COLLABORATIVE RESEARCH FOR THE INTERNATIONAL ALUMINA INDUSTRY

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Abstract

For more than a decade the Australian alumina industry has collaborated together to fund a range of research projects which have delivered tangible benefits to the industry. The vehicle used to coordinate these efforts has been the Australian Mineral Industries Research Association, now AMIRA International. Recently this effort with the alumina companies has been “re-energised” with the organisation of an Alumina Technology Roadmap.

In recent years the projects have increasingly involved alumina producers based outside of Australia such that the efforts now are truly international.

The research projects have, in the main, focussed on fundamental studies that deliver high level outcomes amenable to implementation of tangible benefits by the company-based technology groups. Substantial areas of study have been in precipitation, its interaction with calcination and product quality, solid/liquid separation, physicochemical properties of synthetic and Bayer liquors, fluid dynamics, equipment engineering, comminution and classification.

An important adjunct of the projects has been the development of world-standard public research groups active in Bayer process technologies and maintaining them at a critical level. These groups in turn have produced a range of graduate students well versed in alumina refining who are sought after as industry employees. Australia is now recognised as having the world’s leading public sector and private company alumina research groups. Many of the private sector groups are used as a corporate facility to service that company’s refineries worldwide.

The paper will describe the background to the collaborative research efforts, engagement of the alumina companies, discuss the range of projects undertaken and, in particular, highlight the successes, and look to what will happen in the future with such research.

1. Introduction

For many years the world aluminium industry has been dominated by a few key producers with vertically integrated operations spanning across many countries. Historically these companies included the “big six”: Alcan, Alcoa, Alusuisse, Kaiser, Pechiney and Reynolds. They operated bauxite mines, alumina refineries, aluminium smelters and downstream fabrication facilities.

In more recent times the industry has become more open, particularly in aluminium smelting, as regions with cheaper forms of energy established production plants utilising alumina feedstock purchased on the open market.

Most recently the industry has rationalised its structure with company mergers and takeovers bringing substantial changes, a process mirrored with other key commodities around the world such as gold.

Those major producers mentioned earlier pursued their activities in a strongly competitive business environment. All of them invested in technology development to a greater or lesser extent, often with substantial in-house capabilities for conducting research, development and incremental improvements to key production processes. There are excellent examples of major technological breakthroughs achieved by these companies which were implemented to ensure competitive advantage over their rival producers. Secrecy and confidentiality were the order of the day. The anti-trust laws in the USA dictated that competitors did not talk to each other.

During the period leading into the 1980s three factors came into play that started to impact on this situation:

- Joint venture operations were established between two or more of the major companies, with defined areas of technological knowledge being shared.
- New producers entering the industry exerted changes that forced more openness onto the industry. New companies establishing greenfields smelters compared available smelting technologies before choosing that one most suited to their needs. They purchased alumina on the open market, after having closely scrutinised quality parameters as well as price. The vertical integration so prevalent for so long was starting to break down.
- A more mobile workforce with employment prospects worldwide resulted in transfer of process technologies and industry knowledge, thereby broadening some of the corporate knowledge previously held internally.
- Australia established a major presence in the industry, for all facets of the processing chain: bauxite production, alumina refining, aluminium smelting and downstream fabrication, but especially in refining (more than 30% of world production of smelting grade alumina). These developments were the result of involvement by one or more of the “big six” as Table 1 shows.

The influence of expanding refining capacity in Australia on technological developments for alumina processing cannot be over-emphasised. Such capacity was declining in the home countries of the “big six”, such as the USA and Canada, and only slightly increasing in Europe. More emphasis was placed on the Australian refineries to drive technology enhancement and change. Alcoa was perhaps the best example with a significant R&D capability being established in WA at Kwinana, which has continued to expand and now serves the Alcoa World Alumina operations. Other examples include Comalco

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Table 1

Major	Company	Bauxite Mining	Alumina Refining	Aluminium Smelting	Downstream Fabrication
Alcoa	Alcoa of Australia Ltd	Western Australia	Western Australia	Victoria	Victoria
Reynolds	Worsley Alumina Pty Ltd	ditto	ditto		
Alusuisse	Nabalco Pty Ltd	Northern Territory	Northern Territory		
Alcan, Kaiser, Pechiney JV*	Queensland Alumina Ltd	Queensland*	Queensland		
Pechiney	Tomago Aluminium Ltd			New South Wales	
Alcan	Alcan Kurri Kurri Ltd			ditto	New South Wales

*Comalco Aluminium Ltd also a JV partner, as well as operating the bauxite mine and smelters in Queensland and Tasmania (and New Zealand).

Aluminium, QAL and Nabalco (now Alcan with new facilities in Brisbane). But in the main the alumina refining focus was still on internal R&D: confidential outcomes which would be implemented to maintain and enhance competitive advantage.

However, some of these boundaries were becoming more flexible. Key industry people were realising that there existed many technical challenges of a more fundamental nature, which could not be successfully overcome by internal efforts alone. Hiring research teams are expensive, especially to acquire the best people. The sophisticated equipment and facilities needed to tackle these problems are often unique and very costly to purchase and maintain. Could some of the research be undertaken in a different way? How? Could an organisation of independent standing add any value?

2. AMIRA

The Australian Mineral Industries Research Association (AMIRA) was established in 1959 by a number of mining industry visionaries who recognised that the public research infrastructure in Australia was insufficient to support that industry's needs into the future. They realised that industry must continually improve and seek technological breakthroughs for new processes or it will be overtaken by its competitors.

The brief for AMIRA in those early days was quite simple:

- To foster and manage collaborative research projects which deliver real benefits to members;
- To enhance relevant public research infrastructure in Australia which serves the technological needs of members.

The emphasis on collaborative projects was quite deliberate: the leverage that accrues from multiple companies sponsoring a project can be many times the individual contribution. What is required is a careful definition of the project scope to ensure competitive neutrality; this usually implies that the research is of a more fundamental nature.

Since being established AMIRA has developed a portfolio of some 600 successful projects with a total expenditure of some $170 million in dollars of the day, spanning activities from exploration through mining, processing and the environment. It has been successful in nurturing an active, capable research infrastructure within Australian universities and government organisations such as CSIRO and ANSTO. Since the establishment of the Australian government's Cooperative Research Centres program some ten years ago AMIRA has been instrumental in the formation and activities of most of the relevant Centres.

3. Collaborative Activities commence

By the late 1980s AMIRA had well established its credentials as a successful broker of collaborative research projects for the mining industry. Quite a number of projects, which delivered key outcomes, were continued at the industry's requests into extension projects.

The involvement of the Australian alumina producers in AMIRA's collaborative projects was somewhat serendipitous. At the turn of the decade two key industry figures, John Sibly from Alcoa and Tony Kjar from Comalco, happened to be closely involved with AMIRA: John as Chairman of its Council with Tony as Vice-Chairman. Both understood the research needs of their industry. Both appreciated the extra value that AMIRA could bring via the collaborative approach.

As a result the alumina producers in Australia at that time (Alcoa, Comalco, Nabalco, QAL and Worsley Alumina) agreed to sit round the table, with AMIRA as the broker, to seek out and agree on common areas of interest for pre-competitive collaborative research. This led to the identification of several broad areas that might be tackled via public research organisations:

- Hydrate precipitation;
- Influence and control of impurities; and
- Solid-liquid separation

The equal if not greater challenge was to identify and nurture appropriate research teams which would actively pursue these topics utilising their expertise. The interaction between the public researchers and the Australian alumina industry was mostly very limited at that time. To develop that infrastructure required time, money and faith from the industry.

The first area (hydrate precipitation) was chosen as the initial project to pursue. Research groups around Australia were invited to submit proposals for work in project P380 "*Fundamentals of Precipitation*". The project commenced in February 1992.

[It is worth recording that Australian alumina producers first became collectively involved in sponsoring AMIRA projects in late 1988 with project P266 *Thickener Technology*. Alcoa were a major sponsor and Comalco a minor one, although Alcoa had been sponsoring the comminution activities of the P9 *Mineral Processing* project for several years prior to this. However, both these projects involved sponsors across a range of commodities as well as equipment and reagent suppliers. As such, the subjects were not considered as especially competitive by those alumina companies.]

In July 1994 several of AMIRA's alumina producing members (Alcoa, Comalco and Worsley Alumina) requested that a meeting be called to discuss the progress made since 1991 in developing public domain R&D infrastructure. In particular, the group wished to focus on the industry's future requirements from the public R&D infrastructure and how to develop collaborative mechanisms to assist the infrastructure growth.

The feeling was that the industry had made considerable progress since collaborative research projects had begun in 1992 but that it was time to review the situation.

The consensus was that substantial progress had been made in building relationships between researchers and the alumina industry.

However, a number of difficulties still persisted with the main problems being:

- The infrastructure was not adequate to deliver on all research requirements (generic, competitive, site specific) and the then current projects had not employed enough new researchers to add significantly to the pool of expertise.
- The scale of research and pool of expertise was still very small and fragmented with no obvious leaders or experts in the Bayer process.
- Issues of intellectual property, including poaching of research staff and tying up of research capacity, were of concern and had to be addressed in the best interests of both the industry and research infrastructure.
- There was poor communication between the industry and the public domain R&D institutions.
- Long project development times and slow progress in projects.

The companies agreed to fund AMIRA (P461 *Alumina Industry R&D Study*) to undertake a study of the industry's R&D requirements and to propose mechanisms as to how to manage the development of the public R&D infrastructure. Phil Campbell from AMIRA, who is now a manufacturing manager with Alcoa, undertook the study and produced a seminal report in November 1995. The key findings were:

- The industry was seeking, from the public domain R&D infrastructure, excellence in:
  - — chemistry as pertaining to the Bayer process;
  - — process modelling capabilities, especially validated CFD.
- The preferred infrastructure organisation was for a number of R&D providers in priority areas with little support for a "centre of excellence" in alumina processing.
- There was a lack of linkage between public R&D capability and industry knowledge of the research activity.
- Industry commitment to working with a research provider over a long term was necessary for the collaboration to be mutually successful.
- Project management by external R&D organisations was seen as a major problem needing improvement. The alumina industry had a role to play in setting project management standards.
- The basis for a critical mass in alumina research existed in Australia. The issue was that the research focus and quality, and industrial coordination, was not optimised.

To address a number of the issues noted in the findings, AMIRA established an Alumina Technical Panel comprised of representatives of the Australian alumina producers. The Panel met twice a year to review progress on existing collaborative projects, assess proposals for new projects and provide expert advice on requirements for new R&D areas. CSIRO, as a major R&D provider to the industry, established a similar Panel, which subsequently incorporated the Parker Centre's alumina research activities.

4. The AMIRA Program expands

From the tentative beginnings in the early 1990s a wide range of collaborative projects have been sponsored by the alumina industry to date. In essence there are two main types:

- Those projects of sole interest to the alumina producers who were the only sponsors; they usually relate to the unique chemistry, engineering or unit operations in the Bayer process such as the fundamentals of gibbsite precipitation.
- Those projects that cut across industry sectors and often focus on a particular unit operation, such as solid-liquid separation (of relevance to Bayer process thickeners and washers but equally in base metal, gold, mineral sands, etc. operations).

A full tabulation of past and current projects is provided in the appendix. The total value of the work amounts to $35 million in the dollars of the day. Note however that a number of the projects had sponsorships broader than just the alumina producers.

Wherever possible the project funding delivered by the industry sponsors has been leveraged up with successful applications to government funding agencies such as the Australian government's ARC programs and the MERIWA agency in Western Australia. This has benefited both the industry and the researchers: a win-win situation.

5. Key Research Areas and Public Infrastructure

The collaborative AMIRA projects undertaken thus far fall into a few key areas of the Bayer process. These areas are described in overview: the purpose is to portray the breadth of projects rather than the detailed outcomes from each one.

5.1 *Gibbsite Precipitation and Alumina Quality*

(P380, P380A, P380B, P380C, P521, P521A, P575, P575A, P625)

The P380 project *Fundamentals of Alumina Precipitation* set the scene for collaborative research in what was traditionally considered a very competitive area amongst producers. This is not surprising, as the precipitation step is the slowest part of the Bayer process requiring substantial volumes of liquor to be held in tankage, involving high capital and operating (descaling and pumping) costs. Hence any significant gains in precipitation technology represent major impacts. P380 was successively extended into P380A, B and finally a small extension P380C.

Project P521 *Relationship between Hydrodynamics and Gibbsite Precipitation* was a spin-off activity from P380B, running in parallel for the third and final year. More recently this was extended into the current project P521A *Development of a Macroscopic Model for Gibbsite Agglomeration*.

The interrelation between the properties of gibbsite particles and the resultant smelting grade alumina has been closely investigated in P575 *Gibbsite and Alumina Quality* and its current extension P575A. The latter has the broadest range of alumina industry sponsors to date: nine alumina producers and one supplier of calciners to the industry.

The P380 series of projects raised some tantalising questions about the presence of impurities in gibbsite, in particular soda. This topic is receiving attention in project P625 *Incorporation of Impurities in Gibbsite during the Bayer Process*.

5.2 *Properties of Bayer Solutions*

(P468, P507, P507A)

Project P468 *Determination of Sodium Oxalate in Alumina Process Liquors by Chemiluminescence Detection* focussed on a critical impurity which requires close control and hence timely and accurate analysis.

P507 *Bayer Liquor Physicochemical Properties* was a small precursor project which led into a substantial effort in the extension P507A *Prediction and Measurement of the Physicochemical Properties of Bayer Liquors*, finishing earlier this year. Being able to predict with high confidence the values of liquor parameters such as density, viscosity and osmotic coefficient are vital for process and engineering applications.

5.3 *Solid-Liquid Separation*

(P266–P266D, P527, P527A, P587)

P266 *Improving Thickener Technology* and its successors have the overall vision to build a comprehensive and holistic understanding of thickener operation in order to identify the means to confidently enhance full-scale performance. All aspects of thickener technology are being studied using a multi-discipline team. Significant benefits from this project have been delivered to the alumina industry and applied within sponsors' refineries, resulting in improved throughput and O/F clarity, reduced flocculant consumption and reduced capital cost of new plant.

P527 *Bayer Process Flocculants* and its extension P527A aim to understand the relationship between the role of flocculants in the Bayer process and the dewaterability of flocculated red mud. A number of new methods for characterising the dewaterability of suspensions of particles have been developed and a simple model of thickening incorporating these measured parameters has been tested and validated through on-site tests.

P587 *Filtration* involves a comprehensive review of filtration equipment, operational issues and will define future industry requirements for improving filtration technology. An extensive research program, will subsequently be undertaken.

5.4 *Crushing and Grinding*

(P9J–M)

The AMIRA flagship project P9 *Mineral Processing*, is a large long-running program aimed at better understanding and developing control, simulation and modelling capabilities for mineral processing unit operations. The key unit operation of interest to alumina companies has been the comminution module. Significant benefits have been delivered from the project, which have now been incorporated into several refineries. A recent major benefit has been the development of the better design of pulp lifters, a product referred to as JKJetLift. This discovery has been implemented at the Wagerup refinery resulting in large increases in throughput and grinding efficiency and large savings in capital cost associated with plant expansions.

5.5 *Equipment and Facilities*

(P379, P379A, P419, P419A, P455, P464, P500, P582)

P379 *Hot Gas Cyclones* and its extension P379A delivered a new monitoring tool to measure the mass and gas flows within hot gas cyclones used in the calcination process. Improved understanding and efficiency of this process have resulted.

P419 *Agitator and Mixing Vessel Design* and its extension P419A delivered new modelling techniques and the ability to understand the mixing efficiency in agitated tanks. The output from this series of projects has been applied extensively at alumina refineries around the world resulting in large increases in mixing efficiency, reduced scaling and reduced energy requirements.

P464 *Pachucas* delivered a better understanding of the design of pachucas in mixing tanks leading to greater process efficiency.

P500 *High Efficiency Pumps* resulted in the development of an improved and more efficient pump design.

P582 *Concrete Slab Design* is a project to better understand the reactions between liquor spillage from refineries and the underlying concrete slabs. Much improved concrete formulations have resulted leading to longer life slabs and reduced liquor ingress into groundwater.

The delivery of successful outcomes from these projects has been contingent on the quality of the research providers involved. The majority of these are located in Australia, the main ones being:

- The A J Parker Cooperative Research Centre for Hydrometallurgy (with key nodes at CSIRO Minerals, Curtin and Murdoch Universities)
- CSIRO Division of Building, Construction & Engineering
- The University of Melbourne
- The University of Queensland (Julius Kruttschnitt Mineral Research Centre)
- The University of South Australia (Ian Wark Research Institute).

The Parker Centre has now established itself as the world leader in public sector research for the alumina industry. Its contributions to the AMIRA collaborative projects have resulted in a substantial ongoing body of contract work for individual companies on a confidential 1:1 basis, often as spin-offs from the projects.

6. The Emphasis and Collaboration become International

In response to major changes to the mining industry AMIRA has turned its attention to global activities, setting up offices in South Africa and North America, and rebadging itself as AMIRA International. It increasingly draws support from international sponsor companies and utilises the expertise of public research organisations worldwide in many projects.

Not surprisingly this has been mirrored by a broader range of alumina producers involved in collaborative projects. The presence of the Australian producers is still evident but we now have Kaiser and Pechiney in their own right as well as Aughinish Alumina and Hydro Aluminium. This is in recognition of the value of being involved in such projects, the changing company structures within the industry, and the capabilities of the alumina research infrastructure created (primarily in Australia) to service the industry.

There is a challenge in expanding the public research infrastructure that serves the industry. To date the focus has been primarily on Australian providers. This is where most of the expertise currently resides. However, there are opportunities to involve new areas of expertise from groups external to Australia. There will need nurturing (just as the Australian ones did in the early days of collaborative projects) to ensure they grow into key providers. Active linkages across these diverse research groups must develop to ensure the industry gains maximum advantage from their expertise.

7. The Alumina Technology Roadmap

Most recently the industry, with AMIRA's assistance, has collaborated in the production of an Alumina Technology Roadmap [1] — recognition of the technical challenges the industry faces over the next two decades — which when implemented will enable the industry to achieve its technology vision. This will be no small task, requiring the active participation of the alumina industry globally and the delivery of excellent outcomes from the world's best researchers.

The background to the Roadmap [2, 3, 4] and progress with its implementation is the subject of a separate presentation at this Workshop.

8. Conclusion

The road of collaborative research can at times be rocky and some risk-taking is required. However, there is now ample proof that the AMIRA model can and does deliver real outcomes and benefits to those companies that become involved and implement the advances in their operations.

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Appendix

AMIRA Projects having one or more Alumina Companies as Sponsors

Project	Start Date	Title	Value/AU$	Research Team
P266	11/88	Thickener Technology	625,930	CSIRO Minerals
P9J	01/89	Mineral Processing	1,740,000	JKMRC
P9K	01/92	Mineral Processing	3,094,000	JKMRC
P380A	02/92	Fundamentals of Alumina Precipitation	1,174,854	Parker Centre +
P380	03/92	Alumina Precipitation	183,141	Uni. S.A., etc.
P379	08/92	Hot Gas Cyclones	612,480	CSIRO BCE
P266A	01/93	Improving Thickener Technology	985,400	CSIRO Minerals
P406	01/93	Hydrogen Fluoride Monitor	168,000	CSIRO Minerals
P419	07/94	Agitator & Mixing Vessel Design	990,000	CSIRO BCE
P406A	02/95	Hydrogen Fluoride Monitoring	74,000	CSIRO Minerals
P455	02/95	Modelling Alumina Precipitators	171,000	CSIRO BCE
P461	06/95	Alumina Industry R&D Study	30,000	AMIRA
P9L	01/96	Mineral Processing	5,928,666	JKMRC
P464	02/96	Pachucas	377,000	CSIRO BCE
P380B	04/96	Fundamentals of Alumina Precipitation	1,402,011	Parker Centre +
P266B	05/96	Improving Thickener Technology	228,000	BHP Engineer.
P468	05/96	Determin. of Sod. Ox. in Alumina Liquors	91,000	Deakin Uni.
P527	03/97	Bayer Process Flocculants	801,235	Uni. Melb.
P379A	06/97	Hot Gas Cyclones	312,500	CSIRO BCE
P507	08/97	Physicochemical Props of Bayer Liquors	92,000	Murdoch Uni.
P521	10/97	Relation. betw. Hydrodynamics & Precip.	270,000	Parker Centre
P266C	11/97	Improving Thickener Technology	2,130,000	Parker Centre
P500	11/98	High Efficiency Pumps	70,000	Pump Techno.
P507A	01/99	Physicochemical Props of Bayer Liquors	801,000	Parker Centre
P419A	04/99	Agitator & Mixing Design	255,000	CSIRO BCE
P575	04/99	Gibbsite & Alumina Quality	431,000	Parker Centre
P582	07/99	Concrete Slab Design	85,000	CSIRO BCE
P380C	09/99	Fundamentals of Gibbsite Precipitation	68,000	Parker Centre
P9M	01/00	Mineral Processing	6,738,000	JKMRC
P625	07/00	Incorporation of Impurities in Gibbsite	520,000	Parker Centre
P527A	05/01	Bayer Process Flocculants	126,000	Uni. Melb.
P266D	06/01	Improving Thickener Technology	3,442,500	Parker Centre
P521A	06/01	Macroscopic Model for Gibbsite Agglom.	478,000	Parker Centre
P575A	11/01	Gibbsite & Alumina Quality	650,000	Parker Centre
P587	01/02	Filtration	108,000	Uni. Melb.
		TOTAL:	**35,253,717**	