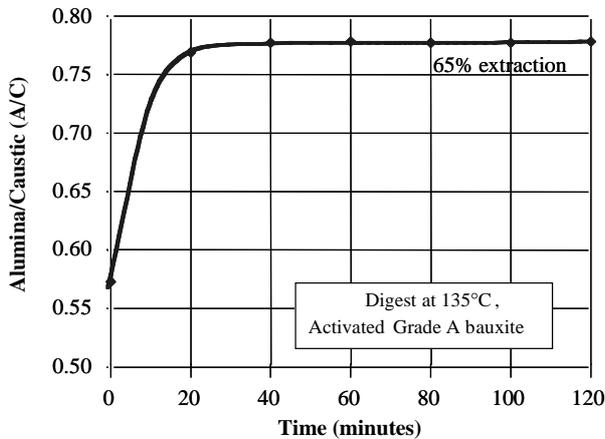

Figure 5 — Overcharged Extended Low Temperature Digestion of Activated Bauxite.

Table 4 — Composition and characteristics of optimally activiated bauxite

Component	Weipa A	Weipa B
Al_2O_3 %	67.8	72.7
Fe_2O_3%	19.8	8.2
Total SiO_2 %	4.2	9.4
Quartz %	0.9	3
LOI %	5.5	5.6
Organic carbon % (original bx basis)	0.06	0.06
Organic C rate (kg/t alumina, excl oxalate)	0.28	0.28
Sodium oxalate rate (kg/t alumina)	0.095	0.049
Sodium carbonate rate (kg/t alumina)	2.2	1

At 175°C the extraction achieved for this material when a single stage digestion test was conducted at the elevated caustic strengths that can be used with activated bauxite was 90.3% to an A/C of 0.71. (Note that the extraction is of the "available alumina" in feed that transfers to liquor, i.e. is net of all alumina precipitation mechanisms). This net extraction is comparable with that achieved in lime assisted high temperature digestion of Weipa bauxite, in which some quartz digests, and some alumina is precipitated as

hydrogarnet, but at a lower temperatures, and a higher liquor loading. That is, the bauxite to alumina ratio is preserved.

Caustic consumption associated with the Weipa bauxite, especially the higher silica grades, is substantially reduced by bauxite activation, as the effective digestion of quartz of 30 to 55% that occurs depending on process conditions in high temperature digestion can be eliminated in low temperature digestion.

The single stage digestion characteristics of the activated bauxite can be compared with the digestion characteristics of as received Weipa bauxite, as in Figure 6.

The limits imposed by boehmite solubility have been removed. Results also show a much reduced dependence of extraction on charge ratio. Increase in charge ratio by 0.04 (A/C) results in only a 3% loss of extraction, with no down flash or settler stability side effects. There is no sharp digestion curve break point as there is for digestion of as received bauxite. Lower than traditional extractions may therefore be chosen to provide significantly enhanced productivities, with substantial economic benefits.

6. Bayer Process Implications: Flowsheets, Carbon, Caustic Strength, Productivity, Consumables

The application of activated bauxite to Bayer flowsheets will depend on particular circumstances. In all cases liquor circuit productivity will be higher than available with as received bauxite, as a result of the higher liquor loadings (i.e. A/C) that are available even with low temperature digestion, and due to the higher caustic strengths that can be used without penalty where liquors have very low contents of organic and inorganic impurities. Laboratory and circuit modelling work has confirmed circuit impurity levels corresponding to 2 gpL total organic carbon (balancing insoluble and adsorbed outputs in mud, and outputs in liquor with mud and washed product with carbon inputs) and a C/S ratio in excess of 0.95 when fed with activated Weipa bauxite. Further, lime addition is reduced to the small amount needed for phosphorus control, and caustic consumption is reduced by the amount that is normally consumed in quartz digestion.

Bauxite slurrying is self heating for the purposes of predesilication, by virtue of the heat of rehydration that is partially released at this point. In fact slurrying potentially overheats in many applications, requiring the installation of vacuum spray condensers on slurry tanks for temperature
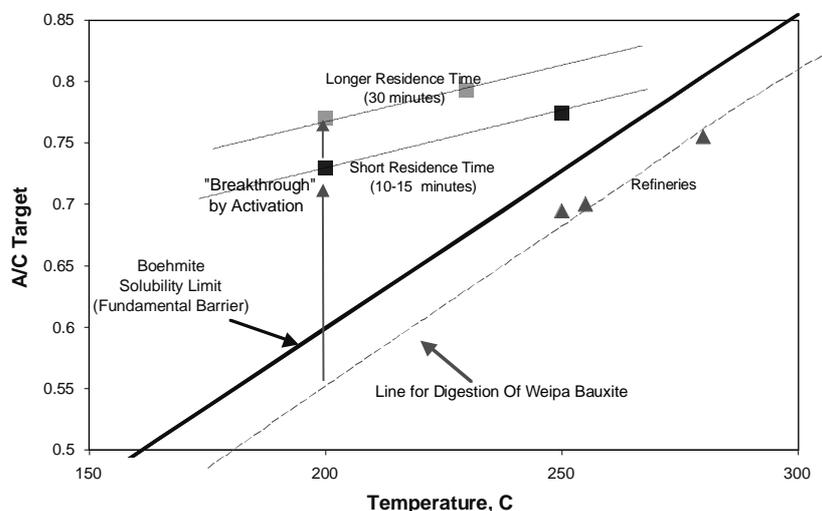

Figure 6 — Digestion Characteristics of Untreated and Activated Weipa Bauxites (at 92.5% Extraction to Liquor).

control in cases where there is insufficient spent and dilution liquor diverted through the slurry tanks to capture the heat. The dry dehydrated feed, coupled with the avoidance of seed wash, and evaporation from slurry tanks where necessary, results in a reduced evaporative load in the liquor circuit, so that evaporation plant can be avoided other than for emergency purposes, and virtually all steam can be applied in digestion.

Dilution liquor from mud and product washing is advantageously bypassed around its customary inclusion in precipitation liquors, being now introduced to maintain caustic strength in a slurry storage that would otherwise concentrate the liquor (interfering with efficient predesilication). This bypass also reduces the heat exchange load between pregnant and spent liquors. Further, the bypass reduces the supersaturation in agglomeration, which will nevertheless equal or exceed that of any presently operating refinery. The bypass has benefits in product quality, particularly for silica (and occluded soda) in product.

In the case of a new line or a greenfields refinery the best means of application is almost certainly the installation of countercurrent double digestion, with each stage operated at about 175°C splitting spent liquor between slurrying and second stage liquor heating, with pressure decantation after each digestion stage, and no need for interstage flashing. In this case a target ex settler A/C of 0.78 has been proven at circuit extractions exceeding 92% in internally balanced laboratory flowsheet simulations. With choice of caustic strength appropriate to the oxalate and organics free liquor, a circuit productivity of 110 gpL, taken on an "all liquor entering precipitation" basis, has been modelled as an appropriate target. Since recycled seed will not need washing it can easily be diverted to provide the necessary area in agglomeration for the higher implicit supersaturation.

In the more probable case of the expansion of an existing high temperature refinery by retrofit, the otherwise redundant high temperature flash tanks can be enlisted to add digestion residence time for the lower temperature digestion, and high pressure steam can first be let down through turbines to provide power by backpressure cogeneration, while still providing sufficient energy for the same liquor flow through the now higher productivity digestion. This energy effectiveness reflects the elimination of steam demand for evaporation and predesilication duties. Otherwise idled liquor heating capacity (given the lower digestion temperature) can be applied to partial replacement of direct steam injection (in the case where slurry heating is not already installed), improving condensate quality and further ensuring that evaporation plant is not needed.

The optimum digestion temperature for a *retrofitted* high temperature digestion plant may be as high as 200°C, reflecting the trade-off between digestion kinetics and residence time freed up by enlistment of existing flash units for digestion. In this case the A/C in liquor to precipitation will be approximately 0.73 from the single stage digestion of activated Weipa bauxite, for a yield in an economically optimised precipitation circuit, assuming the same finishing temperature, of approximately 94 gpL (same basis as above). The modelled circuit corresponds to an improvement of 33% to 50% in production capacity of present high temperature Bayer plants fed with Weipa bauxite.

Necessary plant modifications outside of the activation process itself are minimal, due to the retention of present flows, the elimination of seed wash, the reduced liquor circuit energy consumption, and the elimination of causticisation and oxalate destruction. Seed wash filters can be redeployed as seed filters to provide a larger load of recirculating and flexibly deported seed. Bauxite milling (dry closed circuit air swept milling) will be adequately conducted within the activation scope. Additional mud settling, washing and handling capacity will be needed, as will additional seed slurrying and a calcination expansion. That is, the retrofitted expansion will be very low cost in the Bayer circuit itself, given the incremental production that can be obtained.

Further, since much higher liquor loadings in precipitation liquors are achievable with an activated bauxite feed there is little or no incentive to operate sweetening, significantly simplifying the operation of the converted refinery. It has been shown in laboratory tests that for the activated bauxite digested at 200°C the extraction/liquor loading relationship is not further improved by sweetening compared with introduction of the bauxite directly into digestion.

The destruction of virtually all of the most active organics groups in the activation process is expected to result in a dramatic reduction in odour emissions from a Bayer process that is fed with activated bauxite. The activation process itself does not produce any detectable odours.

The activation of the bauxite can be conducted in pre-heater/calciners that can each handle up to 1.5 Mtpa of bauxite at a fuel consumption of approximately 2 GJ/t (original bauxite), if primary energy is used. This direct energy consumption is much lower than that which could be achieved if the process was to be limited to low water vapour pressures, and the equipment for application is much simpler. The configuration of the calciners is not substantially different from alumina calciners, but the thermal duty is much lower per tonne of feed. The required maximum temperature is also substantially lower. Each calciner will require a dedicated mill, and a single small dust calciner (single stage) will also be required, servicing several main calciners. There is no necessity to use primary energy in bauxite activation. In particular, the exit gases from a gas turbine are particularly suited to bauxite activation, supplemented as needed with duct firing, providing a further cogeneration opportunity.

The primary energy consumption gain in moving to 94 gpL yield will be 2.4 GJ per tonne of alumina (approximately 1.2 GJ per tonne of original bauxite feed to activation), as a result of reduced energy losses per unit of hydrate produced in the higher productivity circuit. It is also necessary to account for the contribution of power generated by cogeneration through use of steam turbines between boilers and digesters. Converting this power into primary energy terms (for the alternative means of producing power) a credit of 0.5 GJ per tonne of original bauxite is obtained. The net outcome is a *very small* energy disadvantage to the use of bauxite activation in the "bauxite to alumina" production chain in the case where gas turbine exit gases are not available. Where cogeneration of hot gases can be applied, the energy effect is positive. Where backpressure steam from a nearby pre-existing thermal power station is available, which is the case in many circumstances, the now low temperature digestion enables the dedicated Bayer plant boiler to be shut down, with energy now supplied as waste heat. In this case the overall energy effect is highly favourable.

7. Alumina Quality and Scaling Effects

Alumina quality effects of interest include soda, silica and iron in product, and physical quality effects, particularly hydrate strength.

Soda in product is more readily controllable (Grocott 1998) by virtue of the absence of organic matter in liquor, the absence of solid phase oxalate, and the ability to divert

seed (which now does not need to be washed) between growth and agglomeration.

It has been confirmed that iron in product is a function of the original iron content in the bauxite (as it is for digestion of as received bauxite). Dilution of precipitated iron by virtue of the higher alumina yield in precipitation offsets higher iron in liquor at the higher caustic strengths employed to enable targeted alumina iron contents of 0.008% Fe_2O_3.

Silica in product will be lower for high caustic circuits (Roach, 1996), where despite higher silica supersaturation in precipitation liquor silica precipitation is impeded. In Comalco testwork the mechanism for this effect (confirmed in laboratory testwork) has been identified as the occlusion of sodalite seed where there is higher alumina yield in the agglomeration section of precipitation. Silica in product (at 0.008–0.010%, all contributions included) is expected to benefit from the resulting lower silica yield to alumina yield ratio.

Hydrate strength has been demonstrated as the primary concern in avoidance of dusty calcined alumina (Olsen, 1999). An oxalate free circuit in which seed hydrate surface is remarkably clean, and in which the supply of seed to the agglomeration section is not limited by seed washing capacity will favour the deportment of hydrate yielded in precipitation to growth rather than to nucleation, reducing the need to agglomerate fine seed. Consequently, hydrate grains are expected to be more homogeneous and less subject to attrition and decrepitation.

A further issue that is raised by the higher silica supersaturation is the possibility of scaling of sodalite onto the walls of the highest temperature liquor. Heater scaling rate testwork conducted in Comalco showed that the silica scaling rate from the high silica liquors was only commensurate with that from the lower silica liquors in present high temperature liquor heaters, by virtue of the lower temperature of the heaters, and associated lower seeded desilication rate constant. Scaling in precipitators that immediately follow interstage cooling is also expected to be reduced, by virtue of the absence of oxalate precipitation. The lamellar scales that are typically produced in this environment in oxalate coprecipitation circuits should cease to be a significant issue.

Testwork on the deportment of other minor impurities in bauxite that normally report to mud almost exclusively, for example manganese, has not identified any significant change in behaviour between activated and as received bauxites.

8. Conclusions

It has been found that some of the major issues that complicate the Bayer process can be alleviated by thermal pretreatment of bauxite, producing a low temperature digestible form that is virtually free of harmful organic impurities.

Even if the process is applied in a manner that uses primary fuel combustion as a main heat source (which is not necessary if gas turbine exit gas is used) it is roughly thermally neutral with the alternative process treating as received bauxite in high temperature digestion, while very significantly enhancing liquor circuit productivity. Substantial savings in caustic and lime consumption are achieved. Process odour is eliminated, and scaling is reduced. Product quality enhancements in levels of impurities and physical properties are expected.

Equipment costs are small in the context of the enabled expansion of the order of 33 to 50% that can be achieved by retrofit of an existing refinery, especially in view of the available process simplification. In assessing the economic effectiveness of bauxite activation in particular circumstances it is important to take maximum advantage of the yield benefits that come from the very high A/C ratios that are made available in digestion (especially double digestion) of the activated bauxite, and the near absence of autoprecipitation.

That is, bauxite activation has advantages that extend *well beyond* the nevertheless substantial advantages of conversion of high temperature refineries to lower temperature refineries, with associated cogeneration opportunities, and of higher caustic strength liquors.

Acknowledgements

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