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Light Metals Project Distills Decades of Knowledge to Its Essential Elements

Lynne Robinson

Between the covers of *Essential Readings in Light Metals* is testament to the power of great ideas and the lasting impact of keen insight.

Papers dating back to the 1962 AIME International Symposium on the Extractive Metallurgy of Aluminum present the foundation of current practice, while also illuminating directions for future progress. "This is not a textbook, but a collection of the best papers from talented people representing leading aluminum companies, research institutions or themselves," said Geoff Bearne, *Aluminum Reduction Technology* volume editor. "It presents the results and conclusions of more than a generation of work dedicated to improving the industry."

In addition to *Aluminum Reduction Technology*, the *Essential Readings* collection is comprised of volumes on *Alumina and Bauxite*, *Cast Shop for Aluminum Production*, and *Electrode Technology for Aluminum Production*—all spanning more than 40 years of scholarship presented in the TMS *Light Metals* conference proceedings. Each volume was developed under the leadership of two or three editors coordinating teams of topic experts. The sheer magnitude of material that these individuals took on was staggering—at least 1,000 papers per volume, with nearly 5,000 papers overall considered for the project. In total, 33 volunteers gave of their time and expertise to the effort, completing their work in less than a year.

Despite the rather daunting metrics associated with the process, Alan Tomsett, *Electrode Technology* volume editor, said that he found it an enriching experience. "It has been a pleasure rediscovering the older papers published in the *Light Metals* volumes through this project," he said. "It is a credit to the organizers and authors that such a large proportion of the technical knowledge of our industry was originally published and presented at the TMS Annual Meeting."

"Many of the problems that we face—and the ideas that we have—have existed before. Hopefully, these volumes will make it easier to learn from our predecessors."

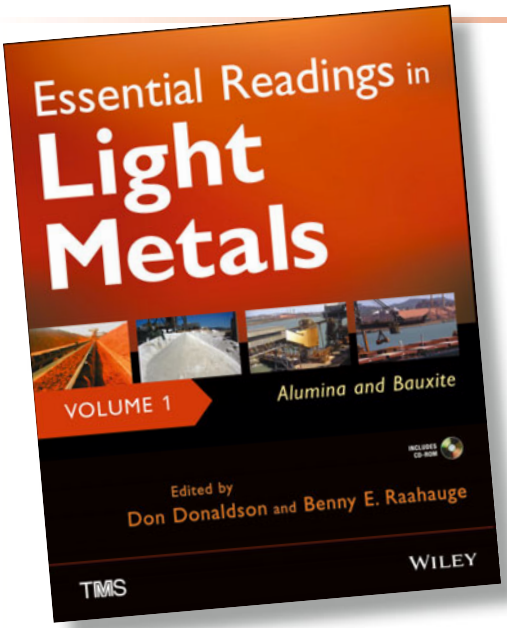
–Geoff Bearne

An easier approach to selecting the *Essential Readings* articles would have been to limit the volumes to the Light Metals Division Best Paper Award winners recognized through the years. The editorial teams, however, saw the undertaking as an opportunity to provide the industry with a comprehensive historical retrospective of industrial innovation. "The project reminded me that we should spend more time looking back as part of the improvement process," said Bearne. "Many of the problems that we face—and the ideas that we have—have existed before. Hopefully, these volumes will make it easier to learn from our predecessors."

To accomplish this goal, the editorial teams established rigorous selection criteria that were applied to all papers, across all volumes. Priority was given to papers that described technological breakthroughs, had a significant impact on the industry, or were highly rated by peers and other sources. Of particular interest were review papers that amassed contemporary thinking on key topics, but were still timeless in their relevance and application.

Another unique challenge faced by

the teams was simply gaining access to all the *Light Metals* proceedings from 1971 through 2011, since so much of the material pre-dated computerized publishing technologies and was not available electronically. It was also determined that papers from the 1962 AIME symposium should be considered, as it was viewed as the precursor to the TMS Light Metals symposia initiated nearly a decade later. A single copy of that event's 1963 proceedings, *Extractive Metallurgy of Aluminum*, was eventually unearthed in a corporate library. "Some of us working on the project weren't even aware of that volume's existence until one of the teams discovered it and suggested that it be part of the selection process," said Matt Baker, TMS publications manager and the staff coordinator for the



Editors:

Don Donaldson, Alumina Industry Consultant

Benny E. Raahauge, General Manager, Pyro & Alumina Technology, FLSmidth A/S

Main Subjects: Bauxite; Bayer Process; Digestion; Clarification, Red Mud Washing and Liquor Filtration; Precipitation, Classification, and Seed Filtration; Product Hydrate Filtration and Alumina Production by Calcination; Water, Evaporation, and Energy; Alumina Quality; Health, Safety, and Plant Maintenance; Process Control/Simulation; Red Mud Disposal and Other Environmental Concerns; Alternative Processes and Raw Materials; Non-Metallurgical Uses of Bauxite, Hydrate, and Alumina.

Alumina and Bauxite

Earliest Papers and Their Impact:

Donaldson: "'Basic Principles of Bayer Process Design,' by A.N. Adamson, E.J. Bloore, and A.R. Carr from *Extractive Metallurgy of Aluminum* (1963) will be useful to anyone as an introduction to understanding the basics of Bayer Process technology."

Raahauge: "The oldest paper included on calcinations is from 1973 and describes the change from a 'vertical' to a 'horizontal' plant design of circulating fluid-bed calciners, illustrating the ongoing efforts by technology suppliers to stay competitive. There are also two papers [from the same timeframe] on alumina quality. One deals with the mineralogical dehydration path of gibbsite in rotary kilns and stationary calciners. This is fundamental for understanding the products of different calcinations technologies, with respect to producing optimized smelter-grade alumina quality. The other describes how to measure dustiness of alumina—a very complex field and highly relevant to the daily smelter operation."

Milestones Reflected in this Volume:

Donaldson: "The evolution of the Bayer Process refinery design from batch to continuous operation started about the time that World War II began in Europe, with continuous precipitation developed in Europe for the production of floury alumina. It wasn't until 1967 that continuous precipitation was developed, using North American technology, for the production of sandy alumina. The use of sandy alumina to remove HF from smelter off-gasses, developed in the late 1960s, virtually eliminated the production of floury alumina by European technology."

Raahauge: "In calcination, a technology shift away from rotary kilns to stationary calciners using classical fluidized-bed technology was initiated by Alcoa in 1951–1952, followed by the circulating fluid-bed technology in 1971–1972, reducing solids calcination time from hours to minutes. The introduction of the gas suspension calciner technology in 1976–1986 reduced the calcination time to seconds."

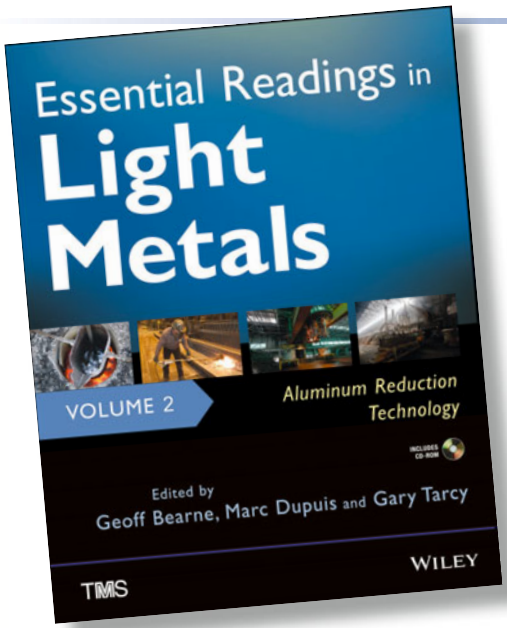
Observations on Innovation:

Donaldson: "The introduction of synthetic flocculants in the separation of red mud was developed by suppliers outside the industry. The flocculants worked extremely well in the laboratory, but when tested in the refinery, the results were not good and refinery operators rejected them. The flocculant manufacturers then developed refinery demonstration equipment to convince operators of the benefits, [and] the use of flocculants became universal. Over a period of time, clarification settlers and washers were reduced in size and number to a fraction of the size required previously. These very significant developments in clarification could not have been done without synthetic flocculants."

Raahauge: "Access to good quality bauxite may be less frequent in the future for various reasons, requiring application of flotation and other mineral processing technologies and improvements to de-silication and digestion in order to economically process bauxite of lesser quality. On the residue side, the 2010 breakdown of the red mud residue dam in Hungary has placed development of safe and cost-efficient bauxite residue technology and management at the top of the agenda for ensuring the 'license to operate' for alumina refineries in various places in the world."

effort. "We were fortunate to be able to include it because of its historical significance."

After months of scanning, exchanging, and reviewing many thousands of pages, the teams succeeded in distilling the years of *Light Metals* wisdom to a list of about 140 to 160 candidate papers for each volume. Manufacturing restrictions—the books could not be physically bound beyond 1,200 pages—compelled even further fine



Editors:

Geoff Bearne,
General Manager,
Rio Tinto Technology
& Innovation

Marc Dupuis,
Consultant,
GeniSim

Gary Tarcy,
Manager, Smelting
Research and
Development, Alcoa

Main Subjects: Fundamentals; Modeling; Design; Operations; Control; Environmental; Alternative Processes

Aluminum Reduction Technology

Earliest Papers and Their Impact:

Bearne: "We have been fortunate to be able to include two papers from the very first conference proceedings, published in 1963. The ideas presented in these papers are as relevant today as they concern process fundamentals for what is effectively still the same process."

Dupuis: "From 1973, heat balance, finite difference method to calculate heat flux, [and related concepts] are obviously as relevant today as they were 40 years ago. This has now become training course material, but at the time, it was at the forefront of research and development."

Tarcy: "One paper from 1963 discusses some of the fundamental electrochemistry of the process that has led to impressive control of the cells. Another from that year covers aspects of the ever-prevalent fluoride pollution issue. It is impressive that, from the very beginning, the industry has been very open about sharing information with respect to fluoride emissions issues."

Milestones Reflected in This Volume:

Bearne: "As we all know, the Hall-Héroult process for making aluminum is still going strong after 127 years, with no commercial alternatives in sight. What we have seen in the last 50 years is evolution, not revolution. For me, a key milestone in reduction technology occurred in the 1970s, when computers first impacted the industry through their application to modeling and control. Their influence is self-evident in the collection of papers."

Dupuis: "As described in the introduction to the modeling section, that activity went from essentially non-existing, to being very expensive and mostly fruitless, to finally becoming a big success story by becoming indispensable in the process of designing modern, efficient high-amperage cells."

Tarcy: "I think the key milestones were driven by an improvement in the fundamental understanding of how the process works, leading to ever-improving current efficiency, energy efficiency, and cell size. When the first volumes were published, current efficiency was about 85 percent, energy efficiency was approximately 15 kWh/kg, and there were almost no cell designs greater than 100 kA. We now have regular publications of current efficiency above 95 percent, energy efficiency less than 13 kWh/kg, and cell designs in the 500-600 kA range."

Observations on Innovation:

Bearne: "One interesting example of disruptive innovation in the volume is the Aluminium Pechiney 280kA pots paper published in 1986. This technology, subsequently rebadged AP30, became a benchmark that has been used in the majority of smelter projects outside of China. Its development was enabled mainly by advanced computer modeling and engineering, as well as innovative control strategy."

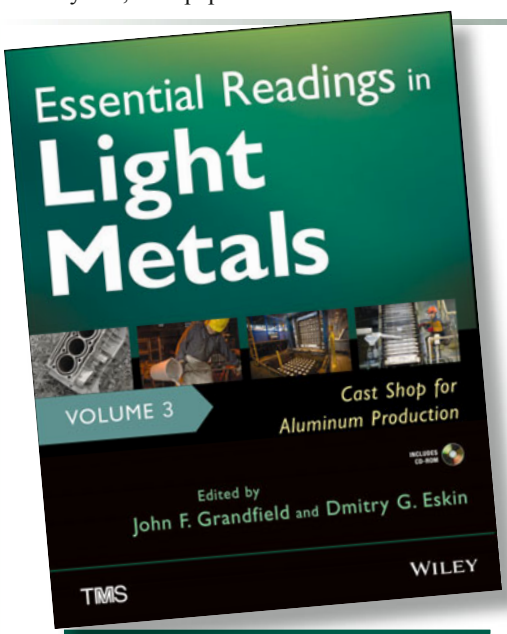
Dupuis: "I especially like the Leroy story on his discovery of the negative impact of excessive alumina feeding on current efficiency and the subsequent development of the continuous tracking alumina feeding scheme. For almost 20 years, Pechiney remained isolated in thinking this way. It greatly contributed to the commercial success of the AP family of cell technology."

Tarcy: The quantitative description by Roberts and Ramsey of the cause and effect relationship of PFC emissions with anode effect duration opened the floodgate for other papers and a remarkable improvement in the PFC emission rate by smelters all over the world."

tuning to a final selection. The "short list" articles that were ultimately not published in *Essential Readings* are indexed in "Recommended Readings" sections throughout each volume, reflecting their value as part of the industry's knowledge base. At the conclusion of the selection process, only about 10 to 15 percent of all *Light Metals* articles published over the decades made it into *Essential Readings*.

While many of the fundamental concepts and technologies represented in the volumes have held firm over the years, the papers—considered as a whole—provide valuable perspective on how the industry has grappled with such issues as energy efficiency, environmental impact, resource availability, and economic pressures over time. As noted in the preface to the *Cast Shop* volume, the project has also helped shed light on "innovative concepts that perhaps the industry did not capitalize on at the time, [but] may now be viable due to the development of modern enabling technologies." Later papers reflecting the impact of some of those "enabling technologies"—particularly the power afforded by computerization and computational tools—offer stepping stones to future innovation.

Highlighting these connections between the learning of the past to future discoveries is probably the most significant contribution of the *Light Metals* project. "Very little really new learning has happened over the recent years," commented Benny E. Raahauge, *Alumina and Bauxite* volume editor. "It is as though some of the former published technical papers had been forgotten—There has been a tendency to repeat some of the old work using new analytical tools. This is not necessarily



Editors:

John Grandfield,
Grandfield Technology

Dmitry Eskin,
Brunel University

Main Subjects: Furnaces, Melting, Fluxing, and Alloying; Oxidation and Dross Processing; Melt Quality: Degassing, Filtering, Analysis; Structure: Grain Refinement, Modification, and Microsegregation; Direct-Chill Casting; Casting Defects and Their Control; Other Casting Methods; Heat Treatment; Safety

Cast Shop for Aluminum Production

Earliest Papers and Their Impact:

Grandfield: "O.G. Gjosteen, A. Aarflot, T. Ternum, 'Vacuum Treatment of Molten Aluminum,' (1971). Vacuum treatment has not been widely adopted, although the SIR inline degasser uses partial vacuum to achieve reduced argon consumption. The wholesale processing and casting of liquid aluminum under vacuum present tantalizing possibilities to reduce dross generation and achieve high-quality metal."

Milestones Reflected in This Volume:

Grandfield: "Improvement in cast shop safety; development of spinning rotor degassing units to achieve fast, efficient degassing with less gas consumption; development of filtration technology to improve product quality; gas pressurized DC casting to reduce scrap during extrusion; advances in understanding of DC casting physics in water cooling, deformation, and fluid flow to enable better process design and control to reduce scrap and improve quality; automation of direct chill casting to enable safe, operator free casting; metal quality measurement systems.

Eskin: Introduction of melt processing as standard operations; application of physical chemistry, physical metallurgy, and computer simulations for understanding why the technology works and to improve it; development of various mold designs based on understanding of thermal management and shell formation; improved understanding of grain refining efficiency and links to alloy composition; research into new melt processing techniques.

Drivers of Innovation:

Grandfield: "There has undoubtedly been a 'technology push' from equipment suppliers to provide new gear to increase sales, but these developments have met real quality and productivity needs in the cast shop. The downstream quality requirements of cast shop customers still drive development, along with the intent to reduce costs and safely produce products in a sustainable way."

Eskin: "The role of modeling and computer simulations is increasingly high, both in the development and optimization of technology, and in the understanding of mechanisms for structure and defect formation."

bad, but the conclusions may be misleading if the results are misinterpreted or non-representative, owing to non-representative test conditions, when compared to industrial-scale processing. Fortunately, publishing *Essential Readings in Light Metals* will reduce such events in the future."

Dmitry Eskin, *Cast Shop* volume editor, agreed, saying, "The role of such a reference source is to not only remind us about the treasures of the past, but to also save time for the current researcher by not repeating what others have done, and instead moving forward."