DEVELOPMENT OF LIQUOR PURIFICATION AT ALCAN GOVE

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Abstract

Over the last 25 years the capacity of the Alcan Gove alumina refinery has increased from its original 1.0 Mt/y to approximately 2.0 Mt/y mainly through liquor productivity and flow increases. Gove bauxite, like other Australian bauxites, has high organic impurities. Consequently, Alcan Gove has been obliged to purge caustic to control impurities, such as sodium oxalate that has a detrimental affect on product quality. As a result, other organic and inorganic impurities have remained at acceptable levels. This purge of sodium oxalate, apart from the high cost of sodium hydroxide, has made the rehabilitation of the red mud disposal area more demanding.

Therefore, it was decided in the early 1990s to investigate environmentally acceptable means of controlling and destroying these liquor impurities.

Processes that were available at that time were not suitable/adaptable to the Gove situation. After a detailed literature survey was carried out to review all existing processes, the potential solutions were narrowed down to the following two possible options:

1. Combustion of liquor organics at high temperatures
2. Wet oxidation at high temperatures and pressures (similar to installations that have operated in the paper industry).

Laboratory scale trials were carried out for both liquor calcination and wet oxidation, and heat and mass balances were modelled for these scenarios.

After a thorough review, Alcan concluded that the 'Solid Liquid Calcination' process was the most appropriate option.

Details of the studies carried out for Alcan Gove are presented in this paper.

1   Introduction

Alcan Gove (previously known as Nabalco) alumina refinery, situated near Nhulunbuy, Northern Territory, Australia, has been in operation since 1972. During the intervening years, the refinery has increased production from 1.0 Mt/y to approximately 2.0 Mt/y mainly through optimisation, liquor productivity and flow increases. Alcan Gove's bauxite is high in organic carbon, ~0.25%, that degrades during digestion into sodium carbonate, sodium oxalate and various oxidised non-oxalate organic carbon (NOOC) compounds. Sodium carbonate concentration in the main process liquor is low because of carbonate removal through the precipitation of sodium alumino silicates in digestion, and is controlled at low concentrations because of causticisation of mud washer overflow liquor with milk-of-lime.

Sodium oxalate is recovered by co-precipitation with hydrate then dissolved by washing off fine seed to produce an 'oxalate rich stream'. Despite the high organic content of the Gove bauxite, the concentration of NOOC in the refinery liquor is not excessively high due to the strategy to purge sodium oxalate. The consequence of this purge is a higher soluble caustic loss with the red mud to the disposal area, and an increased challenge to rehabilitate the red mud disposal site.

A significant reduction in soluble soda losses with red mud would increase impurities and impact on refinery efficiencies. The impurity concentration increase can be divided into three chemical groups: sodium oxalate, NOOC and inorganic compounds. An increase in sodium oxalate concentration would require an adjustment of precipitation temperatures. An increase in NOOC concentration would reduce liquor productivity, and increase liquor viscosity that would adversely affect the performance of seed filtration and washing. Other impacts of an increase in NOOC would be increased foam generation, greater incorporation of soda impurity in hydrate, and possible issues with red mud settling through competition with flocculants for active sites on red mud particles. The increase in inorganic impurities such as sodium fluoride and sodium fluoro vanadate is difficult to predict depending on the solubility equilibria in digestion and is a relatively minor issue for Alcan Gove.

There are various technologies available for the removal and destruction of sodium oxalate. However there are only two stand-alone, industrial scale processes that are proven and do not require excessive dilution, or cause bio-degradation odour issues. These two processes are causticisation of oxalate rich seed wash water with milk-of lime and oxalate precipitation from concentrated spent liquor followed by causticisation. For Alcan Gove, the most economical approach is to causticise an oxalate rich stream, which is practised by several alumina refineries around the world.

Therefore, the main concern to Alcan Gove was finding a proven, reliable and environmentally friendly technology for the removal of NOOC compounds. Although there has been considerable work undertaken over the years by various companies to reduce organic concentrations in refinery liquors, no method was an obvious choice for Alcan Gove.

2   Refinery Organic Balance

As mentioned in the introduction, Alcan Gove's bauxite contains ~0.25% total carbon, of which the majority is organic carbon.

An overall carbon mass balance was conducted for Alcan Gove refinery liquor for the year 2000 as well as two detailed carbon balances using Aspen and the Mulloy-Donaldson model. All three carbon balances not only accounted for total carbon, but also for sodium carbonate, sodium oxalate and NOOC. The two main carbon inputs to the process were bauxite and pond water return. Minor quantities of carbon enter the refinery with chemical additives such as flocculants, crystal growth modifiers, drainage aids, lubricating oils and from air agitation in precipitation.

The main exits of NOOC from the refinery liquor in order of significance were:

1. Final red mud washer underflow to residue disposal
2. Oxalate purge
3. Hydrate to calcination
4. Sand stream to residue disposal

A research study of organic carbon degradation conducted by Alusuisse's Neuheussen R&D some years earlier indicated the extent of carbon conversion of Gove bauxite during digestion (at current Gove conditions) to sodium carbonate, sodium oxalate and NOOC of 16%, 14% and 35% respectively. The remainder is insoluble, 'refractive' organic in the red mud digestion residue; see Figure 1.
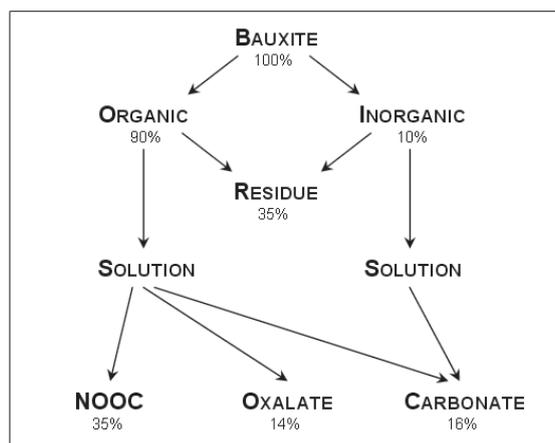

Figure 1 – Neuheussen R&D determination of breakdown of Gove bauxite carbon during low temperature digestion

In order to close the overall carbon balances, these three conversions of bauxite total carbon to liquor sodium carbonate, sodium oxalate and NOOC were adjusted; see Table 1.

Table 1 – Comparison of Gove refinery mass balance with results obtained from Neuheussen R&D

	Overall Carbon Balance	Neuheussen Research
1. Liquor sodium carbonate	15%	16%
2. Liquor sodium oxalate	16%	14%
3. Liquor NOOC	40%	35%

The implication of the mass balance basis used is that 29% of the bauxite carbon remains in the solid phase and leaves the refinery with the red mud.

The match between the overall mass balance and the previous results from Neuheussen R&D were admirable, considering the usual simplifications inherent in the laboratory simulation (small number of digestion cycles, content of air and its efficiency of contact during digestion, heat-up and other thermal effects, secondary degradation of liquor NOOC, analytical discrepancy, etc). The distribution of bauxite carbon in refinery liquor of other refineries will be different depending on the type of organic carbon in the bauxite and the digestion conditions. As part of the Alcan Gove expansion the mud will be redigested at high temperatures that would generate higher proportions of sodium carbonate and oxalate, and a lower proportion of undissolved carbon reporting to the red mud.

To achieve a reduction of nett soluble loss of 70%, the mass balance calculation established the required capacity of NOOC removal/destruction to be 570 kg C/hr.

3 Survey of NOOC removal and destruction processes

In the long term, it was recognised that the higher than best practice soda losses for Alcan Gove were unsustainable. So in 1990, a 'Caustic Soda Saving' investigation was initiated by Alcan Gove to reduce the refinery's soluble caustic losses with red mud, by establishing an environmentally acceptable means of controlling and destroying NOOC impurities. The reduction in soluble soda losses would also facilitate future rehabilitation of the red mud disposal site.

The former Alusuisse Martinswerk alumina refinery near Cologne, Germany did have a successful small, but operationally expensive organic combustion facility using a small rotary kiln. An attempt had been made at Martinswerk to improve the energy efficiency of the process, but this proved to be unsuccessful. Due to the size of the unit required in conjunction with the high operating costs of the Martinswerk liquor combustion process, this option was not considered for Alcan Gove.

The next step for the investigation was to conduct a literature survey to establish a list of potential technologies within and outside the alumina industry that could remove or destroy organic carbon in alumina refinery liquor; see Table 2.

4 NOOC removal and destruction technologies selected for further Study

After preliminary reviews and minor investigations, some of the above were eliminated.

Significant investigative and/or laboratory work was conducted on the following options.

4.1 Membrane Technology
4.1.1 Ultra Filtration

A number of membrane-based techniques have been proposed for removal of organics from various Bayer process streams. Recent patents generally claim treatment with 'semi-permeable membranes' to remove coloured organics and improve the whiteness of hydrate or alumina (The, 1987 & 1988). Further developments of ultrafiltration membranes to hollow-fibre polysulfone material (The, 1987) claimed liquor purification by removal of sodium salts, humates and sodium oxalate. For stability in caustic media, membranes were proposed with a sulfonated polysulfone layer to separate impurities from caustic solutions (Yacubowicz, 1995).

Research testing was conducted at Nabalco during the late 1980's using plant liquors. Although organic removal showed some promise, the treatment encountered low flows and high costs. At the time of the Alcan Gove evaluation, none of these processes was in commercial use in the Bayer industry.

4.1.2 Ion Exchange and Electro-dialysis

Claims have also been made about application of Ion Exchange and Electrodialysis in purification of Bayer liquor process streams (Brown, 1988; 1989A, & 1989B). At the time of the Alcan Gove evaluation, neither of these processes was proven commercially in the Bayer industry.

4.2 Bauxite Leaching with Dilute Caustic

Laboratory tests conducted at Martinswerk in the 1970s indicated that 50% of organic compounds could be removed from Gove bauxite by washing with a very dilute caustic solution. The issue comes when considering the disposal of the organic laden dilute caustic solution, and the capital costs associated with the logistics of the exercise. For this reason this alternative was not pursued furtherfor Alcan Gove.

4.3 Chemical Additives
4.3.1 Quaternary amines – Poly Dadmac and Crystal Growth Modifiers

Chemical agents for humate removal have been used in a range of alumina refineries around the world, mainly for hydrate quality control, especially if the hydrate is intended for speciality chemical production where 'whiteness' is a quality specification. Poly Dadmac, a cationic sequestrant, reacts with a fraction of the higher molecular

Table 2 List of organic removal / destruction technologies considered

1. Membrane Technology
2. Froth Flotation
3. Deep liquor evaporation
4. Bauxite organic leach with dilute soda (Beneficiation)

5. Absorption on active surfaces
    a. Carbon
    b. Alumina
    c. Hydrate
    d. Ion exchange

6. Treatment with magnesium salts
7. Treatment with calcium oxide
8. Treatment with barium salts
9. Treatment with alcohol
10. Treatment with ammonia

11. Wet oxidation
    a. With oxygen under high pressure
    b. With oxygen under high pressure and catalyst
    c. Spray drying
    d. With oxygen in digestion
    e. Electrochemical
    f. With ozone or peroxide
    g. With chromate
    h. With manganese dioxide
    i. With potassium permanganate
    j. With chlorine or hypochlorite

12. Combustion
    a. of bauxite
    b. of liquor with hydrate
    c. of liquor with bauxite
    d. of liquor with iron oxide

weight compounds, sometimes known as 'humates'. This fraction may represent only ~0.1% of the organic carbon compounds, with specific effects on the process.

Poly Dadmac's most significant, immediate impact on operations may be removing organics that are oxalate stabilisers in solution that sometimes cause an upset or at least a decrease in liquor oxalate levels. As well there is usually a noticeable colour change in refinery liquor associated with the humate reduction. The humate removal also contributes in a minor way to lower organic carbon levels by removing the humates that would otherwise break down into lower weight organic compounds. Alcan Gove's experience is that the majority of the breakdown of complex organic compounds in bauxite occurs during their first cycle contact with caustic under digestion conditions, with further cycles contributing a small, though not insignificant, degradation to simpler organic compounds and sodium carbonate.

Crystal growth modifiers (CGM) are chemical additives that alter the crystallisation sub-processes, principally seen in agglomeration and nucleation behaviour. CGM has sometimes been added to refinery liquors in conjunction with Poly Dadmac in an attempt to manage its side effects on co-precipitation of sodium oxalate.

In any case, CGM's role is to assist sizing or nucleation control rather than organics mitigation. Both Dadmac and CGMs were not considered significant to bulk organics removal or control in an expanded Gove flowsheet.

4.4 Barium process

The barium process was originally conceived for sodium carbonate removal. It was developed for refineries treating bauxites with high levels of calcite, e.g. Alumine de Grèce (ADG) and Gardanne.

This process can also remove sodium oxalate and a portion of the NOOC if applied in two successive steps. Firstly, an excess of a barium salt is added to on organic rich stream, such as fine seed wash water. All the sodium carbonate and oxalate and part of the NOOC that is precipitated as barium salts is separated from the stream and the remaining soluble barium is removed by mixing with a sodium carbonate rich stream. The reaction of soluble barium with the fresh source of sodium carbonate creates a second precipitate that is also separated.

It can be seen that the process is feasible only if the refinery has sufficient excess of sodium carbonate to justify its complete removal from the treated wash water, plus provide sufficient to treat the excess soluble barium. Therefore the barium process does not suit refineries treating bauxites that are not only high in organics, but are also high in reactive silica, as these refineries will have low sodium carbonate in their liquors.

The main drawbacks of the barium process are its capital and operating costs, and its potential environmental impact. The operating cost includes a loss in refinery productivity from the alumina trihydrate added to the precipitated barium cake fed to a kiln to regenerate the reagent, barium aluminate. As for the environmental issue, heavy metals such as barium are toxic making the management of raw materials, residues and barium traces in red mud difficult.

Alcan Gove did not pursue this process because of the potential environmental impact, but also because its bauxite is high in both organic and reactive silica.

It was due to the environmental aspect that even ADG, who were focussed only on sodium carbonate removal, took the decision to shut down the process; despite the fact that it was working well with reasonable operating costs.

4.5 Wet Oxidation

Wet oxidation, as applied to the Bayer process, is the degradation of complex organic compounds to sodium carbonate and short-chain organic compounds such as sodium oxalate and sodium acetate by the use of oxygen or other oxidant at high temperatures and pressures.

Broadly, the process as patented uses oxygen gas injected into digestion or to a spent liquor side-stream at a wide range of temperatures, residence time, and oxygen partial pressures, sometimes in conjunction with catalysts, (Malito, 1987). The desilication process in digestion can remove some of the sodium carbonate by-product, thereby re-purifying the liquor. Caustic can be recovered from remaining sodium carbonate by causticisation with lime, while caustic from sodium oxalate can be recovered through the causticisation of an oxalate-rich stream.

4.5.1 Catalytic wet oxidation

Catalytic wet oxidation hypothetically allows the degradation of long-chain organic compounds at more moderate temperatures, possibly 50°C below an equivalent 'un-catalysed' wet oxidation. Past work has resulted in several patents (Inao, 1980; The, 1986; Brown, 1987). More recently, research interest has been rekindled in catalyst development (Eyer, 2000; Bhargava, 2000; Hoang, 2000).

Alcan Gove only briefly considered catalytic wet oxidation. The main reason for not pursuing this option was the difficulty of recovering the catalyst from the product stream, contamination of alumina with unrecovered catalyst, and the unproven (to date) operational viability.

4.5.2 Wet oxidation integrated with high temperature digestion

Alcan Gove considered applying Otukumpu's combined single-stream digestion and wet oxidation process, similar to the installations at Stade alumina refinery, Germany, (Arnswald, 1991) and Comalco's alumina refinery at Gladstone, Australia. This process requires a high operating temperature, ≥250°C and preferably ≥270°C and the use of the entire refinery's spent liquor to maximise the degradation of organic compounds. The process has a relatively short residence time, ≤10 minutes.

The Otukumpu technology, which was initially developed at Stade alumina refinery, only adds oxygen up to its solubility limit in refinery liquor, thus minimising the risk of corrosion and eliminating the risk of explosion in the digestion process, but also limits the capacity for degradation of organic species removal per volume of liquor and volume of 'reactor' (Anderson, 2001).

Alcan Gove's expansion is based on Alcan's double digestion technology while keeping the existing low temperature digestors. Thus, only a small proportion of the refinery liquor will experience moderate digestion temperatures in each cycle. Therefore the Otukumpu digestion/wet oxidation option was not pursued further.

4.5.3 Dedicated wet oxidation

A dedicated wet oxidation process for Alcan Gove refinery based on USFilter/Zimpro technology was thoroughly investigated by Alcan

Gove. USFilter/Zimpro have experience in designing dedicated wet air oxidation (WAO) units for the Pulp & Paper Industry treating flows of 60 m³/h, and operating with residence times up to 1 hour, temperatures up to 325°C and with excess oxygen as air. The Burnie Soda Pulp Mill oxidation unit achieved 95 to 98% organic oxidation, where the remaining organic compounds were mainly short-chained aliphatic acids such as sodium acetate. (Maddern, 1980)

USFilter/Zimpro were commissioned at the end of 2000 by Alcan Gove to conduct wet oxidation laboratory tests with Gove liquor at 150°C, 200°C, 250°C, and 300°C for 60 minutes and to propose a design for a wet oxidation unit for the refinery. In early 2001, USFilter/Zimpro completed the tests to give clear trends:

- Increasing the temperature for wet oxidation, with sufficient air to maintain excess oxygen remaining at the end of the 1 hour period, showed:
  ○ An increase in suspended solids (mainly sodium oxalate) in the product stream (see Figure 2), and an increase in sodium carbonate in liquor, from the increasing degradation of NOOC to these species;
  ○ A decrease in TOC and in the colour of the liquor (Figure 2);
  ○ A steady decrease in caustic in liquor largely through production of sodium carbonate and oxalate. (Gibbsite remained at a constant concentration in product liquor at all conditions.)
- The amount of sodium acetate produced increased as temperature increased up to 250°C, but it then decreased substantially at 300°C. Conversely, sodium formate was at a maximum at 150°C and then continually reduced with increasing temperature.
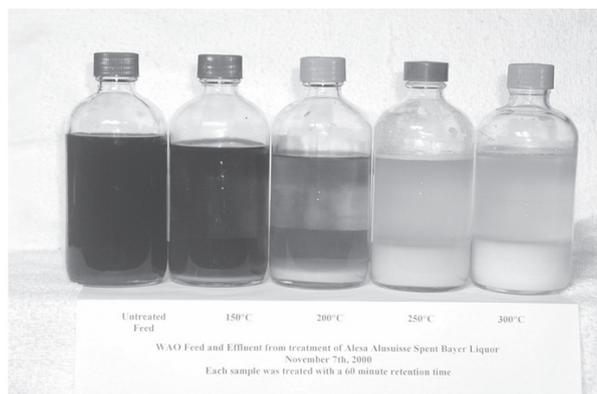

Figure 2 – Product of wet air oxidation (WAO) of Alcan Gove spent liquor

The results obtained were promising, but what would be the optimum operating temperature of the wet oxidation unit? This would be influenced by the nett effect of the remaining 'wet oxidised organic compounds' on alumina refinery productivity. To answer this and other questions, Alcan Gove prepared other wet oxidised refinery liquors from runs at 150°C, 200°C, 250°C and 280°C, re-adjusted the organic concentrations to reflect potential future refinery balances, and conducted laboratory precipitation trials.

The two different wet oxidation trials gave a measurable difference in NOOC conversion at the same temperatures, as shown in Table 3. This is not unexpected, as conditions other than temperature can have a significant impact on the degree of oxidation, including heat-up rate and thermal contact, oxygen content and its contact with liquor species. For example, the two trials used different mixing methods (rocking versus stirred autoclaves) and different oxygen doses (USFilter/Zimpro used an air charge, the other used oxygen at a constant molar dose, 1.2 moles/mole TOC).

Table 3 – Alcan Gove liquor after 1 hour residence in the presence of excess oxygen

Temperature	Reduction in NOOC	
	Performed by USFilter/Zimpro	Performed by Alcan
150°C	13%	—
200°C	29%	45%
250°C	50%	56%
280°C	—	73%
300°C	73%	—

The precipitation trials were conducted at Alcan Gove to take into account the effect of liquor impurities on precipitation at constant caustic, with feed alumina supersaturation kept at a constant ratio (as much as possible), to reflect that plant protocol.

Results showed that the range of oxidised organic compounds (from 200, 250 or 280°C runs with oxygen gas) produced a similar impact on precipitation kinetics and alumina solubility, as did the original untreated organics within test repeatability, when both were expressed on a per gram of TOC basis. The overall impact on plant productivity however will be the outcome of these two factors, and other secondary issues, as caustic is increased to benefit from the reduced TOC in precipitation. In practical terms, the nett benefit is the reduction of NOOC through its conversion to sodium carbonate and oxalate, and the extent that these can be causticised to recover caustic in the refinery process for optimal productivity.

Although preliminary, this work indicated the choice of operating design temperature for a wet oxidation unit, i.e. for a given rate of organic oxidation to sodium carbonate and oxalate, it was simplified to a direct trade-off between unit flow with operating temperature.

The design of wet oxidation proposed by USFilter/Zimpro in 2001 was simple and had few pieces of equipment.
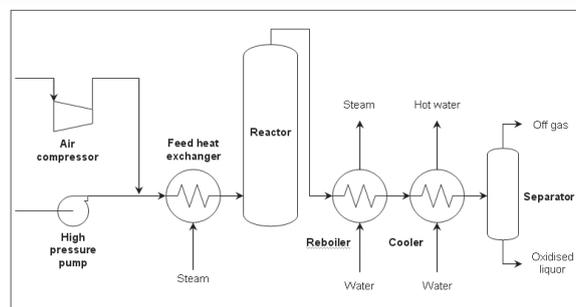

Figure 3 – USFilter / Zimpro wet air oxidation process

4.6 Combustion
4.6.1 Showa Denko liquor burning process

The Showa Denko liquor burning process is a relatively simple process (Shibue, 1990). A source of alumina, bauxite or aluminium trihydroxide (a.k.a. 'hydrate') is mixed with strong caustic liquor. The resulting slurry is then intimately mixed with hot gasses, recycled dried material from the gas cleaning system to form a granulated dry powder, and subsequently heated to combustion temperatures in a rotary kiln. The sinter discharged from the kiln is cooled and dissolved in refinery liquor. The gasses from the dryer are cleaned of solid particulates and trace organics before being discharged to atmosphere. Unlike the other, non-combustion process, this process removes 100% of the organic species that are present in the feed.

In 1993, Alusuisse studied three potential flow sheets of liquor burning, each at different levels of total organic carbon in refinery liquor. All three options assumed the principal feed to the liquor burner was bauxite as the alumina source (so as to obtain an associated increase in refinery production), and an evaporated fine seed wash, which is rich

Table 4 – Estimate of major inputs and outputs of USFilter/Zimpro wet air oxidation (WAO) for Alcan Gove at 22 g/L NOOC in feed

Wet Oxidation Estimated Major Inputs / Outputs							
	Relative Unit	CASE					
		°C / m³/h	°C / m³/h	°C / m³/h	°C / m³/h	°C / m³/h	°C / m³/h
Electricity	kW / kW@280/22	1.0	2.3	0.8	1.8	0.5	1.2
Methane (Steam Boiler)	Sm³/h/ Sm³/h@280/22	1.0	2.3	1.0	2.2	1.0	2.3
Steam Produced (5 bar g)	Kg/h/ Kg/h@280/22	1.0	2.3	0.8	1.9	0.3	0.6
Cooling Water (32 – 43°C)	m³/h/ m³/h@280/22	1.0	2.3	1.2	2.7	1.9	4.3

in sodium oxalate. With liquor productivity gains and potential reduction in product soda, the preliminary study indicated favourable returns. The major concern at that stage of evaluation was the dissolution of iron and silica when the liquor burner sinter is mixed with refinery liquor. The crystallisation of oxalate from the fine seed wash could also prove problematic and require frequent water washing of the associated evaporator.

Alcan Gove did not pursue this option due to its high cost while the strict limitations posed by the technology supplier were unacceptable to Alusuisse, the technology manager for Gove at that time. In addition, there seemed to be environmental issues with the process that required stack gas treatment that would further add to its cost.

4.6.2   Alcan/FL Smidth solid/liquid calcination (SLC) process

The development of the SLC process was part of Alcan's long-term goal to design 'closed circuit' alumina refineries. In the early 1990's, Alcan were familiar with the principle of the Showa Denko liquor burning process as a similar process had been operated from 1954 to 1983 at Vaudreuil alumina refinery Québec, Canada. The process was decommissioned, as it was no longer required for the mix of bauxite then being fed to the refinery. Alcan's experience is that the process was not only expensive to operate, but also required high maintenance. As with Showa Denko, Vaudreuil found the operation of the wet scrubber problematical, but instead of modernising an old technology, Alcan set out to form a joint development agreement with FFE Minerals, Alumino Española, and initially Aughinish Alumina to develop an improved liquor organic combustion process.

The SLC process was developed and tested at FL Smidth Research Centre, Dania, Denmark, (Fenger, 1996) and a demonstration unit was installed at the San Ciprián alumina refinery, Spain (Alvarado, 1996).

Alusuisse was able to evaluate this technology for the Gove refinery prior to merger with Alcan based on commissioning and operation of the unit at San Ciprián.

A subsequent visit to the San Ciprián SLC unit in 2002 confirmed the operation was still as described in the paper by Alvarado 1996. The site visit also confirmed that there seemed to be no atmospheric environmental issues. A significant issue did arise from the visit; this was the tall aspect ratio of the structure that would be unacceptable for the cyclone-prone Northern Territory coast. The SLC design has been adapted from the original concept illustrated in Figure 4 below, following additional work with FFE Minerals to minimise its height to width aspect ratio ('low set') thus making its structure cyclone resistant.

5   Comparison of dedicated wet oxidation with SLC process

In mid-2001, the technical study outlined in this paper conducted by the then Alesa Alusuisse Engineering (now Alcan Engineering) on behalf of Nabalco (now Alcan Gove) concluded that both the SLC and the dedicated wet air oxidation (WAO) from USFilter/Zimpro were technically feasible for Gove's Liquor Purification project. An economic evaluation was conducted for both the SLC process and the WAO process for the Alcan Gove conditions. The result showed a marginal advantage for the SLC process. Considering the accuracy of the study, this was insufficient to be conclusive for the SLC process.

A review of key criteria for the Liquor Purification project was conducted and a weighting and score given to each. The result showed the SLC process still had the advantage over WAO; see Table 5. Of the key criteria reviewed, one of note was the 'technical risk'. Whereas the SLC process had an operating demonstration unit at San Ciprián,
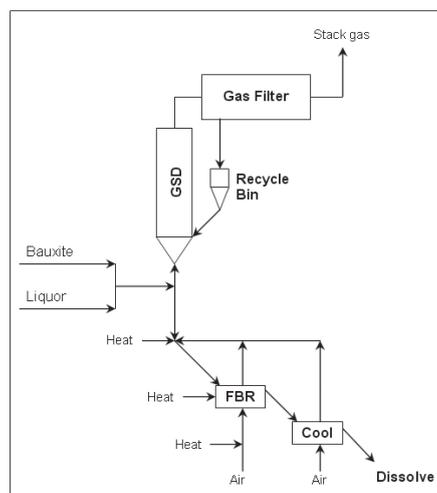
Figure 4 – "Original" Solid Liquid Calcination process for San Ciprián

Spain, the WAO process no longer had an operating reference plant similar to that required for Gove's Liquor Purification project as the Burnie Soda Pulp Mill had been decommissioned in 1998.

Table 5 – Weighted score of key criteria of SLC and WAO processes

CRITERIA	Weight	Score		Weighted Score	
		WAO	SLC	WAO	SLC
Operating Cost	10	7	10	70	100
Capital Cost	10	10	8	100	80
Complexity	4	-	-	0	0
Safety	10	5	8	50	80
Odour / Dust	10	5	2	50	20
Technical Risk	9	4	7	36	63
Space / Location	3	8	4	24	12
Impact on Major Mtce	2	5	5	10	10
Oxalate Destruction	7	7	10	49	70
TOTAL				389	435

6   Conclusions and Recommendations

Of all the technologies reviewed for Alcan Gove's Liquor Purification project, only two were retained for detailed consideration, the Solid Liquid Calcination (SLC) and Wet Air Oxidation (WAO) processes. Alcan chose the SLC process mainly because there was no proven WAO facility in the Bayer process.

The appropriate choice of technology and its adaptation to Alcan Gove was undertaken with the best knowledge available and the constraints of that refinery. It is recommended by the authors that for any similar undertaking by other alumina refineries, a diligent review of the available technologies be undertaken before a solution is chosen that is appropriate for their operational and environmental constraints.

Acknowledgements

References

Alvarado JM, Hillary JE, Hiscox BA, Raahauge BE, 1996, 'Solid-Liquid Calcination (SLC) Process for Liquor Burning', 4th Alumina Quality Workshop, pp. 383–391

Anderson J, Armstrong LG, Thomas D, 2001, 'Wet Oxidation in QAL high temperature digestion for Plant productivity improvement', Light Metals, pp. 121–126

Arnswald W, Kaltenberg HG, Guhl E, 1991, 'Removal of Organic Carbon from Bayer Liquor by Wet Oxidation in Tube Digesters', Light Metals, pp. 23–27

Bhargava SK, Sumich M, Eyer S, Akolekar D, 2000, 'Wet oxidation catalyst and method for preparation of same', Patent AU 2000/17606

Brown GP, Tschamper O, 1988, 'Process for reducing the impurities in lyes in the Bayer process', Patent WO 88/07975

Brown GP, Tschamper O, 1989A, 'Removal of dissolved inorganic and organic impurities from aqueous Bayer process liquor for the manufacture of aluminium hydroxide', Patent EP 310,553

Brown GP, Tschamper O, 1989B, 'Purification of Bayer process liquors by electrodialysis', Patent EP 310,554

Brown N, Kudermann G, Fuchs M, 1987, 'Method for removing organic substances from caustic aluminate liquors', Patent US 4,668,486

Brown N, 1989, 'Kinetics of copper catalysed oxidation of Bayer liquor organics', Light Metals, pp. 121–130

Eyer SL, Bhargava S, Sumich M, Tardio J, Akolekar D & Nyeboer H, 2000, 'Removal of Organics from Bayer Liquor and Wet Oxidation' Light Metals, pp. 45–51

Fenger J, Ilkjaer J, Fleming L, Pulpeiro J, Carruthers A, 1996, 'Operation of a 24MTD Solid Liquid Calciner for Liquor Purification of a Bayer Plant', Light Metals , pp. 161–167

Hoang M, 2000, 'Catalysts and Processes for Treatment of Industrial Process and Waste Streams, Patent WO 00/00285

Inao J, Yamada K, Harato T, Kato H, 1980, 'Method for the removal of organic substances from alkali metal aluminate solution', Patent US 4,215,094

Malito JT, Robertson ML, 1987, 'Removal of high molecular weight organic compounds from Bayer process caustic liquor', Patent US 4,663,133

Malito JT, Robertson ML, 1988, 'Removal of HMW organic compounds by partial wet oxidation', Light Metals, pp. 75–85

Maddern KN, 1980, 'Wet air oxidation recovery at Burnie', ADDITA, vol 34, no. 32, pp. 130–134.

Mlilto JT, Roberson ML, 1987, 'Removal of high molecular weight organic compounds from Bayer process caustic liquor', Patent US 4,663,133

Shibue Y, Sakamoto A, Arakawa N, Kawai Y, Ishida H, 1990, 'Liquor Burning Process–It's Modification and Increase in Capacity', Light Metals, pp. 35–40

The PJ, Williams FS, Sivakumar TJ, 1986, Patent US 4,581,208, 'Lowering organic contaminant content in a sodium aluminate solution by oxidation in a packed bed'

The PJ, Misra C, 1987, Patent US 4,676,959, 'Bayer process for producing aluminium hydroxide having improved whiteness'

The PJ, Misra C, 1987, Patent US 4,678,477, 'Process for lowering level of contaminants in Bayer liquor by membrane filtration'

The PJ, Misra C, 1988, Patent US 4,786,482, 'Bayer process for producing aluminium hydroxide having improved whiteness'

Yacubowicz J, Yacubowicz H, Katraro R, Perry M, 1995, 'Process and System for Purifying a Contaminated Caustic Feed Solution', Patent AU-16258/95