

Essential Readings in **Light Metals**

VOLUME 4

*Electrode Technology for
Aluminum Production*

Edited by
Alan Tomsett and John Johnson

TMS

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PREFACE

The *Light Metals* proceedings are widely recognized as the definitive reference for electrode technology for aluminum production. The papers published in 1963 (based on the 1962 symposium) and then annually from 1971 to the present contain the combined knowledge of both industry and international research institutes.

The 1962 New York symposium, organized by Robert Lewis (Kaiser) and Phillip Stroup (Alcoa), was remarkable in many ways. First, almost every primary aluminum producer in the Western world participated. Second, the openness and willingness to share and disclose internally developed research or practices of both basic and operational relevancy, which could conceivably be regarded as “proprietary” or “corporately advantageous,” was surprising and illuminating. This new-found freedom and reciprocity for sharing information possibly reflected the pride each company had in its internal technological strength. It may also have been prompted by a company’s hidden agenda in promoting an aspect of the Hall-Héroult process that was perceived to be superior to competitors and therefore, potentially marketable. The meeting comprised sessions on the Bayer process, fundamentals, modeling, modern developments in cell design, methods of analysis relating to the Hall-Héroult process, anode and cathode technology, new processes and materials. The contacts made by the subcommittees organizing the agenda paved the way for what was to emerge in the future. The quality of the papers and the rapport and camaraderie of the attendees at that symposium were so evident and stimulating that it became the precursor for the subsequent Light Metals Symposia at the Annual Meeting of The Minerals, Metals & Materials Society.

This collection of the papers published between 1963 and 2011 provides a single reference for electrode technologists. It can be used by those new to the industry and require a rapid introduction to the technology or by more experienced practitioners and researchers who need information of what has been done on an issue in the past.

An international team of experts with more than 300 years of combined experience in the industry was formed to review the papers in the *Light Metals* books. The team members have all been regular contributors to *Light Metals* as authors, session chairs and/or the electrode symposium chair. The selected papers are those that the team assessed as:

- important and have had a large influence on work,
- having had a large impact on the industry,
- describing breakthroughs in the science of electrode technology, and
- important review papers that bring together the thinking of key topics at the time, and have stood the test of time.

The papers that were considered for the volume were based on the current definition of electrode technology at the TMS Annual Meeting. This required some transfer of papers between reduction technology and electrode technology from earlier years. The papers have been separated into three distinct sections:

1. **Hall-Héroult Cell Carbon Anodes**, including all papers on anode raw materials, anode production, and anode performance
2. **Hall-Héroult Cell Cathodes**, including papers on reduction cell materials and reduction cell failure mechanisms, but not modeling or start-up
3. **Inert Anodes and Wettable Cathodes**, including all papers on materials and performance

The papers have been sequenced to place like topics together and to have a technology rather than historical progression. It is expected that this will be a more usable format for the reader.

At the end of each section, there is an additional list of recommended reading on the topic. These are *Light Metals* papers that the editorial team believes are useful resources but could not be included in final volume due to the book production requirements.

The task of reviewing the papers was very large. Within electrode technology there have been 1,190 papers published between 1963 and 2011. We are extremely grateful to all the authors of these papers for recording their work in *Light Metals*. The time and efforts of the session and symposium chairs over the years for the review of papers and encouragement for the authors must

also be acknowledged.

This volume was only made possible with the outstanding contributions of the remainder of the editorial team:

- Carbon Anodes: Roy Cahill, Frank Cannova, Petter Lossius, Barry Sadler, and John Secasan
- Cathodes: Dick Jeltsch, Jeff Keniry, Steve Wood, and Roy Cahill
- Inert Anodes and Wettable Cathodes: Gary Tarcy and Greg Hardie

All have donated a significant amount of time and effort to the project. Our heartfelt thanks go to this team for its assistance in making this project a success. We must also recognize and thank the production team at TMS and Wiley led by Matt Baker for their support and efforts in formatting and digitizing the papers.

It has been a rewarding experience re-reading and selecting the papers included in this book. We have prepared a volume that will be used as a reference book for many years to come. It is, however, not the end of the development of electrode technology. Through reading these papers, we hope we inspire new authors from industry and universities to contribute to future *Light Metals* volumes.

Alan Tomsett

John Johnson

Lead Editors

LEAD EDITORS



Alan Tomsett

Alan Tomsett has more than 25 years of experience in carbon anode and cathode technology. He received his B.Sc. and Ph.D. in Chemical Engineering from the University of New South Wales in Sydney, Australia. Alan joined the Comalco Research Centre in Melbourne, Australia in 1987 and has held numerous positions at Comalco/Rio Tinto/Pacific Aluminium including Carbon R&D Manager, Program Director for the global Rio Tinto Alcan Carbon Team, and Carbon Technical Manager for the Rio Tinto Alcan Pacific Region. In these roles, he has provided technical support on process and raw materials to the Australasian Carbon Plants, led the material development program for the Comalco Drained Cathode Project, and evaluated carbon plant technologies for brownfield and greenfield expansions. Alan is now Technical Director for the Pacific Technology Centre, Pacific Aluminium. In this broader role, he provides technical support and advice across all areas of the Pacific Aluminium smelters. Alan has been a member of The Minerals, Metals & Materials Society since 1996 and has been the 2011 Electrode Symposium Chair, an Electrode Technology Session Chair, and Secretary of the TMS Aluminum Committee in 2011 and 2012. He is the coauthor of several TMS papers, has been a guest lecturer for the University of New South Wales/University of Auckland Graduate Program in Smelting Technology, and a regular contributor to the Australasian Smelting Conference.



John A. Johnson

John A. Johnson holds a B.A. in chemistry and M.S. in Chemical Engineering. He has 42 years of experience in the aluminum, specializing in prebake and VSS anode technology; design, prebake cell design and development, and currently heads his own consulting business. He joined Martin Marietta Aluminum (MMA) in 1971 where he held positions of laboratory manager, carbon superintendent, project engineer, and technical manager. He was responsible for implementation of Sumotomo and Mitsubishi Söderberg dry anode technology at MMA, and became the technical manager for Commonwealth Aluminum (Comalco). In 1987, he left the industry for four years to become the engineering and production manager for Injection Metal Molding Production where he was responsible for developing processes and programs for the powder injection molding technology used to form near net shape sintered metal parts. He joined Kaiser Aluminum International in 1990 as technical manager for Kaiser's project at the JSC Krasnoyarsk Aluminium Plant. Later, as Technical Manager, Kaiser Aluminum International, he was responsible for technology transfer and sales. In 2001 he joined UC RUSAL's Engineering and Technical Centre Ltd., Krasnoyarsk, Russia, where he held the positions of Head of Carbon Department, Manager of Carbon Projects, and Manager of the RA 300 and RA 400 Cell Development program through December 2008. He was the editor of *Light Metals 2010*, has been a TMS author, and is a former member of the TMS Light Metals Division Aluminum Committee where he held the positions of Chair and Co-Chair of the TMS Light Metals Electrode Technology for Aluminum Production Symposium.

EDITORIAL TEAM



Roy Cahill

Roy Cahill started in the aluminum business in 1996 with Reynolds Metals Company. Since that time he has had positions within Alcoa and Rio Tinto Alcan, and is now working for Pacific Aluminium. Roy has worked in areas ranging from alumina production, coke calcination, carbon anode production, and spent cathode treatment processes. He is currently the Principal Carbon Consultant at the Pacific Aluminium, Pacific Technology Centre in Brisbane, Australia. Roy holds a Ph.D. in Chemistry from Texas A&M University.



Frank Cannova

Frank Cannova is presently the Technology Manager for BP's Coke and Bitumen Technology group based in Huntington Beach, California. Frank has worked in support of BP's (and previously ARCO's) refining operations for more than 30 years and has been leading BP's Coke Product Technology Support efforts since 2000. He has had a varied career in the industry, holding positions in technology, operations, engineering, maintenance, and business development. Frank has been a regular contributor to the TMS Electrode sessions, contributing multiple technical papers and serving frequently as a session chair. He is an Engineering Authority in BP, received a bachelor's degree in Chemical Engineering from the New Jersey Institute of Technology, obtained an MBA from the California State University at Fullerton, and is a licensed professional engineer.



Greg Hardie

Greg Hardie is the Chief Technologist for Rio Tinto Alcan (RTA) Technology based in Voreppe, France. Greg joined Rio Tinto as a Research Metallurgist at the Cockle Creek Research facility in the Hunter Valley, Australia, in 1984. He has held numerous technical roles in the iron and aluminum divisions of Rio Tinto based in Germany, Western Australia, Tasmania, and Canada. Greg was Project Manager for the Comalco Coated Cell Project for more than 10 years. In his current role, Greg supports the development and implementation of new technology in RTA. Greg has a B.E. with First Class Honours in Chemical Engineering from the University of New South Wales.



Richard Jeltsch

Richard Jeltsch is a graduate of Case Western Reserve University, Cleveland, Ohio, with a Master of Science in Chemistry. He spent 22 years with Kaiser Aluminum in process engineering and environmental management, with the last 12 years at Kaiser's Primary Products Technical Center as Cathode Technology Specialist. Since leaving Kaiser, Richard has spent 10 years consulting with an international clientele in the area of cathode technology, specializing in cell life improvement and reduction cell autopsies. Richard has presented several papers at the TMS Annual Meeting and has been a lecturer on cathode technology for the TMS Aluminum Electrolysis course since 1999.



Jeff Keniry

Jeff Keniry has been associated with aluminum smelting operations, project development, and technology for 35 years. Corporate roles have included Technical Manager with New Zealand Aluminium Smelters, and General Manager of Smelting R&D with Comalco Aluminium. He is currently Director of Alumination Consulting, based in Melbourne, Australia, and for the past 15 years has provided consulting services to some 25 international smelters on every continent. Jeff has degrees in Applied Science and Business Administration from Australian universities.



Lorentz Petter Lossius

Lorentz Petter Lossius has an M.Sc. in instrumental analysis from the Norwegian University of Science and Technology (NTNU) and completed his Dr.ing. at NTNU in 1991 with the thesis “Removing Impurities from Secondary Alumina.” He then spent a year as a post-doc at the Université de Fribourg, Suisse, studying the electrochemistry of batteries and three years with Harald A. Øye as a research assistant/group leader at SINTEF/NTNU. He joined Norsk Hydro in 1996 and is a principal engineer in the Anode Production section of the Hydro Aluminium Primary Metal Technology research unit; his main area is pilot scale anode development and laboratory operational support. He is Chair of the ISO Technical Committee 226 “Materials for the production of primary aluminium” and is Secretary of ASTM Sub-committee D02.05 “Properties of fuels, petroleum coke and carbon material.” He is on the board of the Norwegian X-ray Conference. He has more than 30 published papers including the 2008 TMS Light Metals Division Electrode Technology section award-winning “Coke and Anode Desulfurization Studies” (co-authored with Les Edwards and Keith Neyrey), and the 2010 TMS Light Metals Division award-winning “Charcoal in Anodes for Aluminium Production” (co-authored with Bodil Monsen and Arne Petter Ratvik). Both studies are based on original work mostly performed at the Hydro pilot scale facility in Årdal, Norway.



Barry Sadler

Barry Sadler has been involved in the aluminum industry for more than 30 years in a range of positions but always with a focus on anode carbon technology. He has a Ph.D. in Metallurgy, and commenced his career in 1982 at the Comalco Research Centre in Melbourne, Australia, before moving to Comalco’s New Zealand Aluminium Smelter (NZAS) as Carbon Plant Manager in 1989. After more than 7 years at NZAS, Barry was appointed as a Corporate Technical General Manager at Comalco Aluminium’s headquarters in Brisbane, Australia. Barry left Rio Tinto/Comalco in 2002 to set up Net Carbon Consulting Pty Ltd. As a consultant,

he provides advice, training, and support to clients on improving carbon plant performance and process technology, always maintaining a strong focus on the practical application of statistical thinking and methods to process management. Barry has authored or co-authored more than 27 technical papers, and is a regular lecturer on anode technology at post-graduate courses run by the University of Auckland. He has been an active member of the The Minerals, Metals & Materials Society for over 25 years as a presenter, session chair, subject organizer, 2013 Chair of the Aluminum Committee, and editor of *Light Metals 2013*.



John Secasan

John Secasan holds a B.S. in engineering from the University of Materials Science and Engineering, Cluj Napoca, Romania. During his time with Alcoa, he has held several technical positions with responsibilities in aerospace and primary metals. He has specialized in areas including carbon raw materials for anodes, carbon anode manufacturing, and carbon anode performance in the Hall-Heroult electrolysis cells. In these areas, he initiates and leads technical projects related to carbon raw materials and anode quality improvements and additionally provides technical expertise on carbon raw materials and anodes to Alcoa's Primary Metals division worldwide. John is currently a research and development engineer in the Technology Development Group within Alcoa's Technology, Innovation and Center of Excellence, located at the Alcoa Technical Center in Pittsburgh, Pennsylvania, USA.



Gary Tarcey

Gary Tarcey is the Manager of Smelting R&D at Alcoa Technical Center, New Kensington, Pennsylvania, USA. Gary has worked for Alcoa for 34 years. He holds 26 patents and has published 31 papers. In 1986 he was the winner of the Alcoa Chapter of Sigma Xi best technical paper award and in 2000 the winner of Alcoa's Arthur Vining Davis Award for Technical Excellence. In 2005 he was the winner of the TMS Light Metals Award for best paper. In 2011 he won the TMS Light Metals Award for the best paper for the second time and also won the Professor Barry Welch Best Paper at the 10th Australasian Smelting Technology Conference. In 2006 he was the winner of the alumni of the year from the Department of Chemistry. Only six such awards have ever been given. Gary is also an invited lecturer for the TMS Industrial Electrolysis course and has been an invited lecturer at several of the Australasian Aluminum Smelting and Technology Conferences. Gary holds both B.S. and M.S. degrees in chemistry from Bowling Green State University where he specialized in the study of electrochemistry and photo-electrochemistry.



Steve Wood

Steve Wood is a graduate of Murray State University with degrees in chemistry and mathematics. He was a Staff Process Engineer at NSA in Hawesville, Kentucky, USA. Included in his responsibilities was the testing and evaluating of cathode materials and cathode design improvements with the long term goal of increasing cathode life and improving overall cell performance.