Conference Program

13th Biennial Worldwide Congress on Refractories

Unitecr 2013

The Unified International Technical Conference on Refractories

SEPT. 10-13, 2013

The Fairmont Empress and Victoria Conference Centre
Victoria, British Columbia, Canada

www.unitecr2013.org

Hosted by:

The American Ceramic Society
www.ceramics.org

Scan for UNITECR'13 app

CMA 72

Leading castable technology

- Calcium-Magnesium-Aluminate binder with built-in micro spinel obtained by reaction sintering
- Placing properties similar to SECAR® 71
- Ultra-fine spinel grains providing superior corrosion resistance

Visit the SECAR® website
www.secar.net

kerneos™
ALUMINATE TECHNOLOGIES

Kerneos S.A.: 8, rue des Graviers • 92521 Neuilly-sur-Seine Cedex • Phone: +33 (0)1 46 37 90 00 • Fax: +33 (0)1 46 37 92 00

REF. KMA72|GB|1_1|06|2013 Design by : j-creation.fr

13th Biennial Worldwide Congress on Refractories

Unitecr 2013

The Unified International Technical Conference on Refractories

CONTENTS

Scan for UNITECR'13 app

UNITECR ORGANIZATION

UNITECR 2013 Officers

Lou Trostel PhD, President, Ceramic Concepts, Princeton, MA USA

Dana Goski PhD, Technical Program Chair

Robert Crolius, Co-Finance Chair, The Refractories Institute, Pittsburgh, PA USA

Nancy Bunt, Social Program Chair and Co-Finance Chair, Kerneos, Inc.,Chesapeake, VA USA

North American UNITECR Committee

Jeffrey Smith PhD, Chairman, Missouri University for Science & Technology, Rolla, MO USA

Nancy Bunt, Kerneos, Inc., Chesapeake, VA USA

Dana Goski PhD, Allied Mineral Products, Inc., Columbus, OH USA

Mike Alexander, Riverside Refractories, Pell City, AL USA

Founding Members

– The American Ceramic Society (ACerS)
– The German Refractories Association (GRA)
– Association Latinoamericana de Fabricantes de Refractarios (ALAFAR)
– The Technical Association of Refractories, Japan (TARJ)

Principal Members

– Chinese Ceramic Society (CCS)
– Indian Refractory Makers Association (IRMA)
– Fédération Européenne des Fabricants de Produits Réfractaires (PRE)

Secretariat

The American Ceramic Society, 600 North Cleveland Avenue
Suite 210, Westerville, OH 43082 U.S.A.
unitecr@ceramics.org | Phone: +1-614-794-5829

WELCOME FROM UNITECR'13 PRESIDENT

Welcome on behalf of the UNITECR 2013 organizers. We are pleased that you are attending UNITECR 2013, September 10-13, 2013 at the Victoria Conference Centre in Victoria, British Columbia.

UNITECR 2013 is the 13th Biennial Worldwide Congress on Refractories. It is the fourth time UNITECR has been hosted by the United States and is the beginning of the fourth cycle of these meetings that rotate among founding members in the U.S., Germany, Latin America, and Japan. These founding members are The American Ceramic Society (ACerS), German Refractory Association (GRA), Association Latinoamericana de Fabricantes de Refractorios (ALAFAR), and The Technical Association of Refractories, Japan (TARJ). In addition to these founding members, UNITECR is also supported by other principal members including the Chinese Ceramics Society (CCS), the Indian Refractory Makers Association (IRMA), and the Federation Europene des Fabricants de Produits Refractaires (PRE)

While the technical exchange of information at UNITECR is the highlight, focus, and purpose of the meeting, it seems that the social interaction and the exchange of commercial and market information is of equal importance to many attendees. As the refractory industry and its markets become more global in nature, the UNITECR meeting presents a unique opportunity for learning what happens in other parts of the world and becomes ever more important for companies that are growing their global presence. For those participants outside of the segment represented by industry, the meeting is an opportunity to renew acquaintances face to face and exchange information on topics of mutual interest.

To all of you in the worldwide refractories community, I encourage you to participate fully in UNITECR 2013. This is truly the premier congress of refractory manufacturers, users, technologists, and scientists from around the globe, exchanging information in the field of refractories on which the industry of our world depends.

I look forward to seeing you this week.

Lou Trostel, PhD
President UNITECR 2013
Ceramic Concepts, Princeton, MA USA

Free Internet Access in the Victoria Conference Centre

1. Connect your Wi-Fi enabled device to the "VCC" wireless network.
2. When you are taken to the login page, select "I have a code" and enter information as requested.
3. The code to enter is : **GKPFWB**

Access the Itinerary Planner 2 Ways

1. Download the free meeting app by scanning the QR code at the bottom-right front corner of the conference program.
2. Visit http://unitecr2013.abstractcentral.com/planner.jsp

The Members of

THE REFRACTORIES INSTITUTE

express their appreciation to the volunteers, staff, company sponsors, and participants who are contributing their time, resources, experience and knowledge for the benefit of the international refractories community.

Unitecr 2013

TRI

Companies working together
In support of the
refractories industry

For membership information:

The Refractories Institute
P.O Box 8439
Pittsburgh, PA 15218
Phone: (412) 244-1880 Fax: (412) 244-1881
www.refractoriesinstitute.org

WELCOME FROM UNITECR'13 CHAIRS

Welcome to the 13th Biennial Worldwide Refractories Congress recognized as the Unified International Technical Conference on Refractories (UNITECR), held September 10-13, 2013 in Victoria, British Columbia, Canada.

UNITECR has become the premier worldwide congress on refractories and is the most prominent international technical conference on refractories. This is the first time the conference has been held in Canada. UNITECR 2013 was organized by current and previous members of the North American Executive Board of UNITECR comprised of Tom Vert, Rob Crolius, Jeff Smith, Dana Goski, Nancy Bunt, and Mike Alexander with the assistance of The American Ceramic Society (ACerS). The organizers want to share a special thank you to Mark Stett, Lou Trostel, Jr. and Charlie Semler for their continuing support, providing both historical details of previous UNITECR meetings and offering new suggestions to continually advance the meeting to benefit attendees, authors and industry.

The UNITECR 2013 poceedings are published electronically and contain 231 manuscripts. Two new communication opportunities have been created for authors this UNITECR. Authors were provided the option to have manuscripts peer reviewed, a new approach for UNITECR that was implemented in the expectation to further elevate the quality of the congress. Fifty manuscripts were peer reviewed and are identified in the table of contents, and with an additional header at the top of the title page of the paper recognizing it as a peer reviewed manuscript. The second new opportunity was to publish a manuscript yet have a different avenue to interact with authors by discussing their work via a poster presentation. Over 30 authors submitted papers in which their presentation technique was a poster.

The editors want to thank the 34 symposia organizers listed below, the many session co-chairs listed in this program, the authors for their contributions, the manuscript reviewers and the meetings and publication staff at ACerS.

Advanced Testing of Refractories – **Len Krietz**, Plibrico Company LLC, USA; **Nigel Longshaw**, Ceram, UK

Advanced Installation Techniques & Equipment – **Jim Stendera**, Vesuvius, USA; **Hirohide Okuno,** Taiko Refractories, Japan

Monolithic Refractories – **Dale Zacherl**, Almatis, USA; **Goutam Bhattacharya,** Kerneos, India

Iron & Steel Making Refractories – **Mike Alexander**, Riverside Refractories, USA; **Patrick Tassot**, Calderys, Germany

Raw Material Developments & Global Raw Material Issues – **Shane Bower**, Christy Minerals, USA; **Phil Edwards**, Imerys, France

Refractories for Glass – **Dr. M.D. Patil**, Corning, Inc., USA; **Adam Willsey**, Kopp Glass, USA

Cement & Lime Refractories – **Fielding Cloer**, Spar Refractories, USA; **Dr. Swapan Das**, Central Glass & Ceramic Research Institute, India

Modeling and Simulation of Refractories – **Dr. Bill Headrick**, MORCO, USA; **Prof. Harald Harmuth**, MontanuniversitätLeoben, Austria

Petrochemical – **Don McIntyre**, ANH, USA; **Ken Moody**, Refractory System Solutions, USA

Refractory for Waste to Energy Processing & Power – **Ben Markel**, Resco, USA; **Dr. Andy Wynn**, Morgan Engineered Materials, China

Energy Savings through Refractory Design – **Dr. James Hemrick**, Oak Ridge National Laboratory, USA; **Dr. Valeriy Martynenko**, The Ukrainian Research Institute of Refractories, Ukraine

Nonoxide Refractory Systems – **Dave Derwin**, Superior Graphite, USA; **Marcus Vinicius**, **Moraes Magliano**, Morgan, Brazil

Refractories for Chemical Processes – **Dr. James Bennett**, NETL, USA; **Matthias Rath**, Rath, Austria

Developments in Basic Refractories – **Dominick Colavito**, Minerals Tech, USA; **Prof. Andrie Garbers-Craig**, Univeristy of Pretoria, South Africa

Global Education in Refractories – **Dr. George Oprea**, University of British Columbia, Canada; **Prof. Yawei Li**, Wuhan University of Science and Technology, China

Refractories for Nonferrous Metallurgy – **Rick Volk**, United Refractories, USA; **Angela Rodrigues-Schroer**, Wahl Refractory Solutions, USA

Safety, Environmental Issues & Recycling Solutions for Refractories – **Jason Canon**, Christy Refractories, USA; **Dr. Leonardo Curimbaba Ferriera**, US Electrofused Minerals/Electroabrasives LLC, USA

It is hoped that this congress will advance the understanding of refractory technology and promote international exchanges in research, education and industrial practice. The editors envision that these proceedings will serve as a useful resource for research in a field which has limited global publications.


Dana Goski


Jeffrey Smith

Dr. Dana G. Goski

UNITECR 2013 Technical Program Chair

Dr. Jeffrey D. Smith

Chairman, North American UNITECR Executive Committee

SESSION CHAIRS BY SYMPOSIUM

Advanced Testing of Refractories
Len Krietz, Plibrico Company LLC, USA
JP Willi, Sunset Refractory Services, USA
Nigel Longshaw, Ceram, UK
Bob Fisher, Consultant/Nock & Son, USA

Advanced Installation Techniques & Equipment
Jim Stendera, Vesuvius, USA
Hirohide Okuno, Taiko Refractories, Japan

Monolithics
Dale Zacherl, Almatis, USA
Bjorn Myhre, Elkem, Norway
Dave Bakshi, CE Minerals, USA
Goutam Bhattacharya, Kerneos, India
Christos G Aneziris, Technical University Bergakademie Freiberg, Germany
Jens Decker, Stellar Materials, USA
Randy Mauzy, Aluchem, USA
Ted Huang, Allied Mineral Products, China

Iron & Steel Making Refractories
Gary West, Suncoke Energy, USA
Patrick Tassot, Calderys, Germany
Xiaoyong Xiong, Imerys Refractory Minerals, France
Arupk Chattopadahyay, TRL Krosaki Refractories, India
Ningsheng Zhou, Henan University of Science and Technology, China
Vanessa Mazzetti-Succi, ArcelorMittal Dofasco, Canada
Mike Alexander, Riverside Refractories, USA
Gary Hallum, CCPI, USA
Jacques Poirier, University of Orleans - CNRS, France
Arnaud Lafaurie, ALTEO, France
Brian Kenyon, Vesuvius, USA
Helge Jansen, Refratechnik Steel, Germany
Olaf Krause, Forschungsgemeinschaft Feuerfest e.V, Germany
Farhad Golestanifard, Iran University of Science & Technology, Iran
Steve Mangin, Magnesita, USA
Atsuya Kasai, Nippon Steel & Sumitomo Metal, Japan
Carl Zetterstrom, Kerneos, France
Andus Buhr, Almatis, Germany
Thomas Schemmel, Refratechnik Steel, Germany
Carlos Pagliosa, Magnesita Refractories, Brazil
Nathan Leicht, Shinagawa, Australia
Yuechu Ma, Allied Mineral Products, USA
Dilip Jain, Kyanite Mining, USA
Yong Lee, ArcelorMittal Research, USA
Rakesh Dhaka, US Steel, USA
Peter Quirmbach, University of Koblenz-Landau, Germany

Raw Material Developments & Global Raw Material Issues
Shane Bower, Christy Minerals, USA
Phil Edwards, Imerys, France
Bill Peschler, Minerals Technologies, USA

Refractories for Glass
M.D. Patil, Corning, Inc., USA
Matt Lambert, Allied Mineral Products, USA

Cement & Lime Refractories
Fielding Cloer, Spar Refractories, USA
Christoph Wohrmeyer, Kerneos, France

Modelling and Simulation of Refractories
Bill Headrick, MORCO, USA
Harald Harmuth, Montanuniversität Leoben, Austria

Petrochemical
Don McIntyre, ANH, USA
Ken Moody, Refractory System Solutions, USA

Refractory for Waste to Energy Processing & Power
Ben Markel, Resco Products, USA
Steve Chernack, Morgan Thermal Ceramics, USA

Energy Savings through Refractory Design
James Hemrick, Oak Ridge National Laboratory, USA
Valeriy Martynenko, The Ukrainian Research Institute of Refractories, Ukraine

Nonoxide Refractory Systems
Dave Derwin, Superior Graphite, USA
Matt Lambert, Allied Mineral Products, USA

Refractories for Chemical Processes
James Bennett, NETL, USA
Mathias Rath, Rath, Germany

Developments in Basic Refractories
Dominick Colavito, Minerals Tech, USA
Andrie Garbers-Craig, Univeristy of Pretoria, South Africa
Ben Markel, Resco Products, USA

Global Education in Refractories
George Oprea, University of British Columbia, Canada
Yawei Li, Wuhan Univeristy of Science and Technology, China

Refractories for Nonferrous Metallurgy
Rick Volk, United Refractories, USA
Angela Rodrigues-Schroer. Wahl Refractory Solutions, USA

Safety, Environmental Issues & Recycling Solutions for Refractories
Jason Canon, Christy Refractories, USA
Leonardo Curimbaba Ferriera, US Electrofused Minerals/ Electroabrasives LLC, USA

THANK YOU

CONFERENCE LEADERSHIP SPONSORS

ALMATIS
PREMIUM ALUMINA

kerneos™
ALUMINATE TECHNOLOGIES

TRI
THE REFRACTORIES INSTITUTE

CONFERENCE SUPPORTERS

NARCO ~ Harbison ANH Refractories APGreen ~ Walker ®

IMERYS
TRANSFORM TO PERFORM

CALUCEM

Refractory Ceramics Division
The American Ceramic Society

ALUCHEM inc.

CHRISTY MINERALS

IMERYS
Refractory Minerals

KROSAKI HARIMA
KROSAKI HARIMA CORPORATION

VIRGINIA KYANITE

TAM

SCHEDULE

Legend: FE- Fairmont Empress VCC- Victoria Conference Center

Sunday, September 8 – Monday, September 9, 2013		
ISO TC33 Meetings	8:00 a.m. – 5:00 p.m.	Balmoral – FE
Tuesday, September 10, 2013		
ASTM Meeting	8:00 a.m. – 3:00 p.m.	Oak Bay – VCC
FIRE Corrosion Short Course, **Sponsored by ANH Refractories**	8:00 a.m. – 5:00 p.m.	Colwood – VCC
FIRE Castable Short Course, **Sponsored by ANH Refractories**	8:00 a.m. – 5:00 p.m.	Saanich – VCC
Conference Registration	Noon – 6:30 p.m.	Registration – VCC
Speaker Ready Room	Noon – 6:30 p.m.	View Royal – VCC
UNITECR International Executive Board Meeting	3:00 – 5:00 p.m.	Sidney – VCC
Distinguished Life Member Reception (invitation only)	5:00 – 6:00 p.m.	Buckingham – FE
Young Professionals Reception, **Sponsored by ACerS Refractory Ceramics Division**	5:00 – 6:00 p.m.	Esquimalt – VCC
Welcome Reception, **Sponsored by Kerneos SA**	7:00 – 10:00 p.m.	BC Museum
Wednesday, September 11, 2013		
Registration	7:00 a.m. – 5:00 p.m.	Registration – VCC
Speaker Ready Room	7:00 a.m. – 5:00 p.m.	View Royal – VCC
Wednesday Speakers' Breakfast	7:00 – 8:00 a.m.	Ivy Ballroom – FE
Exhibitors' Breakfast (Exhibitors Only)	7:30 – 8:30 a.m.	Carson Hall – VCC
Opening Session & Keynote, Remco de Jong, Imerys	8:40 – 10:00 a.m.	Lecture Theater – VCC
Exhibits	9:30 a.m. – 6:00 p.m.	Carson Hall – VCC
Break,* **Sponsored by Imerys Refractory Minerals**	10:00 – 10:40 a.m.	Carson Hall – VCC
Concurrent Technical Sessions	10:40 a.m. – 12:20 p.m.	VCC
Lunch,* **Sponsored by Almatis**	Noon – 1:40 p.m.	Carson Hall – VCC
Concurrent Technical Sessions	1:40 – 5:40 p.m.	VCC
Break,* **Sponsored by Aluchem**	3:20 – 4:20 p.m.	Carson Hall – VCC
Poster Session, **Sponsored by The Technical Association of Refractories, Japan**	5:30 – 7:00 p.m.	Palm Court – FE
Thursday, September 12, 2013		
Registration	7:00 a.m. – 5:00 p.m.	Registration – VCC
Speaker Ready Room	7:00 a.m. – 5:00 p.m.	View Royal – VCC
Thursday Speakers' Breakfast	7:00 – 8:00 a.m.	Ivy Ballroom – FE
Exhibitors' Breakfast (Exhibitors Only)	8:00 – 9:00 a.m.	Carson Hall – VCC
Plenary Speaker, Tom Vert, ArcelorMittal Dofasco	8:00 – 9:00 a.m.	Lecture Theater – VCC
Concurrent Technical Sessions	9:20 a.m. – 1:00 p.m.	VCC
Exhibits	9:30 a.m. – 5:00 p.m.	Carson Hall – VCC
Break,* **Sponsored by Kyanite**	10:20 – 11:20 a.m.	Carson Hall – VCC
Lunch*	12:40 – 2:00 p.m.	Carson Hall – VCC
Concurrent Technical Sessions	2:00 – 6:00 p.m.	VCC
Break,* **Sponsored by Christy Minerals**	3:40 – 4:40 p.m.	Carson Hall – VCC
Conference Dinner, **Sponsored by The Refractories Institute**	7:00 – 10 p.m.	Crystal Garden
Friday, September 13, 2013		
Registration	7:30 a.m. – Noon	Registration – VCC
Friday Speakers' Breakfast	7:00 – 8:00 a.m.	Ivy Ballroom – FE
Plenary Speaker, Charles E. Semler, Semler Materials Services	8:00 – 9:00 a.m.	Lecture Theater – VCC
Concurrent Technical Sessions	9:20 a.m. – 1:00 p.m.	VCC
Break	10:40 – 11:40 a.m.	
Lunch & Closing Ceremony	1:00 – 2:00 p.m.	Palm Court/Crystal – FE Ballroom

**Breaks and lunches take place in the Exhibit Hall.*

KEYNOTE SPEAKER

Remco de Jong

Vice President and General Manager, Refractory Minerals Division, Imerys

Title: *Minerals to materials: The changing face of the global refractory industry*

De Jong joined Imerys Refractory Minerals group in July 2012. He was formerly the CEO of Almatis Group. With Almatis and previously with Corus Steel and Hoogovens, he held various senior management positions in Asia, Europe and the USA. He was involved in the development of new products and markets and in the optimization of processes and supply chains with global customers in automotive and portable energy end markets.

PLENARY SPEAKERS

Tom Vert

General Manager of Primary Manufacturing, ArcelorMittal Dofasco

Title: *How do steelmakers pick refractories—Logic, emotion, or dartboard?*

Vert is the general manager of primary manufacturing at ArcelorMittal Dofasco, which includes cokemaking, ironmaking, steelmaking, and material handling and logistics. He has held this position since 2010. He graduated from McMaster University in 1987 with a BE (Ceramics) and received his MBA in 1994, also from McMaster University. Vert joined ArcelorMittal Dofasco in 1989 and has moved through a number of positions in steelmaking in technology and operations. He has been chairperson for the Refractory Division of the Canadian and American Ceramic Societies. Vert has served as chairperson of the UNITECR Refractory International Executive Board and is a Distinguished Life Member of this group.

Charles E. Semler

President/Consultant, Semler Materials Services

Title: *Trends for the world's most important, but least known products*

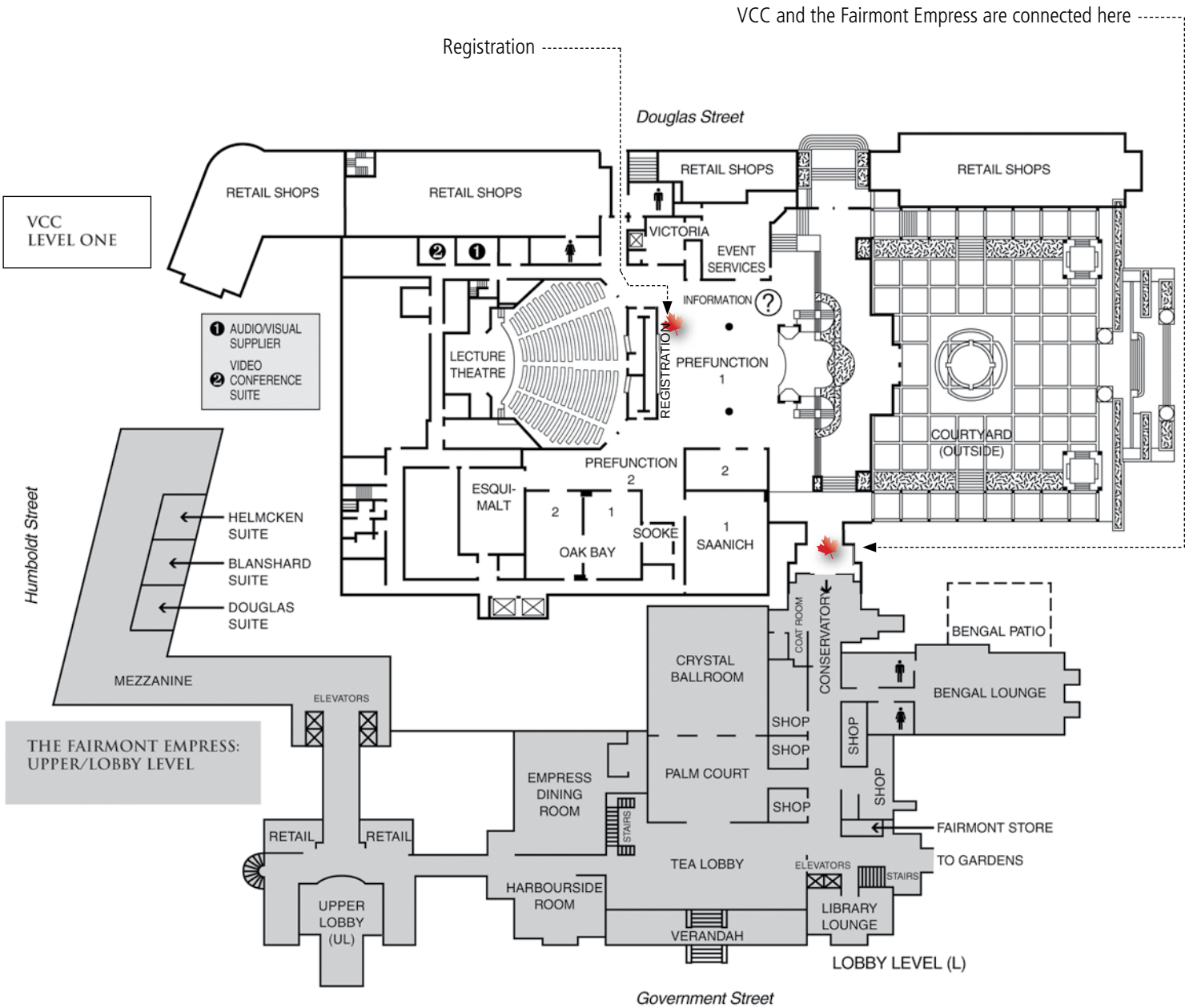
Semler has worked in the refractories industry since 1971. His refractories career began with Harbison-Walker Refractories Co. and then he was a professor of ceramic engineering and director of the Refractories Research Center at The Ohio State University for 12 years. Since 1986, he has worked as an independent refractories consultant, serving many US and foreign companies, including travel to 97 countries. He serves on the advisory board for several refractories publications—*Interceram* and *Refractories World Forum* (Germany), *Journal of Technical Association of Refractories, Japan*, and *China's Refractories*. He has written more than 200 papers, delivered lectures and conducted workshops around the world, and holds four patents. Semler has received the following honors/awards: Fellow of The American Ceramic Society; Distinguished Life Member of UNITECR; T.J. Planje St. Louis Refractories Award; Service Award from Technical Association of Refractories, Japan (TARJ); elected to the International Academy of Ceramics; and Tredennick Award from The Refractories Institute (USA).

TECHNICAL SESSIONS

Sessions	Day	Time	Location	Page
Opening Ceremony and Keynote Speaker	Wednesday	8:40 – 10:00 a.m.	Lecture Theatre	27
Plenary Session I	Thursday	8:00 – 9:00 a.m.	Lecture Theatre	31
Plenary Session II	Friday	8:00 – 9:00 a.m.	Lecture Theatre	36
Poster Session	Wednesday	5:30 - 7:00 p.m.	Palm Court (Hotel)	30
Advanced Installation Techniques and Equipment				
Advanced Installation Techniques and Equipment	Wednesday	10:40 a.m. – 12:20 p.m.	Sidney	27
Advanced Testing of Refractories				
Advanced Testing of Refractories I	Wednesday	10:40 – 11:40 a.m.	Oak Bay	27
Advanced Testing of Refractories II	Wednesday	1:40 – 3:40 p.m.	Oak Bay	29
Advanced Testing of Refractories III	Wednesday	4:20 – 5:00 p.m.	Oak Bay	29
Advanced Testing of Refractories IV	Thursday	9:20 – 11:00 a.m.	Oak Bay	32
Advanced Testing of Refractories V	Thursday	11:20 a.m. – 12:40 p.m.	Oak Bay	33
Cement and Lime Refractories				
Cement and Lime Refractories I	Thursday	9:20 – 11:20 a.m.	Esquimalt	33
Cement and Lime Refractories II	Thursday	2:20 – 4:40 p.m.	Esquimalt	35
Developments in Basic Refractories				
Developments in Basic Refractories I	Wednesday	10:40 a.m. – Noon	Esquimalt	27
Developments in Basic Refractories II	Wednesday	1:40 – 4:20 p.m.	Esquimalt	29
Developments in Basic Refractories III	Wednesday	4:20 – 5:20 p.m.	Esquimalt	29
Energy Savings Through Refractory Design				
Energy Savings Through Refractory Design I	Thursday	11:20 a.m. – 1:00 p.m.	Sidney	34
Energy Savings Through Refractory Design II	Thursday	2:20 – 4:40 p.m.	Sidney	36
Global Education in Refractories				
Global Education in Refractories I	Friday	9:20 – 11:20 a.m.	Sidney	37
Global Education in Refractories II	Friday	11:20 a.m. – Noon	Sidney	38
Facilitated Discussion on Global Education in Refractories	Friday	Noon – 12:40 p.m.	Sidney	38
Iron & Steel Making Refractories				
Iron & Steel Making Refractories - Coke Ovens	Wednesday	10:40 a.m. – Noon	Saanich	27
Iron & Steel Making Refractories - Continuous Casting	Wednesday	4:20 – 5:20 p.m.	Colwood	30
Iron & Steel Making Refractories - Submerged Entry Nozzles	Thursday	9:20 – 10:40 a.m.	Saanich	32
Iron & Steel Making Refractories - Ladles	Thursday	11:00 a.m. – 12:40 p.m.	Saanich	32
Iron & Steel Making Refractories - BOF	Thursday	2:00 – 4:20 p.m.	Saanich	34
Iron & Steel Making Refractories - RH Snorkels	Thursday	4:40 – 5:40 p.m.	Esquimalt	36
Iron & Steel Making Refractories - Spinel Castables	Friday	9:20 – 10:40 a.m.	Lecture Theatre	37
Iron & Steel Making Refractories - Magnesia-Carbon I	Wednesday	1:40 – 4:00 p.m.	Saanich	28
Iron & Steel Making Refractories - Magnesia-Carbon II	Wednesday	4:20 – 5:20 p.m.	Saanich	29
Iron & Steel Making Refractories - Blast Furnace and Troughs I	Thursday	4:20 – 6:00 p.m.	Saanich	35

TECHNICAL SESSIONS

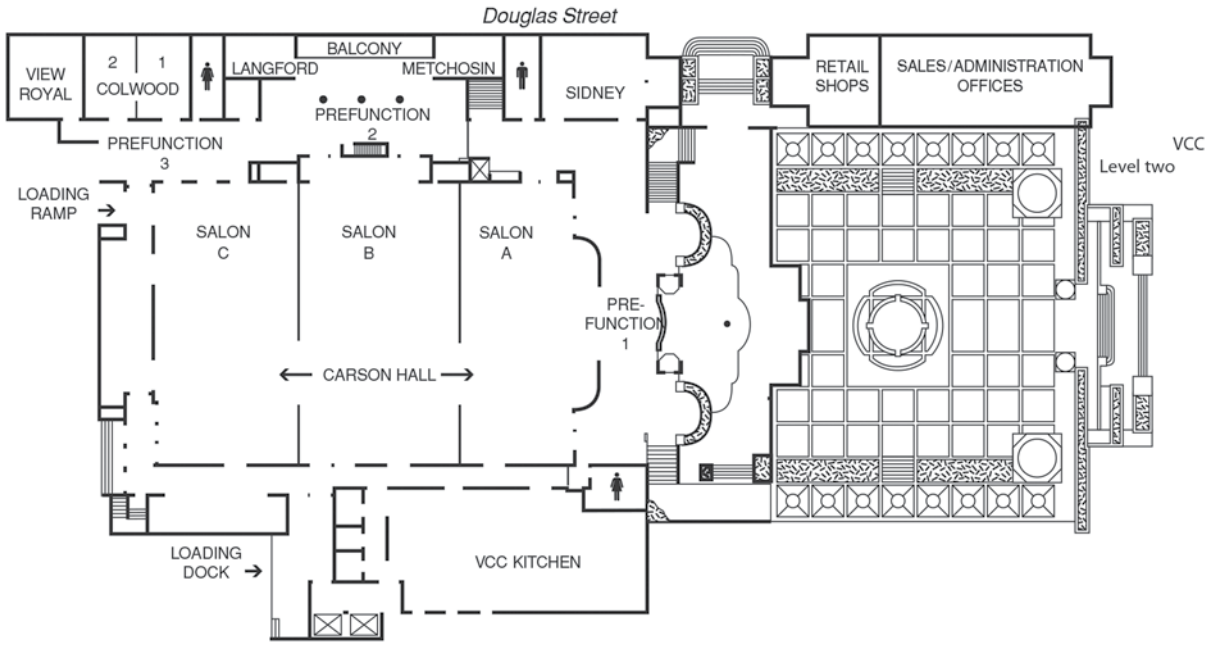
MAPS — Victoria Conference Centre (Level One) and Fairmont Empress (Lobby Level) Technical Sessions, Poster Session and Registration



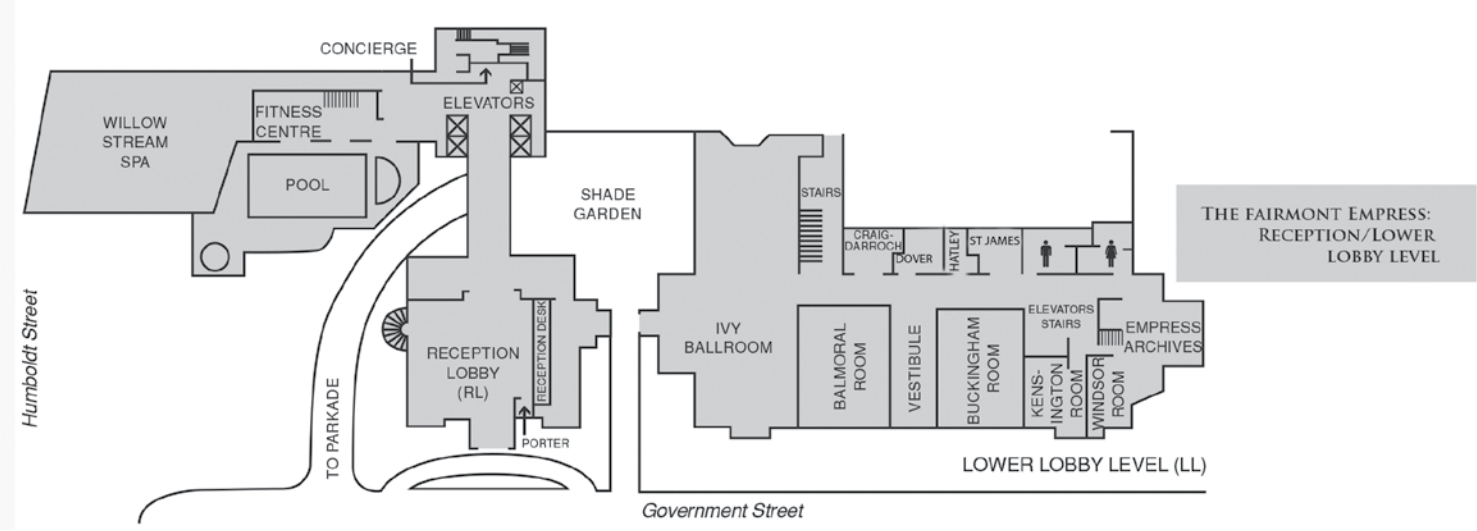
MAPS

Victoria Conference Centre – Level 2

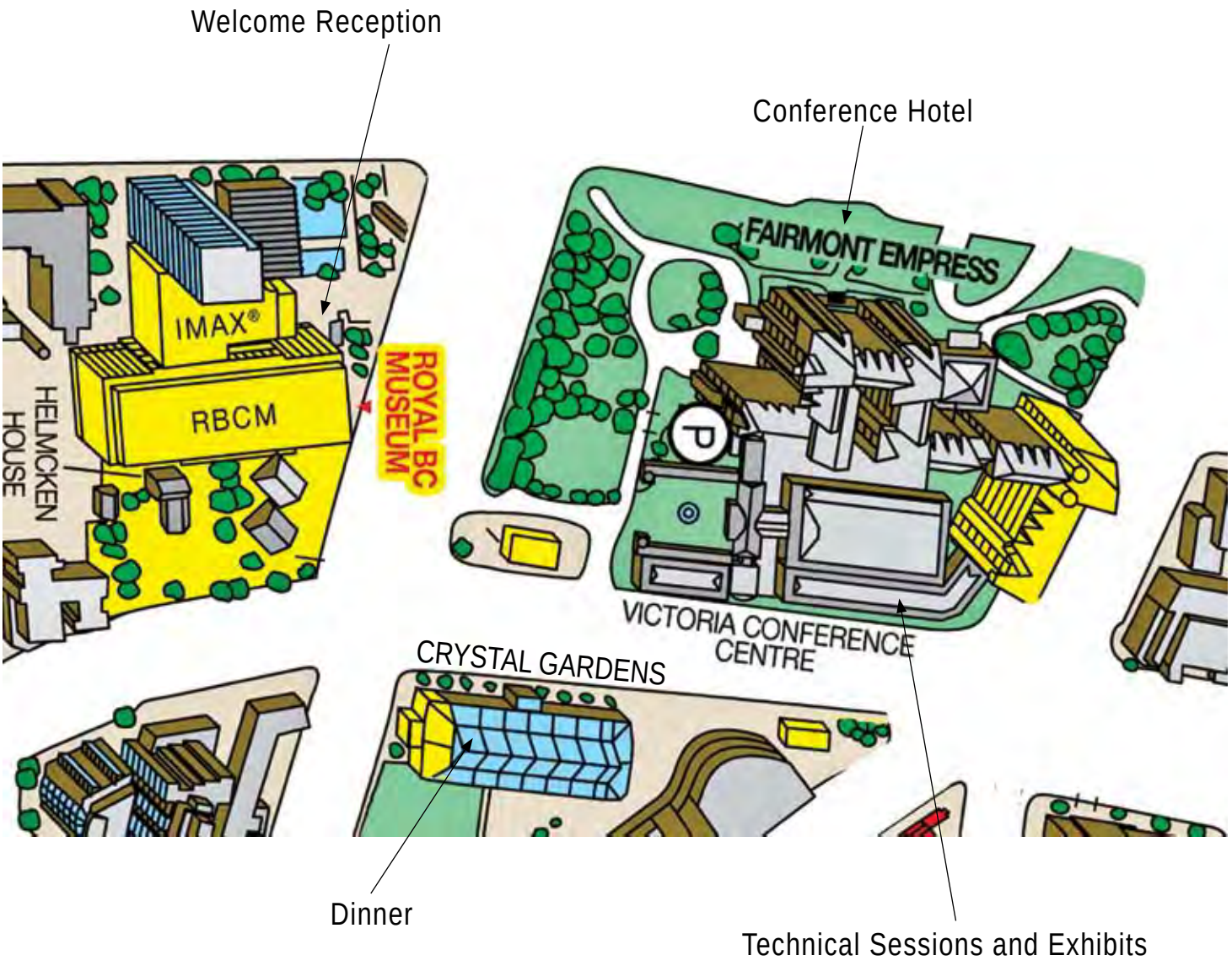
Technical Sessions, Exhibit, Lunch and Breaks



Fairmont Empress – Lower Lobby Level

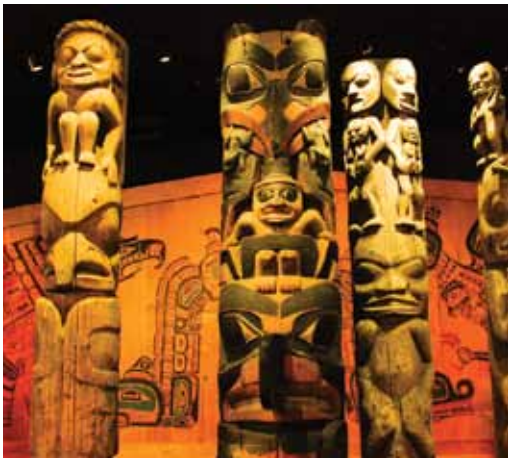


MAPS — Royal BC Museum, Victoria Conference Centre, Fairmont Empress and Crystal Gardens



WELCOME RECEPTION

Sponsored by **Kerneos SA**



UNITECR welcome receptions are events to be remembered. With hundreds of artifacts, specimens and dramatic displays of British Columbia's natural and human history, the **Royal BC Museum** is sure to capture your attention. Add in food, beverages, and your fellow UNITECR attendees, and you have the makings of a truly memorable event. Museum docents will be on-hand to share their knowledge and answer questions. Totem Hall is the central exhibit in the First Peoples gallery, and around the perimeter of the hall are examples of masks, regalia and modern works. The display unites old and new works, which is appropriate in an exhibit that emphasizes the continuing artistic traditions of the Northwest Coast First Nations. The reception includes food and beverage stations highlighting local cuisine. The Dixie Cups band and the Le La La First Nations Dancers will be performing. This event is included in full-conference, one-day, student, guest and DLM registrations. All others must purchase a ticket. Thank you to **Kerneos** for sponsoring this event.

Unitecr2013

SEPT. 10-13, 2013

SPECIAL EVENT – CONFERENCE DINNER

Sponsored by **The Refractories Institute**

The UNITECR '13 conference dinner is your opportunity to eat , drink and enjoy the company of nearly 800 of your closest UNITECR friends. The dinner is hosted in the iconic **Crystal Gardens**, which was Victoria's first convention center, and also spent years as an arboretum, a restaurant, an art gallery, and a swimming pool. This unique structure is the ideal setting for a lively evening of good food, good drink, good friends and live entertainment. A highlight will be the induction of the 2013 class of UNITECR Distinguished Life Members in addition to other award presentations.

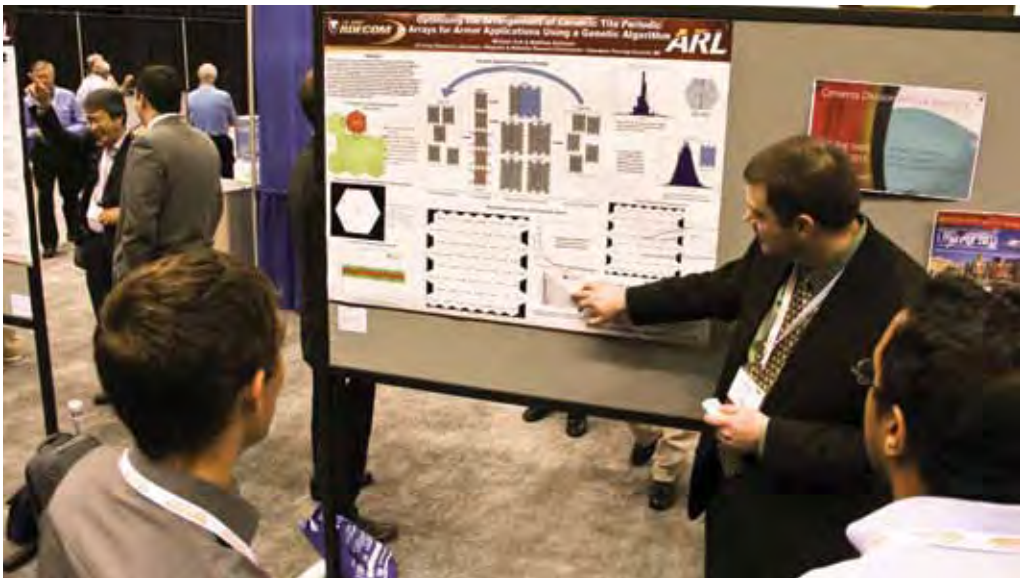
Conference dinner schedule 7 to 10 p.m.

- Enjoy drinks while listening to the Light Jazz Quartet
- Enjoy dinner with your colleagues
- Celebrate the 2013 class of Distinguished Life Members
- Award FIRE diplomas, prizes to the poster contest winner
- Sneak peek at the location for the next UNITECR

This event is included in full-conference, one-day, student, guest and DLM registrations. All others must purchase a ticket. Doors open at 7 pm. Thank you to **The Refractories Institute** for sponsoring this event.

POSTER SESSION

UNITECR'13 plays host to the inaugural poster session, hosted Wednesday, September 11, from 5:30 to 7 p.m. in the **Palm Court room** in the Fairmont Empress. Featuring over 30 presentations, meet with authors to discuss their research over light refreshments. Please attend and cast your vote for Attendee's Choice Best Poster winner. Thank you to **The Technical Association of Refractories, Japan** for sponsoring this event.



YOUNG PROFESSIONAL RECEPTION

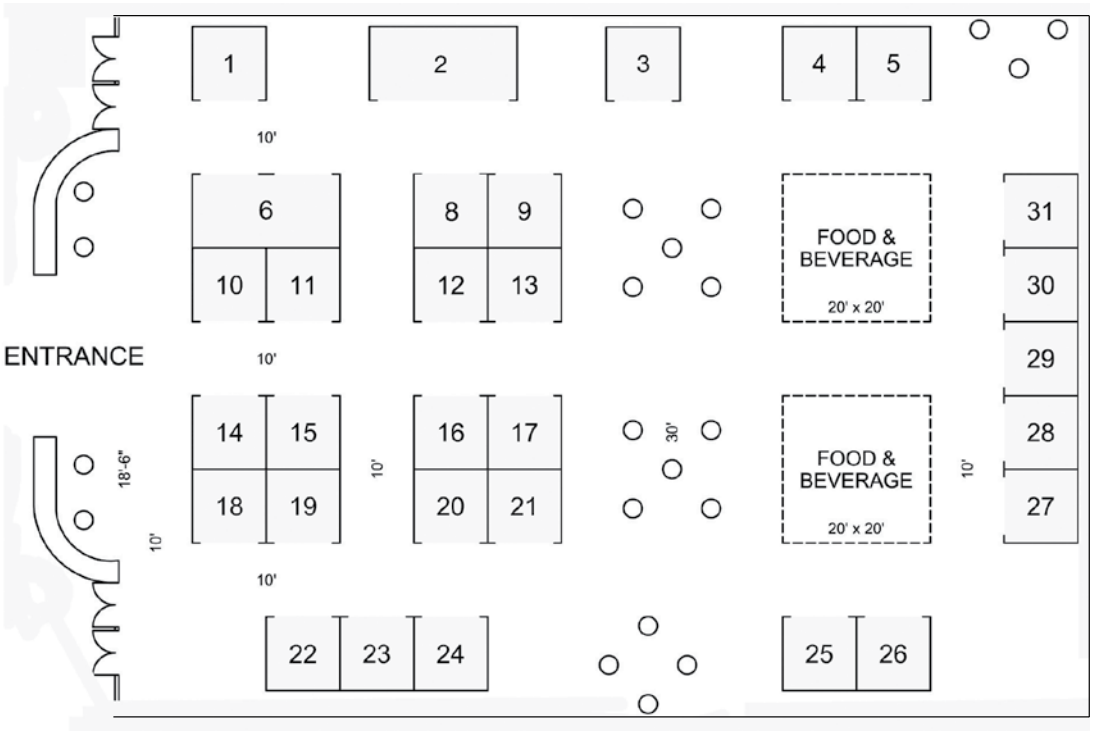
Network with fellow young professionals at the Young Professional Reception, hosted Tuesday, September 10, from 5:00 to 6:00 p.m. in the Esquimalt room.Thank you to the **American Ceramic Society's Refractory Ceramics Division** for sponsoring this event.

CONFERENCE PROCEEDINGS

Each attendee will receive a USB flash drive that includes over 231 papers from UNITECR'13. Thank you to **Imerys** for sponsoring the flash drives. To purchase a printed copy, please go to www.wiley.com/go/ceramics.

EXHIBIT FLOOR PLAN

Wednesday 9:30 a.m. – 6:00 p.m.
Thursday 9:30 a.m. – 5:00 p.m.
Location: Carson Hall



Companies	Booth
ALTEO	21
BassTech International	17
Blastcrete Equipment Co.	31
China Mineral Processing Ltd.	3
Claisse, Corporation Scientifique	24
Curimbaba Group: Electro Abrasives	25
Curimbaba Group: Elfusa	26
Curimbaba Group: U.S. Electrofused Minerals, Inc.	25
Eirich, Maschinenfabrik Gustav Eirich GmbH & Co KG	11
Elkem	10
Fibercon International Inc.	4
Huang He Minerals Co. Ltd.	22
Imerys Refractory Minerals	15
Kerneos	14
Kyanite Mining Corporation	6
Laeis GmbH	13

Companies	Booth
Laser Distance Spectrometry	8
Orind Special Refractories Ltd.	29
Putzmeister Shotcrete Technology	18
Refmin China Co. Ltd.	9
Riedhammer GmbH	12
RÜTGERS Basic Aromatics GmbH	2
Shengquan Hepworth Resin Co. Ltd.	19
Steuler-KCH GmbH	16
Sub-Floor Science LLC	30
Superior Graphite	28
Swindell Dressler International Co.	27
Syrah Resources Ltd	23
VELCO GmbH	1
Verband der Deutschen Feuerfest Industrie	20
Washington Mills Electro Minerals	5

EXHIBITING COMPANY DIRECTORY

ALTEO
Booth No. 21
Alteo is the leading fully integrated supplier of specialty aluminas. Production facilities in France and Germany produce a unique range of products that includes calcined, reactive, tabular, fused and zirconia aluminas. Supported by a global sales network and an expanding R&D facility, Alteo welcomes you to a New World of Alumina.
specialtyaluminas-marketing@alteo-alumina.com
http://www.alteo-alumina.com
Ph: 0033442652222

❖ ❖ ❖ ❖ ❖

BassTech International
Booth No. 17
BassTech International is a supplier of Performance Additives to the Refractory, Coating & Ceramic Industries. This includes a full line of metal phosphates for high temperature binders and deflocculants, PP/PE/Glass Fibers, Sodium Silicate Powders, Silicon Metal, Low Temperature ThermoPolymer Binders and Green Strength Enhancers. We offer technical support through our local offices in the United States, China, Europe & India. Our customers also benefit from just in time deliveries from our local inventories in North America, Europe and worldwide.
info@basstechintl.com
http://www.basstechintl.com
Ph: 201-569-8686 | Fax: 201-569-7511

❖ ❖ ❖ ❖ ❖

Blastcrete Equipment Co.
Booth No. 31
Blastcrete Equipment Co. is an industry leader in the design and manufacture of refractory mixing and placement equipment. The product line includes The Blastcrete Gun featuring the genuine Piccola clamping system and the Dampcon Rig for gunite applications. The 2200 pound capacity refractory mixer is the fastest in the industry. The MX-10 mixer/pump placement is up to 13 tons per hour. The new two stage continuous mixer was officially introduced at UNITCER 2013.
tripp@blastcrete.com
http://www.blastcrete.com
Ph: 256-235-2700 and **1-800-235-4867**
Fax: 256-236-9824

China Mineral Processing Ltd.
Booth No. 3
CMP group has been focused on development and utilization of mineral products since it was founded in 1993. Now it has expanded itself to a big enterprise group with 8 mineral processing plants, containing 4 large business catagories, and producing more than 300,000 mts mineral products annually.
lily@cmptj.com | http://www.cmptj.com
Ph: +86 22 23210158

❖ ❖ ❖ ❖ ❖

Claisse, Corporation Scientifique
Booth No. 24
World leader in sample preparation by fusion for XRF, ICP and AA spectrometry, Claisse® offers gas and electric multi-position automatic fusion instruments (M4™, TheOx™, TheBee™, Peroxide™ Fluxer), fused borate fluxes with integrated non-wetting agents and platinumware for glass disks and solution preparation. Claisse® provides CRM, fusion monitors, in addition to analytical consulting and platinum polishing/scrap services.
carsenault@claisse.com
http://www.claisse.com
Ph: 418-656-6453 | Fax: 418-656-1169

❖ ❖ ❖ ❖ ❖

Curimbaba Group: Electro Abrasives
Booth No. 25
Producers of Fused Minerals including Alumina, Mullite, Black & Green Silicon Carbide, Boron Carbide, MgO-Al_2O_3 Spinel, Magnesia-Chrome, Chrome-Alumina, Calcium-Aluminate Cement, and more for use in refractories, ceramics, abrasives, investment casting, friction, and many other applications.
brian@electroabrasives.com
http://electroabrasives.com/
Ph: 716-822-2500

Curimbaba Group: Elfusa
Booth No. 26
Producers of Fused Minerals including Alumina, Mullite, MgO-Al_2O_3 Spinel, Magnesia-Chrome, Chrome-Alumina, Calcium-Aluminate Cement, and more for use in refractories, ceramics, abrasives, investment casting, friction, and many other applications.
jaime.splettstoser@grupocurimbaba.com.br
http://www.elfusa.com.br/
Ph: (55) 19 3634 2300

❖ ❖ ❖ ❖ ❖

Curimbaba Group: U.S. Electrofused Minerals, Inc.
Booth No. 25
Producers of Fused Minerals including Alumina, Mullite, Black & Green Silicon Carbide, Boron Carbide, MgO-Al2O3 Spinel, Magnesia-Chrome, Chrome-Alumina, Calcium-Aluminate Cement, and more for use in refractories, ceramics, abrasives, investment casting, friction, and many other applications.
http://www.usminerals.com/
Ph: 724-857-9880

❖ ❖ ❖ ❖ ❖

Eirich, Maschinenfabrik Gustav Eirich GmbH & Co KG
Booth No. 11

❖ ❖ ❖ ❖ ❖

Elkem
Booth No. 10
Elkem is the world's leading producer of high quality microsilica and metallurgical silicon for refractories and ceramic applications. Elkem has three production plants in Norway: Elkem Bremanger, Elkem Salten, Elkem Thamshavn. We have a network of sales offices covering the most important markets in Europe, Americas and Asia.
elkem.materials@elkem.no
http://www.elekm.com
Ph: +47 38017500 | Fax: +47 38014970

EXHIBITING COMPANY DIRECTORY

Fibercon International Inc.
Booth No. 4
Manufacturers of steel reinforcing fibers to both the refractory and civil industries. Our fibers include: ASTM Type II (slit/cut sheet) and ASTM Type III (melt extract). Check out our alternate to cold drawn fiber Type I (our special Type II) recently approved by a major refining company. "World leader in steel fiber reinforcing technologies since 1972"
info@fiberconfiber.com
http://www.fiberconfiber.com
Ph: 724-538-5006 | Fax: 724-538-9118

❖ ❖ ❖ ❖ ❖

Huang He Minerals Co. Ltd.
Booth No. 22
Huang He Minerals Co.,Ltd is a leading manufacturer and supplier of a wide range refractory raw materials, we are supplying Brown and White fused Alumina, calcined Bauxite, High Density Alumina Aggregate, Silicon carbide, fused and sintered Mullite, Fused and sintered Spinel, fused silica, Graphite, Dead Burned Mgnesite and Fused Magnesite, and various grade refractory additives.
huanghetj@hotmail.com
http://www.huangheminerals.com
Ph: 86-22-23554891 and **86-13802071138**
Fax: 86-22-27463966 and **23558601**

❖ ❖ ❖ ❖ ❖

Imerys Refractory Minerals
Booth No. 15
Imerys Refractory Minerals is the world leader in the manufacture and supply of superior quality minerals for refractory, investment casting, and other industrial applications. Our broad product range includes Calcined Alumino-Silicates, Chamottes, Andalusites, Fused Silicas, Refractory Grade Clays, Metakaolins and Fused Minerals. Through our extensive global sales network, Imerys Refractory Minerals has local commercial, technical and supply solutions to meet the needs of the refractory and investment casting markets.
inquire@ceminerals.com
http://www.ceminerals.com
Ph: (770) 225-7923 | Fax: (770) 225-7901

❖ ❖ ❖ ❖ ❖

Kerneos
Booth No. 14
Leader in the manufacture of calcium aluminate cements, aggregates and specialty additives.
karine.vaher@kerneos.com
http://www.kerneos.com
Ph: +33 1 46 37 90 00 | Fax: +33 1 46 37 92 00

❖ ❖ ❖ ❖ ❖

Kyanite Mining Corporation
Booth No. 6
Throughout North America, South America and in much of Europe and Asia, the mineral kyanite is used in most monolithic refractory mixes where the alumina content is between about 45 and 85%. Whether the monolith is a mortar, castable, plastic, ramming mix, gunning mix, or a coating, from 5 to 75% to 85% kyanite is used to keep the firing shrinkage to a minimum and, thereby, reduce cracking during initial heat-up. An added benefit of using kyanite is that after decomposition is complete, the resulting phase is mullite, which imparts refractoriness, thermal shock resistance, and strength to the refractory.
hankjamerson@kaynite.com
http://www.kyanite.com
Ph: 434-983-2043 | Fax: 434-983-3579

❖ ❖ ❖ ❖ ❖

Laeis GmbH
Booth No. 13
LAEIS is the leading manufacturer of high performance hydraulic presses for refractories, advanced ceramics, carbon products, and special applications. Presses with up to 4500 metric tons capacity that can be equipped with vacuum systems for delicate materials. Grain heaters, mixers and robotic systems, plant engineering and R&D round off our services.
fournier@laeis.eu | http://www.laeis.eu
+352 27612 202

❖ ❖ ❖ ❖ ❖

Laser Distance Spectrometry
Booth No. 8
MAYA – Real-time laser elemental analyzer
It is now possible to know the chemical composition of a mineral raw material moving on a conveyor belt, in a falling stream, slurry pipeline, and open-pit mine right at the time a material is running! A real opportunity to perform batch sorting of ore or provide corrective additions for raw mix chemistry stabilization before it is too late for a process. MAYA analyzer involves no sampling, runs 24x7x365 under heavy dusty, humidity, corrosive conditions in mining, metallurgy, refractories, fertilizers and other industries without any hazardous gamma or X-ray radiation. Final product quality improvement, cutting customer's claims, reduction of energy and fuel materials consumption involve investment returns in 3-6 months.
alex@laser-distance-spectrometry.com
http://www.laser-distance-spectrometry.com
Ph: +972 3 541 10 22 | Fax: +972 3 541 10 27

❖ ❖ ❖ ❖ ❖

Orind Special Refractories Ltd.
Booth No. 29
OSR is one of the premium refractory company from India with manufacturing of refractories in China. Some of our major products are as follows:Magnesia Carbon Bricks and Monolithics for BOF, EAF & Ladles.Alumina Magnesia Carbon & Alumina Enriched Spinel Bricks for Ladles & Alumina Silicon Carbide Carbon Bricks for Torpedo & Hot Metal Ladle. Magnesite & High Al bricks
siddharth@orindref.com
http://www.orindref.com
Ph: +91 22 26866803 | Fax: +91 22 26866804

Putzmeister Shotcrete Technology
Booth No. 18
The industry leader in refractory placement technology, Putzmeister delivers dependable, high-performance equipment backed by the industry's best service. Putzmeister a offers a wide variety of equipment geared for use in the refractory industry. Small gunning machines easily accomplish patch work without disruption to operations. Mid-sized trailer- mounted units feature small footprints that allow them to easily navigate the refractory plant to the placement location, while larger units can be stationed outside and have the lower to pump the shotcrete via hoses over long distances to the exact point of placement. Additionally, all of your hose, nozzle and accessory needs can be met by Putzmeister Shotcrete Technology. Respected worldwide for our comprehensive range of sprayed concrete equipment, we offer more than 50 complementary products for large and small applications.
pmr@putzam.com
http://www.PutzmeisterShotcrete.com
Ph: 262-886-3200 | Fax: 262-884-3070

❖ ❖ ❖ ❖ ❖

Refmin China Co., Ltd.
Booth No. 9
Refmin is one of major processor and distributor of Chinese refractory raw materials like flake graphite, bauxite, fused magneiste, tabular alumina, bfa,wfa, sic etc. Refmin supplied more than 100,000 mta various materials to our esteemed customers all around the world.
info@refmin.com.cn | http://www.refmin.com.cn
Ph: +86 25 5703 3901 | Fax: +86 5703 3900

❖ ❖ ❖ ❖ ❖

Riedhammer GmbH
Booth No. 12
Riedhammer GmbH is the leading manufacturer of kiln plants worldwide. The company, located in Nuremberg, Germany, offers new and innovative kiln technology for the refractory industry. Riedhammer is the perfect partner for customers requiring advanced and reliable technological solutions for all thermal processes, including complete plant solutions, both upstream and downstream the kilns with installation – worldwide.
ernst.hartung@riedhammer.de
http://www.riedhammer.de
Ph: +49 911 5 21 80 | Fax: +49 911 5 21 88336

❖ ❖ ❖ ❖ ❖

RÜTGERS Basic Aromatics GmbH
Booth No. 2
Producer of binders for refractories.
jens.stiegert@ruetgers-group.com
http://www.ruetgers-group.com
Ph: +49 2305 70533 | Fax: +49 2305 705446

EXHIBITING COMPANY DIRECTORY

Shengquan Hepworth Resin Co. Ltd.
Booth No. 19
Founded in 1997 as a Sino-UK joint venture, now SQH is Chinese leading phenolic resin manufacturer with total capacity 350,000 tons annually, serving customers from industries like refractories, friction materials, foundry, abrasives, electronic materials, etc.
chris.huang@shengquan.com
http://e.shengquan.com/news_508
Ph: +86-531-88980618 | Fax: +86-531-83502303

❖ ❖ ❖ ❖ ❖

Steuler-KCH GmbH
Booth No. 16
Steuler is one of the most innovative suppliers in the field of Refractory Systems worldwirde. The production range of the company comprises shaped and unshaped non basic refractory products. The sope of supply and services includes refractory engineering, R&D, production and turn key insatllation of refractory systems in all range of industries such as Iron&Steel, Cement&Lime, Chemical, Petrochemical, Non-Ferrous-Metals and Waste Incineration.
ulf.frohneberg@steuler-kch.de | www.steuler.de
Ph: +49 2624 13 683 | Fax: +49 2624 13 291

❖ ❖ ❖ ❖ ❖

Sub-Floor Science LLC
Booth No. 30
Bill Allen "X-town" returns as Sub-Floor Science LLC proudly representing Walter+Bai AG in North America. Visit us to see a SWG-H-400 for measuring dimensional change. Other tests and w+b equipment include: Static Tension, Compression, Flexure and Shear, LCF – Low Cycle Fatigue Testing, HCF – High Cycle Fatigue Testing, Component Life Testing, Fatigue Crack Growth Testing, Fracture Toughness Testing, Tensile Proof and Ultimate Strength Testing, Creep and Visco Elastic Characteristics, Modulus of Elasticity, Poisson's Ratio.
bill@subfloorscience.com
http://www.subfloorscience.com
Ph: 425-242-1217 | Fax: 425-242-1217

Superior Graphite
Booth No. 28
Superior Graphite, headquartered in Chicago, IL, was founded in 1917. Delivering unparalleled quality, Superior Graphite specializes in thermal purification, advanced sizing, blending and coating technologies, providing value-added graphite and carbon-based solutions globally. Advanced technologies are incorporated into every facet of the organization serving a wide range of markets including: agriculture, battery, fuel cells, ceramic armor, carbon parts, ferrous and nonferrous metallurgy, friction management, hot metal forming, polymer and composites, powder metals, lubricity, and performance drilling additives.
cbaer@superiorgraphite.com
http://www.superiorgraphite.com
Ph: 312-466-2861

❖ ❖ ❖ ❖ ❖

Swindell Dressler International Co.
Booth No. 27
Swindell Dressler has serviced the ceramic industry for nearly 100 years. The company custom designs tunnel, shuttle, bell and roller hearth kilns that are heated by either natural gas or electricity. Our customers include the structural clay, whiteware, refractory, technical ceramics and carbon graphite industries. We also design kiln car handling equipment and can provide a turnkey solution to your project.
dbuszinski@swindelldressler.com
http://swindelldressler.com
Ph: 412-788-7100 | Fax: 412-788-7110

❖ ❖ ❖ ❖ ❖

Syrah Resources Ltd
Booth No. 23
Syrah Resources (ASX code: SYR) is an Australian resource company, progressing its core Balama Graphite Project in Mozambique. Balama Graphite Project is the world biggest flake graphite resource with 1,15 billion tones resource and over 10% fix carbon content. Company aims to produce around 200.000 mt of concentrate with over 96% fix C content concentrate and very low impurities.
s.uysal@syrahresources.com.au
http://www.syrahresources.com.au/
Ph: +61 3 9670 7264 | Fax: +61 3 9642 0698

VELCO GmbH
Booth No. 1
VELCO supplies stand-alone refractory gunning machines as well as tailor-made gunning manipulators for the hot repair of EAFs, ladles, RH-snorkels, etc. Combined with VELCO's patented Gunmix® moistening system it is possible to process LC/ULC concretes in the dry gunning procedure.
info@velco.de | http://www.velco.de
Ph: +49 20512087 20 | Fax: +49 20512087 20

❖ ❖ ❖ ❖ ❖

Verband der Deutschen Feuerfest Industrie
Booth No. 20
The German Refractories Association (GRA) was founded in 1949. It represents the interests of the German manufacturers of refractory products to all institutions and social groups, as for example towards governments, parliaments, universities, but also to other associations and user industries. The GRA is one of the four Founding Members of UNITECR and organizes, from September 15 to 18, 2015, the 14th UNITECR Worldwide Congress on refractories in the Hofburg in Vienna, Austria.
info@vdffi.de | http://vdffi.de
Ph: +49 2624 9433-100 | Fax: +49 2624 9433-155

❖ ❖ ❖ ❖ ❖

Washington Mills Electro Minerals
Booth No. 5
Washington Mills is one of the world's largest producers of abrasives and fused mineral products, offering an exceptionally wide line of standard abrasive grain and specialty electro-fused minerals from its worldwide multi-plant locations.
info@washingtonmills.com
http://www.washingtonmills.com
Ph: 800-828-1666

THANK YOU

MEDIA SPONSORS

American Ceramic Society bulletin
World Cement
global cement MAGAZINE
asian ceramics
asianglass
Met Soc CIM ICM
Industrial Minerals
Interceram International Ceramic Review
refractories WORLDFORUM
Ceramic Industry
Cement International
glass worldwide
Refractories Window www.refwin.com
International Cement review

NOTES:

Oral Presenters

Name	Date	Time	Room	Page Number
A				
Adak, S.	11-Sep	2:40PM	Esquimalt	29
Adak, S.	11-Sep	4:20PM	Sidney	30
Al-zahrani, E.S.	12-Sep	3:20PM	Colwood	36
Alex, J.	12-Sep	10:20AM	Lecture Theatre	32
Anderson, M.W.	13-Sep	10:40AM	Oak Bay	37
Aneziris, C.	12-Sep	5:20PM	Sidney	36
B				
Bauer, C.	12-Sep	9:20AM	Oak Bay	32
Beimdiek, K.	12-Sep	3:20PM	Esquimalt	35
Belrhiti, Y.	12-Sep	12:00PM	Oak Bay	33
Bennett, J.	12-Sep	2:00PM	Lecture Theatre	34
Bharati, S.	12-Sep	12:20PM	Saanich	32
Bi, Y.	12-Sep	5:00PM	Esquimalt	36
Bi, Y.	13-Sep	9:20AM	Saanich	37
Böhm, A.	11-Sep	1:40PM	Oak Bay	29
Bonsall, S.	12-Sep	11:20AM	Lecture Theatre	32
Bradt, R.C.	11-Sep	10:40AM	Esquimalt	27
Brandaleze, E.	11-Sep	5:00PM	Colwood	30
Braulio, M.	13-Sep	10:20AM	Lecture Theatre	37
Braulio, M.	13-Sep	9:20AM	Oak Bay	37
Brochen, E.	11-Sep	10:40AM	Oak Bay	27
Buchebner, G.	11-Sep	3:00PM	Esquimalt	29
Buhr, A.	12-Sep	9:20AM	Lecture Theatre	32
C				
Camelli, S.	12-Sep	4:40PM	Lecture Theatre	34
Carden, Z.	12-Sep	11:20AM	Sidney	34
Castillo, G.	12-Sep	10:00AM	Esquimalt	33
Chabas, E.	12-Sep	12:00PM	Lecture Theatre	32
Chen, P.	13-Sep	12:20PM	Lecture Theatre	38
Chernack, S.	13-Sep	12:00PM	Oak Bay	38
Czapka, Z.	12-Sep	4:40PM	Esquimalt	36
D				
da Silveira Sousa, P.C.	11-Sep	11:20AM	Sidney	28
De Ferrari, C.	12-Sep	9:40AM	Sidney	33
de Jong, R.	11-Sep	9:00AM	Lecture Theatre	27
Decker, J.	13-Sep	10:20AM	Oak Bay	37
Deng, C.	12-Sep	12:40PM	Sidney	34
Drózd-Rys, M.	12-Sep	2:20PM	Oak Bay	35
E				
Emmel, M.	12-Sep	5:00PM	Sidney	36
Eric, B.	11-Sep	2:00PM	Colwood	30
F				
Frasson, S.C.	11-Sep	11:00AM	Colwood	28
Fujiwara, H.	12-Sep	2:20PM	Sidney	36
Furuta, Y.	11-Sep	10:40AM	Sidney	27
G				
Galinari, C.M.	11-Sep	4:20PM	Colwood	30
Gallienne, N.	12-Sep	3:00PM	Oak Bay	35
Garbers-Craig, A.M.	12-Sep	3:00PM	Lecture Theatre	34
Gasser, A.	12-Sep	3:40PM	Oak Bay	35
Ge, T.	13-Sep	9:20AM	Esquimalt	37
Geigenmüller, A.	13-Sep	11:40AM	Sidney	38
Geigenmüller, A.	13-Sep	9:20AM	Sidney	37
Gelbmann, G.	12-Sep	10:20AM	Esquimalt	33
Ghanbarnezhad, S.	12-Sep	4:00PM	Esquimalt	35
Ghosh, G.	12-Sep	3:00PM	Saanich	34
Golestani-fard, F.	11-Sep	3:00PM	Oak Bay	29
Gomez Rodriguez, C.	11-Sep	2:20PM	Esquimalt	29
Goorman, F.	12-Sep	9:20AM	Esquimalt	33
Gouraud, F.	11-Sep	11:20AM	Colwood	28
Grasset-Bourdel, R.	11-Sep	4:40PM	Oak Bay	29
H				
Haeussler, K.	13-Sep	11:20AM	Sidney	38
Haldar, M.K.	12-Sep	11:20AM	Esquimalt	33
Harmuth, H.	11-Sep	1:40PM	Colwood	30
Harmuth, H.	12-Sep	9:20AM	Saanich	32
Hemrick, J.G.	12-Sep	2:40PM	Lecture Theatre	34
Hemrick, J.G.	13-Sep	10:00AM	Oak Bay	37
Hong, Y.	13-Sep	12:00PM	Lecture Theatre	38
Hongqin, D.	12-Sep	4:40PM	Sidney	36
Hoshizuki, H.	11-Sep	2:20PM	Sidney	30
Hosohara, S.	11-Sep	11:00AM	Saanich	27
Huang, A.	12-Sep	11:40AM	Saanich	32
Huang, A.	12-Sep	5:00PM	Oak Bay	35
I				
Itoh, S.	11-Sep	12:00PM	Sidney	28
J				
Jia, Q.	11-Sep	3:00PM	Lecture Theatre	28
Justus, S.M.	12-Sep	11:00AM	Saanich	32
K				
Kakihara, M.	12-Sep	9:20AM	Oak Bay	33
Kasai, A.	11-Sep	10:40AM	Saanich	27
Kasper, J.	12-Sep	9:40AM	Lecture Theatre	32
Kim, K.	12-Sep	3:20PM	Saanich	34
Kim, R.	13-Sep	10:00AM	Lecture Theatre	37
Kim, W.	12-Sep	9:20AM	Saanich	32
Kitamura, S.	11-Sep	2:20PM	Colwood	30
Klischat, H.	12-Sep	3:40PM	Esquimalt	35
Koji, N.	13-Sep	11:20AM	Saanich	38
Krasselt, V.	12-Sep	11:40AM	Sidney	34
Krause, O.	12-Sep	11:20AM	Oak Bay	33
Krause, O.	13-Sep	9:40AM	Sidney	37
Kubal, S.K.	12-Sep	2:20PM	Saanich	34
Kusunoki, A.	11-Sep	11:00AM	Lecture Theatre	27
L				
Lafaurie, A.	12-Sep	10:00AM	Lecture Theatre	32
Lee, J.	12-Sep	5:20PM	Esquimalt	36
Lee, Y.M.	12-Sep	12:20PM	Sidney	34
Li, L.	11-Sep	5:00PM	Saanich	29
Li, X.	12-Sep	10:00AM	Colwood	34
Li, Y.	12-Sep	3:20PM	Lecture Theatre	34
Li, Y.	13-Sep	11:40AM	Saanich	38
Lifton, V.	11-Sep	10:40AM	Lecture Theatre	27
Liu, X.	13-Sep	10:40AM	Colwood	38
Lodha, R.	11-Sep	5:00PM	Sidney	30
Ludwig, S.	11-Sep	4:40PM	Colwood	30
Luz, A.	12-Sep	2:20PM	Colwood	36
Luz, A.	12-Sep	3:40PM	Colwood	36
M				
Ma, C.	11-Sep	4:20PM	Saanich	29
Madej, D.	12-Sep	9:40AM	Esquimalt	33
Maity, M.K.	12-Sep	2:40PM	Colwood	36
Martynenko, V.V.	11-Sep	10:40AM	Colwood	28
Martynenko, V.V.	12-Sep	2:20PM	Lecture Theatre	34
Mazzetti Succi, V.	12-Sep	11:20AM	Saanich	32
Meunier, P.	12-Sep	10:40AM	Lecture Theatre	32
Meunier, P.	12-Sep	12:40PM	Lecture Theatre	32
Michel, R.	12-Sep	10:20AM	Sidney	33
Monsberger, G.	11-Sep	2:00PM	Sidney	30
Moores, S.	12-Sep	10:00AM	Sidney	33
Moritz, K.	13-Sep	9:20AM	Lecture Theatre	37
Moriwaki, K.	12-Sep	9:20AM	Saanich	32
Myhre, B.	11-Sep	4:20PM	Lecture Theatre	28
Myhre, B.	11-Sep	4:40PM	Lecture Theatre	28
N				
Nishimura, M.	13-Sep	9:40AM	Lecture Theatre	37
O				
Obszynska, L.	13-Sep	11:40AM	Oak Bay	38
Ohba, Y.	11-Sep	11:20AM	Lecture Theatre	27
Ohmaru, Z.	13-Sep	11:00AM	Colwood	38
Ohno, M.	12-Sep	3:00PM	Esquimalt	35
Oprea, C.	11-Sep	2:00PM	Esquimalt	29
Oprea, G.	13-Sep	9:40AM	Oak Bay	37

Presenting Author List

Oral Presenters

Name	Date	Time	Room	Page Number
P				
Pagliosa, C.	11-Sep	1:40PM	Saanich	28
Palmer, G.	12-Sep	2:40PM	Oak Bay	35
Pandhari, A.A.	12-Sep	3:20PM	Oak Bay	35
Pärkkä, H.	12-Sep	2:40PM	Saanich	34
Pelletier, J.	11-Sep	11:40AM	Sidney	28
Peng, X.	12-Sep	9:20AM	Oak Bay	33
Prasad, B.	11-Sep	11:40AM	Saanich	27
Prorok, R.	11-Sep	2:00PM	Lecture Theatre	28
Q				
Qin, H.	11-Sep	11:20AM	Oak Bay	27
Quadling, A.	12-Sep	9:20AM	Oak Bay	33
Quirmbach, P.	13-Sep	10:00AM	Sidney	37
R				
Ramasubramanian, N.	13-Sep	9:40AM	Saanich	37
Ressler, A.	11-Sep	11:00AM	Oak Bay	27
Rigaud, M.	13-Sep	10:20AM	Sidney	37
Rimoldi, M.	11-Sep	11:20AM	Saanich	27
Rodrigues, J.A.	12-Sep	3:00PM	Colwood	36
Rodrigues, J.A.	12-Sep	4:20PM	Oak Bay	35
S				
Saha, P.	12-Sep	4:40PM	Oak Bay	35
Sahoo, N.	11-Sep	2:20PM	Lecture Theatre	28
Sahu, J.K.	12-Sep	9:20AM	Saanich	32
Sako, E.Y.	11-Sep	2:40PM	Lecture Theatre	28
Sako, E.Y.	12-Sep	4:40PM	Saanich	35
Sato, M.	12-Sep	3:20PM	Sidney	36
Schaffoener, S.	11-Sep	4:40PM	Sidney	30
Scheithauer, U.	11-Sep	4:40PM	Esquimalt	29
Scheithauer, U.	12-Sep	4:00PM	Sidney	36
Schemmel, T.	12-Sep	2:00PM	Saanich	34
Schnieder, J.	11-Sep	4:20PM	Oak Bay	29
Schweez, D.	11-Sep	2:40PM	Sidney	30
Semler, C.	13-Sep	8:00AM	Lecture Theatre	36
Sengupta, P.	13-Sep	12:20PM	Oak Bay	38
Shimizu, K.	11-Sep	5:00PM	Esquimalt	29
Simao, L.C.	12-Sep	12:00PM	Saanich	32
Simmat, R.	11-Sep	5:20PM	Sidney	30
Simmat, R.	12-Sep	11:40AM	Oak Bay	33
Simonin, F.	12-Sep	11:40AM	Lecture Theatre	32
Soltysiak, S.	11-Sep	2:20PM	Oak Bay	29
Soudier, J.	11-Sep	1:40PM	Esquimalt	29
Soudier, J.	12-Sep	4:20PM	Saanich	35
Springer, M.	12-Sep	3:00PM	Sidney	36
Stendera, J.	13-Sep	11:40AM	Lecture Theatre	38
Subramaniam, K.	13-Sep	10:20AM	Colwood	38
Sulkowski, M.	12-Sep	2:40PM	Esquimalt	35
T				
Tamura, S.	11-Sep	11:20AM	Esquimalt	27
Tassot, P.	12-Sep	3:40PM	Sidney	36
Tassot, P.	13-Sep	9:20AM	Colwood	38
Thethwayo, B.	12-Sep	9:20AM	Colwood	34
Tonnesen, T.	11-Sep	1:40PM	Sidney	30
Traon, N.	12-Sep	9:20AM	Oak Bay	33
Tripathi, H.S.	11-Sep	2:00PM	Saanich	28
V				
Van Laar, F.	13-Sep	11:20AM	Lecture Theatre	38
Vert, T.	12-Sep	8:00AM	Lecture Theatre	31
Vivaldini, D.O.	12-Sep	12:00PM	Sidney	34
Voigt, C.	13-Sep	11:00AM	Oak Bay	37
Volckaert, A.	12-Sep	9:20AM	Sidney	33
W				
Wagner, V.	12-Sep	2:20PM	Esquimalt	35
Wang, Z.	11-Sep	5:00PM	Lecture Theatre	28
Wei, Y.	11-Sep	2:20PM	Saanich	28
Wengang, Y.	11-Sep	2:40PM	Colwood	30
Werner, J.	11-Sep	2:00PM	Oak Bay	29
Wilkerson, K.R.	11-Sep	11:00AM	Esquimalt	27
Woehrmeyer, C.	11-Sep	1:40PM	Lecture Theatre	28
Wolf, C.	11-Sep	11:00AM	Sidney	27
X				
Xiong, X.	12-Sep	5:00PM	Lecture Theatre	34
Y				
Yanwen, Y.	11-Sep	4:20PM	Esquimalt	29
Ye, G.	12-Sep	10:40AM	Esquimalt	33
Ye, G.	13-Sep	11:20AM	Oak Bay	38
Yeh, S.	13-Sep	9:40AM	Colwood	38
Yu, R.	12-Sep	5:00PM	Saanich	35
Yuan, W.	12-Sep	12:20PM	Oak Bay	33
Yurkov, A.	12-Sep	9:40AM	Colwood	34
Z				
Zacherl, D.	12-Sep	12:20PM	Lecture Theatre	32
Zacherl, D.	12-Sep	2:40PM	Sidney	36
Zargar, H.	11-Sep	11:40AM	Esquimalt	27
Zetterstrom, C.	11-Sep	2:40PM	Oak Bay	29
Zhang, H.	12-Sep	11:40AM	Esquimalt	33
Zhang, H.	13-Sep	10:00AM	Colwood	38
Zhou, N.	13-Sep	10:00AM	Esquimalt	37
Zhu, H.	11-Sep	4:40PM	Saanich	29
Zhu, H.	12-Sep	12:00PM	Esquimalt	33
Zhu, L.	13-Sep	9:40AM	Esquimalt	37

Poster Presenters

Name	Date	Time	Room	Page Number
Adak, S.	11-Sep	5:30PM	Palm Court	30
Brochen, E.	11-Sep	5:30PM	Palm Court	31
Choi, S.	11-Sep	5:30PM	Palm Court	31
de Bilbao, E.	11-Sep	5:30PM	Palm Court	31
de Paula Rettore, R.	11-Sep	5:30PM	Palm Court	31
Devic, S.	11-Sep	5:30PM	Palm Court	31
Domiciano, V.	11-Sep	5:30PM	Palm Court	31
Dupuy, D.	11-Sep	5:30PM	Palm Court	31
Gutierrez, D.	11-Sep	5:30PM	Palm Court	31
Hongqin, D.	11-Sep	5:30PM	Palm Court	31
Iwamoto, K.	11-Sep	5:30PM	Palm Court	31
Jacobsen, N.	11-Sep	5:30PM	Palm Court	31
Jakobsen, D.	11-Sep	5:30PM	Palm Court	30
Klewski, M.	11-Sep	5:30PM	Palm Court	31
Li, Y.	11-Sep	5:30PM	Palm Court	31
Liu, X.	11-Sep	5:30PM	Palm Court	31
Lodha, R.	11-Sep	5:30PM	Palm Court	31
Mizobe, A.	11-Sep	5:30PM	Palm Court	30
Otake, R.	11-Sep	5:30PM	Palm Court	31
Paul, P.	11-Sep	5:30PM	Palm Court	31
Prendergast, I.	11-Sep	5:30PM	Palm Court	31
Saha, P.	11-Sep	5:30PM	Palm Court	31
Sarkar, A.K.	11-Sep	5:30PM	Palm Court	31
Schickle, B.	11-Sep	5:30PM	Palm Court	31
Sniezek, E.	11-Sep	5:30PM	Palm Court	31
Storm, J.	11-Sep	5:30PM	Palm Court	30
Tomba Martinez, A.G.	11-Sep	5:30PM	Palm Court	31
Wang, G.	11-Sep	5:30PM	Palm Court	31
Ye, G.	11-Sep	5:30PM	Palm Court	31
Zhou, N.	11-Sep	5:30PM	Palm Court	31
Ziegler, F.L.	11-Sep	5:30PM	Palm Court	30

Wednesday, September 11, 2013

Opening Ceremony and Keynote Speaker

Room: Lecture Theatre

Session Chair: Dana Goski, Allied Mineral Products

8:40 AM

Opening Ceremony

Dr. Louis J. Trostel, Jr.; UNITECR 2013 President

9:00 AM

(UNITECR-001-2013) Minerals to Materials: The changing face of the global refractory industry

R. de Jong*, IMERYS, France

Monolithics I

Room: Lecture Theatre

Session Chairs: Dale Zacherl, Almatis Inc.; Goutam Bhattacharya, Kerneos, India

10:40 AM

(UNITECR-148-2013) Next generation alumina binder for cement-free castables

C. Tontrup, Evonik Industries AG, Germany; V. Lifton*, Evonik Degussa Corp., USA; T. von Rymon Lipinski, Institute of Applied Technology, Germany

11:00 AM

(UNITECR-149-2013) Non-cement castable for blast furnaces troughs

A. Kusunoki*, K. Haraguchi, Y. Eguchi, KROSAKI HARIMA CORPORATION, Japan

11:20 AM

(UNITECR-150-2013) No-Cement Alumina - Magnesia Castables

Y. Ohba*, Taiko Refractories Co., Ltd, Japan

Iron & Steel Making Refractories - Coke Ovens

Room: Saanich

Session Chair: Gary West, Suncoke Energy; Thomas Schemmel, Refratechnik Steel GmbH

10:40 AM

(UNITECR-085-2013) Influence of thermal expansion behavior on adhesive strength of silica mortar

A. Kasai*, Sumitomo Metal Industries, LTD, Japan

11:00 AM

(UNITECR-087-2013) Physical Properties of Used Bricks for Coke Oven

S. Hosohara*, H. Matsunaga, Y. Fukushima, JFE Steel Corporation, Japan

11:20 AM

(UNITECR-088-2013) Evaluation of coke oven regenerator checkers after 40 years in service

M. Rimoldi*, S. Camelli, Instituto Argentino de Siderurgia, Argentina; D. Beltran, M. Labadie, Ternium Siderar, Argentina

11:40 AM

(UNITECR-089-2013) Development of zero expansion silica bricks for hot repair of coke oven

B. Prasad*, B. K. Panda, S. P. Das, J. Tiwari, N. Sahoo, OCL India Ltd, India

Advanced Testing of Refractories I

Room: Oak Bay

Session Chairs: Len Kreitz, Plibrico Co., LLC; Nigel Longshaw, Ceram Research Ltd.

10:40 AM

(UNITECR-009-2013) Thermo-mechanical characterisation of magnesia-carbon refractories by means of wedge splitting test under controlled atmosphere at high-temperature

E. Brochen*, C. Dannert, Forschungsgemeinschaft Feuerfest e.V., Germany; P. Quirmbach, DIFK Deutsches Institut für Feuerfest und Keramik GmbH, Germany

11:00 AM

(UNITECR-010-2013) Characterization of magnesia and magnesia-chromite bricks by the use of different destructive and nondestructive testing methods

A. Ressler*, R. Neuboeck, C. Manhart, RHI AG, Austria

11:20 AM

(UNITECR-011-2013) The influence of in-sute formation spinel on the fracture energy of alumina-magnesia refractory castables

H. Qin*, University of Science and Technology Beijing, China; H. Li, Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China; J. Wang, University of Science and Technology Beijing, China; G. Liu, W. Yang, Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China; L. Xu, University of Science and Technology Beijing, China

Developments in Basic Refractories I

Room: Esquimalt

Session Chairs: Dominick Colavito, MINTEQ International Inc.; Andrie Garbers-Craig, University of Pretoria

10:40 AM

(UNITECR-042-2013) Reactant Particle Size Effects on Spinel Expansion

F. Cunha-Duncan, R. C. Bradt*, The University of Alabama, USA

11:00 AM

(UNITECR-043-2013) Thermal Properties in the $MgAl_2O_4$-Al_2O_3 System

K. R. Wilkerson*, J. D. Smith, Missouri University of Science and Technology, USA; J. G. Hemrick, Oak Ridge National Laboratory, USA

11:20 AM

(UNITECR-044-2013) Development of MgO-C NanoTech.Refractories aimed at 0% Graphite content

S. Tamura*, T. Ochiai, S. Takanaga, Nanotech.Refractories Institute, Japan; O. Matsuura, H. Yasumitsu, M. Hirashima, Kyushu Refractories Co.,Ltd., Japan

11:40 AM

(UNITECR-227-2013) Influence of Solid-Solution Formation on the Solid-State Sintering of MgCr2O4 Spinel

H. Zargar*, G. Oprea, T. Troczynski, University of British Columbia, Canada

Advanced Installation Techniques and Equipment

Room: Sidney

Session Chairs: James Stendera, Vesuvius R&D Center; Hirohide Okuno, Taiko Refractories Co. Ltd.

10:40 AM

(UNITECR-004-2013) Development of Automatic Repair Technology by Continuous and Quick Mixing Technology

Y. Furuta*, H. Itoh, K. Seki, J. Tsukuda, Krosaki Harima, Japan; S. Nakai, NS engineering, Japan; S. Hanagiri, Nippon Steel & Sumitomo Metal, Japan; T. Uchida, S. Itoh, Nippon Steel & Sumitomo Metal, Japan; S. Asoh, Nippon Steel & Sumitomo Metal, Japan

11:00 AM

(UNITECR-005-2013) Gunning Robots for the hot repair

C. Wolf*, Velco GmbH, Germany

11:20 AM

(UNITECR-006-2013) Tapholes repair on CSN's Blast Furnace 3: Core & Cast and Core & Plug

P. C. da Silveira Sousa*, Companhia Siderúrgica Nacional, Brazil; T. Talaat, TRE Services, USA; T. I. Souza, A. L. Saraiva Junior, E. S. Neves, P. R. de Oliveira Cordeiro, E. G. Fernandes, Companhia Siderúrgica Nacional, Brazil

11:40 AM

(UNITECR-007-2013) The Next Generation of Monolithic Application Technology: Continuous Mixing of Low Cement Castables for Wet Shotcreting

J. Pelletier*, C. Alt, Kerneos, Inc., USA; C. Parr, Kerneos SA, France; J. Farrell, T. Farrell, Blastcrete Equipment Company, USA

12:00 PM

(UNITECR-008-2013) Development of Continuous Quick Mixing & Repairing Technology

S. Itoh*, S. Hanagiri, T. Uchida, H. Takeuchi, H. Nakamura, S. Asoh, Nippon Steel & Sumitomo Metal, Japan; H. Itoh, Y. Furuta, K. Seki, J. Tsukuda, Krosaki Harima, Japan; S. Nakai, NS engineering, Japan

Refractories for Glass

Room: Colwood

Session Chairs: M. Patil, Corning Incorporated; Matt Lambert, Allied Mineral Products

10:40 AM

(UNITECR-204-2013) Research of Refractories from Aluminaboronsilicate Fiberglass Production Furnace Lining after 88 Months Service

V. V. Martynenko*, V. V. Primachenko, P. P. Kryvoruchko, Y. E. Mishnyova, N. G. Pryvalova, O. I. Synyukova, Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine

11:00 AM

(UNITECR-205-2013) New materials and improvements for the glass industry

S. C. Frasson*, M. F. Guerra, S. M. Justus, V. P. Ramos, E. Y. Sako, Saint-Gobain do Brasil Ltda, Brazil

11:20 AM

(UNITECR-206-2013) Understanding microstructure/properties relationships related to the thermomechanical behaviour of high zirconia refractories

C. Patapy, LMDC INSA, France; F. Gouraud*, SPCTS UMR CNRS 7315, France; N. Gey, M. Humbert, A. Hazotte, LEM3 UMR CNRS 7239, France; D. Chateigner, CRISMAT UMR CNRS 6508, France; R. Guinebretière, M. Huger, T. Chotard, SPCTS UMR CNRS 7315, France

Monolithics II

Room: Lecture Theatre

Session Chairs: Dale Zacherl, Almatis Inc.; Goutam Bhattacharya, Kerneos, India

1:40 PM

(UNITECR-152-2013) Novel Calcium Magnesium Aluminate bonded castables for steel and foundry ladles

C. Woehrmeyer*, J. Auvray, B. Li, H. Fryda, M. Szepizdyn, Kerneos SA, France; D. Poerzgen, Beck + Kaltheuner GmbH & Co., KG, Germany; N. Li, W. Yan, Wuhan University of Science and Technology, China

2:00 PM

(UNITECR-153-2013) Influence of phase evolution and microstructure on mechanical properties of basic castables

J. Szczerba, R. Prorok*, AGH University of Science and Technology, Poland; Z. Czapka, Zaklady Magnezytowe ROPCZYCE S.A., Poland; D. Madej, E. Sniezek, AGH University of Science and Technology, Poland

2:20 PM

(UNITECR-154-2013) Synthesis of Nano MgO from natural raw Magnesite and its application in High alumina castable products

N. Sahoo*, P. Rauta, L. Padhi, Dalmia Institute of Scientific & Industrial Research, India; J. Tiwari, OCL India Limited, India

2:40 PM

(UNITECR-155-2013) Advanced understanding on in situ spinel formation and corrosion performance of spinel-containing refractory castables

E. Y. Sako*, Saint-Gobain Cerâmicas e Plásticos, Brazil; M. A. Braulio, V. C. Pandolfelli, Universidade Federal de São Carlos, Brazil

3:00 PM

(UNITECR-156-2013) Study on the hydration behavior of MgO powders

Q. Jia*, R. Wu, T. Ge, X. Sun, Zhengzhou University, China; X. Qian, J. Zhan, Chengdu Futian New Materials Technology Co., Ltd, China

3:20 PM

Break

Monolithics III

Room: Lecture Theatre

Session Chairs: Dale Zacherl, Almatis Inc.; Goutam Bhattacharya, Kerneos, India

4:20 PM

(UNITECR-157-2013) Cement free MgO castables: Part I: Flow, setting and slaking

B. Myhre*, Elkem Silicon Materials, Norway; M. Luo, Wuhan University of Science and Technology, China; H. Peng, Elkem Silicon Materials, Norway

4:40 PM

(UNITECR-158-2013) Cement free MgO castables: Part II: Strength and explosion resistance

B. Myhre*, Elkem Silicon Materials, Norway; M. Luo, Wuhan University of Science and Technology, China; H. Peng, Elkem Silicon Materials, Norway

5:00 PM

(UNITECR-159-2013) Influence of Dispersants and Bonding Methods on Properties of Alumina Based Castables without Microsilica Addition

Z. Wang*, Z. Li, X. Cao, S. Wang, L. Zhou, State Key Laboratory of Advanced Refractories, Sinosteel Luoyang Institute of Refractories Research, China

Iron & Steel Making Refractories - Magnesia-Carbon I

Room: Saanich

Session Chair: Patrick Tassot, Calderys; Helge Jansen, REFRACTECHNIK Steel

1:40 PM

(UNITECR-096-2013) Effects of Nano Boron Carbide as additive for MgO-C for BOF

C. Pagliosa*, N. Freire, G. Cholodovskis, MAGNESITA Refractories, Brazil

2:00 PM

(UNITECR-097-2013) Development of Al2O3-MgAl2O4-C Refractories for steel ladle: Effect of MgO and Al2O3 reactivity

H. S. Tripathi*, A. Ghosh, CSIR-Central Glass & Ceramic Research Institute, India

2:20 PM

(UNITECR-099-2013) Properties of MgO Based Refractories with Synthetic MgO-SiC-C Powder

Y. Wei*, X. Li, N. Li, Wuhan University of Science and Technology, China; X. Li, B. Wu, L. Wang, L. Ma, Zhejiang Zili Co.,Ltd.,, China

2:40 PM

Break

Iron & Steel Making Refractories - Magnesia-Carbon II

Room: Saanich

Session Chair: Patrick Tassot, Calderys; Helge Jansen, REFRACTECHNIK Steel

4:20 PM

(UNITECR-100-2013) Influence of Zinc catalysis on in-situ reaction of metal composite MgO-C refractories

C. Ma*, H. Ma, Z. Ren, D. Meng, Zhengzhou University, China

4:40 PM

(UNITECR-101-2013) The comprehensive studies of magnesia carbon bricks' anisotropy

H. Zhu*, Puyang Punai Refractories Group Co.,Ltd., China

5:00 PM

(UNITECR-102-2013) Improvement and Maintenance of MgO-C Bottom-Blowing Tuyer in BOF Converter for Prolonging Service Life

L. Li*, X. Peng, H. Ding, F. Gao, China Central Iron and Steel Research Institute Group, China

Advanced Testing of Refractories II

Room: Oak Bay

Session Chairs: Len Kreitz, Plibrico Co., LLC; Nigel Longshaw, Ceram Research Ltd.

1:40 PM

(UNITECR-014-2013) Temperature dependent thermo-mechanical behavior of novel alumina based refractories

A. Böhm*, E. Skiera, J. Malzbender, Forschungszentrum Juelich GmbH, Germany; C. G. Aneziris, Technical University Bergakademie Freiberg, Germany

2:00 PM

(UNITECR-015-2013) Contribution of different bonding agents and amounts to Young's modulus of elasticity at elevated temperatures of carbon-bonded alumina determined by Impulse excitation technique

J. Werner*, C. G. Aneziris, TU Freiberg, Germany

2:20 PM

(UNITECR-016-2013) Influence of the Cabores content on the damage parameters of carbon bonded alumina obtained by means of the Small Punch Test

S. Soltysiak*, M. Abendroth, M. Kuna, TU Bergakademie Freiberg, Germany

2:40 PM

(UNITECR-017-2013) Dry out simulation of castables containing calcium aluminate cement under hydrothermal conditions

J. Auvray, C. Zetterstrom*, C. Wohrmeyer, H. Fryda, C. Parr, C. Eychenne-Baron, Kerneos SA, France

3:00 PM

(UNITECR-018-2013) Corrosion of corundum-mullite refractories in gaseous HCl/H2O atmosphere at elevated temperature

M. Jafari, M. Ghanbari, F. Golestani-fard*, R. Naghizadeh, Iran University of Science and Technology, Islamic Republic of Iran

3:20 PM

Break

Advanced Testing of Refractories III

Room: Oak Bay

Session Chairs: Len Kreitz, Plibrico Co., LLC; Nigel Longshaw, Ceram Research Ltd.

4:20 PM

(UNITECR-019-2013) Microstructural processes in the wake region of the crack in castables containing eutectic aggregates at high temperature thermal shock

J. Schnieder*, N. Traon, T. Tonnesen, R. Telle, RWTH Aachen, Germany

4:40 PM

(UNITECR-021-2013) Thermal shock on the lower slide gate plate when closing: Test development and post-mortem investigations

R. Grasset-Bourdel*, C. Manhart, J. Pascual, RHI AG, Austria

Developments in Basic Refractories II

Room: Esquimalt

Session Chairs: Dominick Colavito, MINTEQ International Inc.; Andrie Garbers-Craig, University of Pretoria

1:40 PM

(UNITECR-046-2013) Thermal cycling resistant MgO based monolithic linings

C. Dromain, Calderys, France; P. Malkmus, Calderys, Germany; J. Soudier*, Calderys, France

2:00 PM

(UNITECR-047-2013) Effect of Magnesia Dissolution in Non-Stoichiometric Chromium-Free Complex Spinel

R. Lodha, C. Oprea*, T. Troczynski, G. Oprea, The University of British Columbia, Canada

2:20 PM

(UNITECR-048-2013) Microstructural and physico-chemical evolution of Al2O3 and Fe2O3 nanoparticles doped magnesia (MgO) sintered at 1600 °C

C. Gomez Rodriguez*, T. K. Das Roy, A. G. Castillo Rodriguez, S. Shaji, E. A. Rodriguez Castellanos, L. V. Garcia Quinonez, Universidad Autonoma de Nuevo Leon, Mexico

2:40 PM

(UNITECR-049-2013) Studies on the Effect of Nano-Carbon in MgO-C: A New Generation Refractories

M. Bag, R. Sarkar, National Institute of Technology, India; R. P. Rana, S. Adak*, A. K. Chattopadhyay, TRL Krosaki Refractories Limited, India

3:00 PM

(UNITECR-050-2013) Magnesia-Carbon Bricks Made in Europe, Challenges and Solutions

G. Buchebner*, A. Kronthaler, W. Hammerer, RHI AG, Austria

3:20 PM

Break

Developments in Basic Refractories III

Room: Esquimalt

Session Chairs: Dominick Colavito, MINTEQ International Inc.; Ben Markel, Resco Products

4:20 PM

(UNITECR-051-2013) The effects of rare earth oxides on the structures and properties of MgO-CaO ceramics

Y. Yanwen*, Baosteel Metal Society, China

4:40 PM

(UNITECR-052-2013) Development of planar and cylindrical refractories with graded microstructure

U. Scheithauer*, T. Slawik, K. Haderk, T. Moritz, A. Michaelis, Fraunhofer IKTS Dresden, Germany

5:00 PM

(UNITECR-053-2013) Development of magnesia refractories with higher slaking resistance

K. Shimizu*, T. Nakamichi, Y. Sadatomi, J. Yoshitomi, Krosaki Harima Corporation, Japan

Refractories for Waste to Energy Processing and Power

Room: Sidney

Session Chairs: Ben Markel, Resco Products, USA; Steve Chernack, Morgan Thermal Ceramics

1:40 PM

(UNITECR-217-2013) Vapor Phase and Melt Corrosion of Refractory Castables in Biomass Gasification and Incineration Processes

T. Tonnesen*, R. Telle, RWTH Aachen University, Germany

2:00 PM

(UNITECR-218-2013) Improvement of the physical properties in Al2O3-SiO2-bricks by sol- impregnation

G. Monsberger*, K. Santowski, RHI-AG technologie Center Leoben, Austria

2:20 PM

(UNITECR-219-2013) The Improvement of Al2O3-Cr2O3 Bricks for Waste Melting Furnaces

H. Hoshizuki*, H. Tanida, S. Ota, Y. Yoshimi, MINO CERAMIC CO., LTD, Japan

2:40 PM

(UNITECR-220-2013) Recent lining concepts for thermal treatment of hazardous wastes

K. Schwickert, U. Frohneberg, J. Sperber, R. Burgard, F. Duennes, D. Schweez*, STEULER-KCH GmbH, Germany

3:00 PM

Break

Refractories for Nonferrous Metallurgy I

Room: Sidney

Session Chairs: Rick Volk, United Refractories Co.; Angela Rodrigues-Schroer, Wahl Refractory Solutions

4:20 PM

(UNITECR-207-2013) Processing and Characterization of MgAl2O4 – Calcium Aluminate Refractories by Reaction Sintering of Alumina-Dolomite

R. P. Rana, A. S. Bal, B. P. Padhy, S. Adak*, P. B. Panda, A. K. Chattopadhyay, TRL Krosaki Refractories Limited, India

4:40 PM

(UNITECR-208-2013) Calcium zirconate refractories for titanium melts

S. Schaffoener*, TU Bergakademie Freiberg, Germany; B. Rotmann, RWTH Aachen, Germany; H. Berek, TU Bergakademie Freiberg, Germany; B. Friedrich, RWTH Aachen, Germany; C. Aneziris, TU Bergakademie Freiberg, Germany

5:00 PM

(UNITECR-209-2013) Chromium-Free Complex Spinel Bonded Basic Castables

R. Lodha*, H. Zargar, T. Troczynski, G. Oprea, The University of British Columbia, Canada

5:20 PM

(UNITECR-210-2013) Influence of corrosive attack by AlMg5 on the hot abrasion resistance of refractory materials for the use in the secondary aluminum industry

R. Simmat*, C. Dannert, Forschungsgemeinschaft Feuerfest e.V., Germany

Modelling and Simulation of Refractories I

Room: Colwood

Session Chairs: Bill Headrick, MORCO, USA; Harald Harmuth, Montanuniversitaet Leoben

1:40 PM

(UNITECR-135-2013) Marangoni convection as a contribution to refractory corrosion - CFD simulation and analytical approaches

S. Vollmann, H. Harmuth*, Montanuniversitaet Leoben, Austria

2:00 PM

(UNITECR-136-2013) Thermomechanical computations of refractory linings accounting for chemical swelling

M. Tarek, B. Eric*, PRISME Laboratory - University of Orléans, France; S. Nicolas, LMT Cachan - ENS de Cachan / CNRS UMR 8535 / UPMC, France; D. Emmanuel, CEMHTI, UPR3079 CNRS - University of Orleans, France; G. Alain, PRISME Laboratory - University of Orléans, France

2:20 PM

(UNITECR-138-2013) Dissolution rate of solid oxide into molten slag

N. Maruoka, IMRAM, Tohoku University, Japan; F. Huang, J. Liu, University of Science and Technology, Beijing, China; S. Kitamura*, IMRAM, Tohoku University, Japan

2:40 PM

(UNITECR-139-2013) Finite element analysis for thermal stress of stopper

Y. Wengang*, L. Guoqi, M. Tianfei, Y. Jianbin, Q. Fan, Sinosteel Corporation Luoyang Institute of Refractories Research, China

3:00 PM

Break

Iron & Steel Making Refractories - Continuous Casting

Room: Colwood

Session Chair: Xiaoyong Xiong, Imerys Refractory Minerals; Olaf Krause, Forschungsgemeinschaft Feuerfest e.V

4:20 PM

(UNITECR-112-2013) Development of Aluminous Nozzles reinforced with SiAlON

C. M. Galinari*, P. R. Dutra, Magnesita, Brazil

4:40 PM

(UNITECR-113-2013) Properties of self-glazing Al2O3-C-refractories influenced by the graphite content and nanoscaled additives

S. Ludwig*, V. Roungos, C. G. Aneziris, TU Bergakademie Freiberg, Germany

5:00 PM

(UNITECR-115-2013) Effects of viscosity and surface tension of Free fluorine fluxes on the wear mechanisms of Al2O3-C nozzle

E. Brandaleze*, M. Avalos, V. Peirani, Universidad Tecnológica Nacional- Facultad Regional San Nicolás, Argentina

Poster Session

Room: Palm Court

5:30 PM

(UNITECR-P002-2013) Development of High Performance Alumina-Chrome-Zirconia Brick for Multiple Applications

A. Chakrabarti, B. Ghosh, S. Adak*, P. B. Panda, A. K. Chattopadhyay, TRL Krosaki Refractories Limited, India; S. Chattopadhyaya, B. Das, Sterlite Industries Limited, India

(UNITECR-P003-2013) Optimum Quantity of Gas blown into the Bore of Tundish Upper Nozzle

A. Mizobe*, J. Kurisu, K. Furukawa, T. Tsuduki, M. Yamamoto, T. Oouchi, K. Oki, KrosakiHarima Corporation, Japan

(UNITECR-P004-2013) Nanostructured self-flow refractory castable to long-life melt aluminum contact lining

F. L. Ziegler*, F. D. Valenzuela, ZTECH Refractories Industry, Brazil

(UNITECR-P005-2013) Thermo-mechanics of ceramic filter structures

J. Storm*, M. Abendroth, M. Kuna, C. Aneziris, TU Bergakademie Freiberg, Germany

(UNITECR-P006-2013) Tape Casting of Coarse-Grained Oxide Powders for the Manufacture of Advanced Refractory Multilayer Composites

D. Jakobsen*, I. Götschel, A. Roosen, University Erlangen-Nuremberg, Germany

(UNITECR-P008-2013) Microstructure and properties of porous ZrO2 ceramics prepared by foaming combined with gelcasting methods
G. Wang*, J. Han, B. Yuan, H. Li, Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China

(UNITECR-P009-2013) Influence of the additive of cordierite on the properties of mullite-andalusite-cordierite brick
D. Hongqin*, L. Fuchao, L. Jiantao, S. Gengchen, Z. Guolu, G. Nan, G. Shijian, zhenzhou Annec Industrial Co., Ltd, China; L. Suping, Y. Fangbao, Zhengzhou University, China

(UNITECR-P010-2013) Development of measuring method of torpedo car brick thickness using commercial 3D laser scanner
R. Otake*, T. Ozato, N. Sakaguchi, K. Nakanishi, K. Kobayashi, KOBE STEEL, LTD, Japan

(UNITECR-P012-2013) Chemical wear of Al2O3-MgO-C bricks by air and basic slags
L. Musante, P. G. Galliano, Center for Industrial Research-TENARIS, Argentina; E. Brandaleze, Universidad Tecnológica Nacional, Argentina; V. Muñoz, A. G. Tomba Martinez*, INTEMA, Argentina

(UNITECR-P013-2013) Alumina-Magnesia-Carbon bricks for steel ladle
M. Klewski*, M. Sulkowski, ArcelorMittal Refractories, Poland; P. Blumenfeld, ArcelorMittal Fos-sur-Mer, France

(UNITECR-P014-2013) Role of design and application in refractory performance
P. Saha*, B. Sarkar, P. P. Lahiri, Engineers India Limited, India

(UNITECR-P015-2013) Application of multi-hole stopper for mould level stability
S. Choi*, I. Lee, D. Choi, K. Choi, S. Lee, S. Sunwoo, Chosun refractories, Republic of Korea

(UNITECR-P016-2013) Improvement of the thermal shock resistance on lower nozzle for tundish and ladle
K. Iwamoto*, H. Kamio, K. Morikawa, J. Yoshitomi, Krosaki Harima Corporation, Japan

(UNITECR-P017-2013) Effects of Particle Size and Impurities on Mullitization of Andalusite
S. Li, G. Ye*, Y. Zhang, X. Song, J. Ma, C. Zhang, Zhengzhou University, China

(UNITECR-P018-2013) Study on Erosion Mechanism of Cr2O3-Al2O3-ZrO2 Bricks for Coal-water Slurry Pressurized Gasifier
Y. Li*, Luoyang Lier Refractories Co., Ltd., China; C. Ke, Y. Zhang, Wuhan University of Science and Technology, China; Y. Zhang, J. Zhao, Luoyang Lier Refractories Co., Ltd., China; G. Ye, Zhengzhou University, China

(UNITECR-P019-2013) Calcium Hexaluminate Distribution and Properties of Calcium Alumina Cement Bonded Castables with Addition of Magnesium Chloride Addition
C. Zhang, G. Ye*, L. Zhu, Q. Wang, Y. Mu, Zhengzhou University, China; C. Wang, Henan University of Technology, China

(UNITECR-P020-2013) New Developments on Refractory Hollowware Materials for Ingot Casting
R. de Paula Rettore*, E. Gueguen, G. Zieba, Magnesita Refractories, Germany

(UNITECR-P021-2013) How do steelmakers pick refractories? A supplier's perspective
I. Prendergast*, ANH Refractories, USA

(UNITECR-P023-2013) Improving Maintenance at Direct-Reduction Plants Using Infrared Thermography
Y. J. Giron, E. J. Estrada, Siderurgica del Orinoco - Sidor, Venezuela, Bolivarian Republic of; D. Gutierrez*, Universidad Simon Bolivar, Venezuela, Bolivarian Republic of

(UNITECR-P025-2013) Steel Cleanliness and Sequence length Improvement through Tundish Configuration and Black Refractories Quality Optimization and by Introducing the Concept of Management at JSW Steel Vijaynagar Works , INDIA
A. K. Sarkar*, JSW Steel INDIA, India

(UNITECR-P026-2013) Present Trend of Pre-cast Shape and Refractory Castable uses in Vizag Steel Plant, India: Challenges Faced and Success Stories
A. Datta, P. Paul*, Rastriya Ispat Nigam Limited, Visakhapatnam Steel Plant, India

(UNITECR-P028-2013) Optical Microscopy and its Contribution to The Control of Applied Submerged Entry Nozzle - SEN in Continuous Casting of Steel
S. Devic*, Institut IMS, Serbia; M. Cocic, M. Logar, Technical Faculty, Serbia

(UNITECR-P030-2013) Volume expansion of SiC-based refractories induced by salts corrosion
E. de Bilbao*, Cemhti, France; P. Prigent, TRB, France; C. Mehdi-Souzani, LURPA, France; M. Bouchetou, Cemhti, France; N. Schmitt, LMT, France; J. Poirier, Cemhti, France; E. Blond, Prisme, France

(UNITECR-P031-2013) Effects of Mg Addition on Phase Composition, Microstructure and Properties of Al2O3-C Material
X. Liu*, X. Zhu, L. Feng, High Temperature Ceramics Institute, China

(UNITECR-P032-2013) Specific material properties for the evaluation of the thermal stress resistance of refractory products: Compendium and new investigation methods
E. Brochen*, C. Dannert, Forschungsgemeinschaft Feuerfest e.V., Germany

(UNITECR-P034-2013) Properties Improvement of Light Weight Al2O3-SiO2 Castables by Andalusite Addition
N. Zhou*, S. Hu, H. Wang, Henan University of Science and Technology, China; X. Xiong, X. Liu, Damrec-Imerys, France

(UNITECR-P035-2013) Influence of process conditions on the crystallization of calcium silicates in the stirring autoclave and their impact on thermal stability
B. Schickle*, R. Telle, T. Tonnesen, Institute of Mineral Engineering, Germany; A. Opsommer, Promat Research and Technology Centre N.V., Belgium

(UNITECR-P036-2013) Influence of aluminates of evaluation thermomechanical properties refractory materials from the MgO-CaO-Al2O3-ZrO2 system
J. Szczerba, AGH University of Science and Technology, Poland; M. Szymaszek, Zaklady Magnezytowe ROPCZYCE S.A., Poland; E. Sniezek*, D. Madej, R. Prorok, AGH University of Science and Technology, Poland

(UNITECR-P037-2013) Basic understanding of physical properties of carbon bonded refractory composites
D. Dupuy*, SPCTS UMR CNRS 70315, France; S. Zhu, D. DeBastiani, P. Guillo, C. Dumazeau, Vesuvius, USA; C. Peyratout, GEMH, France; M. Huger, T. Chotard, SPCTS UMR CNRS 70315, France

(UNITECR-P038-2013) Spinel Inversion and Lattice Parameters in Chromium-Free Spinel Solid Solutions
R. Lodha*, G. Oprea, T. Troczynski, The University of British Columbia, Canada

(UNITECR-P041-2013) Challenges of Blast Furnace Casthouse: Failure Analysis of Main Runner Refractory Castable
V. Domiciano*, A. R. Ollmann, E. I. Clemente, A. K. Duarte, A. M. Brito, Magnesita Refratários S.A., Brazil

(UNITECR-P042-2013) Rotary Kilns: Lining, Design and Energy Savings
P. Trane, N. Jacobsen*, C. Bach, Skamol A/S, Denmark

Thursday, September 12, 2013

Plenary Session I

Room: Lecture Theatre
Session Chair: Dana Goski, Allied Mineral Products

8:00 AM
(UNITECR-002-2013) How Do Steel Makers Pick Refractories - Logic, Emotion or Dartboard?
T. Vert*, ArcelorMittal Dofasco, Canada

Monolithics IV

Room: Lecture Theatre

Session Chair: Bjorn Myhre, Elkem; Christos G Aneziris, Technical University Bergakademie Freiberg

9:20 AM

(UNITECR-161-2013) Cement Hydration and Strength Development – How Can Reproducible Results be Achieved?

D. Schmidtmeier, A. Buhr*, Almatis GmbH, Germany; G. Wams, S. Kuiper, Almatis B.V., Netherlands; S. Klaus, F. Götz-Neunhöfer, University Erlangen, Germany; D. Zacherl, Almatis Inc., USA; J. Dutton, N/A, United Kingdom

9:40 AM

(UNITECR-162-2013) Mixing optimization of an alumina based LC castable by applying variable power inputs and the effect on the rheology during molding, the setting and hardening behavior as well as the derived mechanical properties

J. Kasper*, O. Krause, University of Applied Science Koblenz, Germany

10:00 AM

(UNITECR-163-2013) Rheological & Dispersion behaviour of reactive aluminas in matrix formulation

A. Lafaurie*, E. Chabas, C. Ulrich, ALTEO, France

10:20 AM

(UNITECR-164-2013) Effect of Minor Elements on Solid-liquid Interactions in Calcium Aluminate Cement Refractories

J. Alex*, L. Vandeperre, Imperial College London, United Kingdom; B. Touzo, C. Parr, Kerneos Ltd., France; W. E. Lee, Imperial College London, United Kingdom

10:40 AM

(UNITECR-P027-2013) Methods to assess the drying ability of refractory castables

P. Ermtraud, CALDERYS, Germany; P. Meunier*, J. Soudier, CALDERYS, France

11:00 AM

Break

Monolithics V

Room: Lecture Theatre

Session Chair: Dave Bakshi, C-E Minerals; Jens Decker, Stellar Materials

11:20 AM

(UNITECR-165-2013) The Effect of Aging of Blast Furnace Trough Castables Due to Storage Conditions on Performance in Service

S. Bonsall*, W. Gavrish, Vesuvius USA, USA

11:40 AM

(UNITECR-166-2013) Practical experience of time stable calcium aluminates in low cement castable applications

F. Simonin*, C. Parr, H. Fryda, J. Mahiaoui, M. Szepizdyn, KERNEOS, France; O. Pawlig, KERNEOS, Germany

12:00 PM

(UNITECR-167-2013) Influence of alumina parameters on formulation characteristics and mechanical properties of refractory castables: A new added value range of reactive aluminas

E. Chabas*, A. Lafaurie, C. Ulrich, ALTEO, France

12:20 PM

(UNITECR-168-2013) High Performance Gunning Mix With CT10SG as a Plasticizer

D. Zacherl*, Almatis, Inc, USA; B. Long, Qingdao Almatis, China; Z. Wang, Wuhan University of Science & Technology, China; A. Buhr, Almatis, GmbH, Germany

12:40 PM

(UNITECR-169-2013) Time, energy and cost saving during monolithic refractory lining installation by combining Quick Dry technology and gunning technics

P. Malkmus, Calderys, Germany; P. Meunier*, J. Soudier, Calderys, France

Iron & Steel Making Refractories - Submerged Entry Nozzles

Room: Saanich

Session Chair: Arupk Chattopadahyay, TRL Krosaki Refractories; Farhad Golestanifard, Iran University of Science & Technology

9:20 AM

(UNITECR-116-2013) Main mechanisms of SEN slag band corrosion as observed by post mortem investigations

H. Harmuth*, N. Kölbl, Montanuniversitaet Leoben, Austria; B. Rollinger, RHI AG, Austria; G. Xia, voestalpine Stahl GmbH, Austria

9:40 AM

(UNITECR-117-2013) Critical Evaluation and Optimization of the Li2O-ZrO2 and Li2O-ZrO2-SiO2 systems

W. Kim*, I. Jung, McGill University, Canada

10:00 AM

(UNITECR-118-2013) Studies and optimization of various types of Zirconia to minimize crack propagation and improve corrosion and erosion resistance of slag band of Subentry nozzle

J. K. Sahu*, B. Prasad, A. Sen, J. Tiwari, OCL India Ltd, India

10:20 AM

(UNITECR-119-2013) Evaluation methods of the corrosion resistance of ZrO2-C material used for SEN slag line

K. Moriwaki*, K. Yamaguchi, M. Ogata, Shinagawa Refractories CO.,LTD., Japan

Iron & Steel Making Refractories - Ladles

Room: Saanich

Session Chair: Ningsheng Zhou, Henan University of Science and Technology; Steve Mangin, Magnesita

11:00 AM

(UNITECR-090-2013) Development of Alternative Solutions for Iron Ladle Refractory Lining

S. M. Justus*, V. P. Ramos, S. C. Frasson, D. Galesi, A. Bortolotti, M. Fadel, E. Sako, P. S. Delgado, L. Souza, J. Machado, M. Melo, C. F. Leao, D. Bomfim, G. Silva, C. Salsa, Saint Gobain, Brazil

11:20 AM

(UNITECR-091-2013) Insulation Board Investigation and Trials in 300 tonne Steel Ladles at ArcelorMittal Dofasco

V. Mazzetti Succi*, ArcelorMittal Dofasco, Canada

11:40 AM

(UNITECR-092-2013) Preparation of microporous corundum and its lightweight alumina-magnesia castable for ladle

H. Gu, A. Huang*, M. Zhang, State Key Lab Breeding Base of Refractories & Ceramics, Wuhan University of Science & Technology, China; B. Du, Zhejiang Zili Co., Ltd., China; Z. Li, Jiangsu Jingxing High-Temperature Materials Co., Ltd., China; Q. Wang, Zhejiang Zili Co., Ltd., China

12:00 PM

(UNITECR-093-2013) Steel Ladle Lining: A proven technique to achieve 3.0% productivity in transported volume while reducing refratory cost using a smart lining

L. C. Simao*, Unifrax, Brazil

12:20 PM

(UNITECR-094-2013) Troubleshooting in Steelmaking Areas including Steel Ladles with various Refractory Solutions

S. Bharati*, Tata Steel Limited,, India; S. Bose, Tata Steel Limited,, India; A. R. Pal, Tata Steel Limited,, India; B. Singh, Tata Steel Limited,, India

Advanced Testing of Refractories IV

Room: Oak Bay

Session Chairs: J. Willi, Sunset Refractory Services; Bob Fisher, Consultant / Nock & Son Co.

9:20 AM

(UNITECR-022-2013) Characterization Methods of Zirconia and the Impact of Stabilizing Agents on its Functionality

C. Bauer*, B. Rollinger, J. Pascual, G. Krumpel, O. Hoad, N. Rogers, RHI AG, Austria

9:40 AM

(UNITECR-023-2013) High Temperature Characteristics of Refractory Zirconia Crucibles used for Vacuum Induction Melting

A. Quadling*, L. J. Vandeperre, Imperial College, United Kingdom; P. Myers, Morgan Ceramics, Commercial Rd, United Kingdom; W. E. Lee, Imperial College, United Kingdom

10:00 AM

(UNITECR-024-2013) Influence of the Pore Shape on the Internal Friction Properties of Refractory Castables

N. Traon*, T. Tonnesen, R. Telle, RWTH Aachen University, Germany

10:20 AM

(UNITECR-025-2013) Development of a new spalling test method for bottom blowing tuyeres for BOFs

M. Kakihara*, Shinagawa Refractories, USA; H. Yoshioka, M. Hashimoto, K. Inoue, Shinagawa Refractories, Japan

10:40 AM

(UNITECR-026-2013) Current status and development of Chinese standards on refractory products

X. Peng*, Sinosteel Luoyang Instute of Refractories Research, China

Advanced Testing of Refractories V

Room: Oak Bay

Session Chairs: J. Willi, Sunset Refractory Services; Bob Fisher, Consultant / Nock & Son Co.

11:20 AM

(UNITECR-027-2013) Refractory industry suffers financial damages through imprecise test procedures for the determination of the CO-Resistance of refractory materials: Time to review ISO 12676 and ASTM C 288

O. Krause*, University of Applied Science, Germany; C. Dannert, Forschungsgemeinschaft Feuerfest e. V, Germany; L. Redecker, University of Koblenz-Landau, Germany

11:40 AM

(UNITECR-028-2013) Implementation of a standard test method for abrasion resistance of refractory materials for testing at elevated temperatures

R. Simmat*, C. Dannert, Forschungsgemeinschaft Feuerfest e.V., Germany; P. Quirmbach, DIFK Deutsches Institut für Feuerfest und Keramik GmbH, Germany; O. Krause, Hochschule Koblenz, Germany

12:00 PM

(UNITECR-029-2013) Studying the non-linear mechanical behavior of refractories thanks to digital image correlation

Y. Belrhiti*, GEMH ENSCI, France; A. Germaneau, P. Doumalin, J. Dupré, PRIME INSTITUTE, France; A. Alzina, O. Pop, M. Huger, GEMH ENSCI, France; T. Chotard, SPCTS UMR CNRS 70315, France

12:20 PM

(UNITECR-030-2013) Investigation on reliability of refractories via Weibull distribution

W. Yuan*, Q. Zhu, C. Deng, H. Zhu, Wuhan University of Science and Technology, China

Cement and Lime Refractories I

Room: Esquimalt

Session Chairs: Fielding Cloer, SPAR, Inc.; Christoph Woehrmeyer, Kerneos

9:20 AM

(UNITECR-031-2013) The Performance of High Quality Magnesia Raw Materials in Cement Applications

F. Goorman*, J. Visser, M. Ruer, Nedmag Industries, Netherlands; C. Aneziris, J. Ulbricht, Technical University Freiberg, Germany

9:40 AM

(UNITECR-032-2013) The processes of new phases formation in the Al2SiO5-ZrSiO4 refractory material during industrial test in cement kiln preheater

D. Madej*, J. Szczerba, AGH University of Science and Technology, Poland

10:00 AM

(UNITECR-033-2013) Development of an electrofused MgO-CaZrO3 Refractory with Addition of Hercynite for the Cement Industry

G. Castillo*, F. Davila, T. K. Das Roy, B. Krishnan, A. M. Guzman, S. Shaji, Universidad Autonoma de Nuevo Leon, Mexico

10:20 AM

(UNITECR-034-2013) Hybrid spinel technology for basic bricks in chemically highly loaded cement rotary kilns

G. Gelbmann*, S. Joerg, R. Krischanitz, RHI AG, Austria

10:40 AM

(UNITECR-035-2013) Influence of Andalusite Composition and Particle Size Distribution on Properties of Bauxite-Silicon carbide Brick

J. Ding, G. Ye*, Zhengzhou University, China; L. Yuan, X. Liu, J. Wang, H. Zhao, Ruitai Matetails Technology Co., Ltd., China

11:00 AM

Break

Raw Materials Developments and Global Raw Materials Issues II

Room: Esquimalt

Session Chairs: Shane Bower, Christy Minerals LLC; Philip Edwards, Imerys

11:20 AM

(UNITECR-190-2013) Studies on sintering behaviour and microstructural characteristics of Indian magnesite in presence of additive

M. K. Haldar*, CSIR-Central Glass & Ceramic Research Institute, India

11:40 AM

(UNITECR-191-2013) Preparation, thermal stability and oxidation resistance of Ca-α/β-sialon powders by reaction nitridation method

H. Zhang*, Y. Cao, S. Du, S. Zhang, Wuhan University of Science and Technology, China

12:00 PM

(UNITECR-192-2013) Effects of Fe2O3 and SiO2 on the MgAl2O4-SiC composite powders by forsterite, alumina and carbon black

H. Zhu*, H. Duan, W. Yuan, C. Deng, Wuhan University of Science and Technology, China

Raw Materials Developments and Global Raw Materials Issues I

Room: Sidney

Session Chairs: Shane Bower, Christy Minerals LLC; Philip Edwards, Imerys

9:20 AM

(UNITECR-186-2013) Raw materials for refractories: the European perspective

A. Volckaert*, PRE - European Federation of Refractories Producers, Belgium

9:40 AM

(UNITECR-187-2013) Andalusite, An under-utilized Refractory Raw Material with undeveloped High Potential

C. De Ferrari*, Andalucita S.A., Peru

10:00 AM

(UNITECR-188-2013) Refractory grade graphite: Seeking Chinese independence day

S. Moores*, Industrial Minerals, United Kingdom

10:20 AM

(UNITECR-189-2013) Phase transformation impact on the iron diffusion in olivine raw material refractory

R. Michel*, M. Ammar, P. Simon, J. Poirier, CNRS, France

10:40 AM

Break

Energy Savings Through Refractory Design I

Room: Sidney

Session Chairs: James Hemrick, Oak Ridge National Laboratory; Valeriy Martynenko, Ukrainian Research Institute of Refractories named after A.S. Berezhnoy

11:20 AM

(UNITECR-054-2013) Evaluation of thermal conductivity of refractory monolitihcs by various methods and the issues this raises

Z. Carden*, Vesuvius UK, United Kingdom; D. Bell, Foseco, United Kingdom; I. Whyman, A. J. Brewster, Vesuvius UK, United Kingdom

11:40 AM

(UNITECR-055-2013) Delevopment of a new Calcium Silicate Board with super insulating Properties

V. Krasselt*, J. Rank, Promat GmbH, Germany; A. Opsommer, X. Wu, Promat International, Belgium

12:00 PM

(UNITECR-056-2013) Nanoporous Refractory Insulatings: Solution or Illusion?

D. O. Vivaldini*, A. Mourão, V. R. Salvini, V. C. Pandolfelli, Federal University of São Carlos, Brazil

12:20 PM

(UNITECR-057-2013) Improvement of Thermal Efficiency in Iron/Steel Ladles

Y. M. Lee*, ArcelorMittal Steel, USA; S. Kumar, ArcelorMittal Burns Harbor, USA; L. Rebouillat, Pyrotek Inc, Canada

12:40 PM

(UNITECR-058-2013) Effects of Fe2O3 on properties of novel heat insulation materials synthesized by molten salt method

C. Deng*, J. Ding, W. Yuan, J. Li, H. Zhu, Wuhan University of Science and Technology, China

Nonoxide Refractory Systems

Room: Colwood

Session Chairs: Dave Derwin, Superior Graphite; Matt Lambert, Allied Mineral Products

9:20 AM

(UNITECR-174-2013) Compatibility between graphite as well as micropore carbon and synthetic PGM matte

B. Thethwayo*, A. M. Garbers-Craig, University of Pretoria, South Africa

9:40 AM

(UNITECR-175-2013) Nitride bonded Silicon Carbide refractories: Structure variations and corrosion resistance

A. Yurkov*, O. Danilova, A. Dovgal, Voljsky Abrasive Works, Russian Federation

10:00 AM

(UNITECR-177-2013) Structure evolution and oxidation resistance of pyrolytic carbon derived from Fe doped phenol resin

B. Zhu, X. Li*, Wuhan University of Science and Technology, China

Refractories for Chemical Processes

Room: Lecture Theatre

Session Chairs: James Bennett, National Energy Technology Laboratory; Mathias Rath, Rath AG

2:00 PM

(UNITECR-198-2013) Mechanisms of Wear Reduction in High Chrome Oxide Gasifier Refractories Containing Phosphate Additions Exposed to Coal Slag (Invited Speaker)

J. Bennett*, National Energy Technology Laboratory, USA; B. W. Riggs, Eastman Chemical Company, USA; K. Kwong, National Energy Technology Laboratory, USA

2:20 PM

(UNITECR-200-2013) Investigation of Y_2O_3-stabilized Zirconia Ramming Mix after Service in Carbon Black Reactor

V. V. Martynenko*, V. V. Primachenko, I. G. Shulik, E. B. Protsak, N. G. Pryvalova, Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine; V. I. Ivanovskiy, G. V. Babich, Omsk Carbon Black Plant, Russian Federation

2:40 PM

(UNITECR-201-2013) Spinel-Based Refractories for Improved Performance in Coal Gasification Environments

J. G. Hemrick*, B. Armstrong, Oak Ridge National Laboratory, USA; A. Rodrigues-Schroer, D. Colavito, MinTeq International, Inc., USA; J. Smith, K. O'Hara, Missouri University of Science and Technololgy., USA

3:00 PM

(UNITECR-202-2013) Chemical wear mechanisms observed in basic bricks removed from two high-carbon ferrochrome furnaces

A. M. Garbers-Craig*, University of Pretoria, South Africa

3:20 PM

(UNITECR-203-2013) Effects of Zirconia on the Thermal Shock Resistance of High Chrome Refractories for Coal Slurry Gasifier

Y. Li*, Luoyang Lier Refractories Co., Ltd., China; C. Ke, Wuhan University of Science and Technology, China; G. Ye, Zhengzhou University, China; S. Gao, Wuhan University of Science and Technology, China; J. Zhao, Luoyang Lier Refractories Co., Ltd., China

3:40 PM

Break

Iron & Steel Making Refractories - General Session I

Room: Lecture Theatre

Session Chair: Gary Hallum, CCPI; Yuechu Ma, Allied Mineral Products

4:40 PM

(UNITECR-120-2013) Development of new basic working lining for Ternium Siderar tundishes

S. Camelli*, M. L. Dignani, Instituto Argentino de Siderurgia, Argentina; M. Labadie, J. Mirabelli, Ternium Siderar, Argentina

5:00 PM

(UNITECR-121-2013) Andalusite applied in EAF roof castable

X. Xiong*, Z. Li, F. Hu, Z. Mu, DAMREC-IMERYS, France

Iron & Steel Making Refractories - BOF

Room: Saanich

Session Chair: Vanessa Mazzetti-Succi, ArcelorMittal Dofasco; Peter Quirmbach, University of Koblenz-Landau

2:00 PM

(UNITECR-080-2013) Improvement of the refractory lining concept and of the installation method of a BOF at voestalpine Linz

T. Schemmel*, H. Jansen, L. Schade, Refratechnik Steel GmbH, Germany; R. Exenberger, voestalpine Stahl GmbH, Austria

2:20 PM

(UNITECR-081-2013) *Post mortem* analysis of BOF tuyeres

S. K. Kubal*, Swansea University, United Kingdom

2:40 PM

(UNITECR-082-2013) Improvement of BOF bottom stirring at Ruukki, Raahe Steel Works

H. Pärkkä*, Ruukki Metals, Finland; T. Meriläinen, Ruukki Metals, Finland; J. Vatanen, Ruukki Metals, Finland; J. Kärjä, Ruukki Metals, Finland; P. Tuominen, Ruukki Metals, Finland

3:00 PM

(UNITECR-083-2013) Properties and performance of gunning and patching material of BOF converter at TATA STEEL

G. Ghosh*, A. Banerjee, B. Singh, S. Biswas, A. Pal, TATA STEEL, India

3:20 PM

(UNITECR-084-2013) Improvement of durability and tapping time of Sleeve by composition and shape control

K. Kim*, I. Bae, J. Lee, K. Lee, Poscochemtech, Republic of Korea

3:40 PM

Break

Iron & Steel Making Refractories - Blast Furnace and Troughs I

Room: Saanich

Session Chair: Mike Alexander, Riverside Refractories; Atsuya Kasai, Nippon Steel & Sumitomo Metal Corp.

4:20 PM

(UNITECR-071-2013) High performing Al2O3-SiC-C monolithic refractories releasing no hydrogen for blast furnace casthouse applications

N. Duvauchelle, J. Soudier*, CALDERYS, France

4:40 PM

(UNITECR-073-2013) Novel dry mix technology for tundish refractory lining

E. Y. Sako*, V. Ramos, S. C. Frasson, S. M. Justus, D. Galesi, L. M. Souza, A. Nascimento, C. F. Leão, M. T. Fadel, Saint-Gobain do Brasil Ltda, Brazil

5:00 PM

(UNITECR-074-2013) Hot Strength in Relation with Bonding System of SiC and Al2O3 Based Castables Incorporated with Silicon Powders after Nitridation

R. Yu*, H. Wang, N. Zhou, Q. Meng, Henan University of Science and Technology, China

5:20 PM

Break

Modelling and Simulation of Refractories II

Room: Oak Bay

Session Chairs: Bill Headrick, MORCO, USA; Harald Harmuth, Montanuniversitaet Leoben

2:20 PM

(UNITECR-140-2013) Simulation of the steel ladle preheating process

M. Drózd-Rys*, H. Harmuth, Montanuniversitaet Leoben, Austria; R. Rössler, voestalpine Stahl GmbH, Austria

2:40 PM

(UNITECR-141-2013) The Transient Drying and Heating of Refractory Concrete

G. Palmer*, T. Howes, Y. Ge, Palmer Technologies Pty Ltd, Australia

3:00 PM

(UNITECR-142-2013) Modeling of masonries using homogenization and submodeling methods

N. Gallienne*, Prisme Laboratory, France; M. Landreau, Centre de Pyrolyse de Marienau, France; E. Blond, A. Gasser, Prisme Laboratory, France; D. Isler, Centre de Pyrolyse de Marienau, France

3:20 PM

(UNITECR-143-2013) Modeling Cracking in Refractory Materials Due to Thermal Cycling

A. A. Pandhari*, P. V. Barr, D. M. Maijer, The University of British Columbia, Canada; S. Chiartano, TRB Refractories, France

3:40 PM

(UNITECR-144-2013) Influence of different masonry designs of bottom linings

A. Gasser*, L. Chen, J. Daniel, E. Blond, University of Orléans, France; K. Andreev, S. Sinnema, Tata Steel R&D, Netherlands

4:00 PM

Break

Modelling and Simulation of Refractories III

Room: Oak Bay

Session Chairs: Bill Headrick, MORCO, USA; Harald Harmuth, Montanuniversitaet Leoben

4:20 PM

(UNITECR-145-2013) The load-displacement curve of steady crack propagation: An interesting source of information for predicting the thermal shock damage of refractories

D. Y. Miyaji, C. Z. Otofuji, J. A. Rodrigues*, Universidade Federal de São Carlos, Brazil

4:40 PM

(UNITECR-146-2013) Adequacy check of refractory design by FE modeling

P. Saha*, P. Pal, B. Sarkar, P. P. Lahiri, Engineers India Limited, India

5:00 PM

(UNITECR-147-2013) Mathematical modeling on slag corrosion of lightweight corundum spinel castable for ladle

A. Huang*, H. Gu, Y. Zou, M. Zhang, State Key Lab Breeding Base of Refarctories & Ceramics, Wuhan University of Science & Technology, China

Cement and Lime Refractories II

Room: Esquimalt

Session Chairs: Fielding Cloer, SPAR, Inc.; Christoph Woehrmeyer, Kerneos

2:20 PM

(UNITECR-036-2013) A new type of basic castable for the cement industry

V. Wagner*, P. Malkmus, Calderys, Germany

2:40 PM

(UNITECR-037-2013) Magnesia-spinel refractories for rotary kiln burning 60% alternative fuels

M. Sulkowski*, L. Obszynska, C. Golawski, ArcelorMittal Refractories, Poland

3:00 PM

(UNITECR-038-2013) Development of Magnesia-Spinel Brick for the Transition Zone of Cement Rotary Kilns under the Vastly Increasing Use of Waste

M. Ohno*, H. Toda, K. Tokunaga, Y. Tsuchiya, Y. Mizuno, MINO CERAMIC CO.,LTD., Japan

3:20 PM

(UNITECR-039-2013) Dry and wet gunning: Technico-economic refractory concrete concepts for highly loaded cement plants

K. Beimdiek*, H. Klischat, Refratechnik Cement GmbH, Germany

3:40 PM

(UNITECR-040-2013) Achieving Higher Thermochemical Resistance by Installation of Magnesia Forsterite Bricks

H. Klischat*, H. Wirsing, Refratechnik Cement GmbH, Germany

4:00 PM

(UNITECR-041-2013) The effect of TiO2 on microstructure and properties of chrome-free basic brick

S. Ghanbarnezhad*, Azad University, Islamic Republic of Iran; A. Nemati, Sharif University of Technology, Islamic Republic of Iran; M. Bavand, Azad University, Islamic Republic of Iran; R. Naghizadeh, Iran University of Science and Technology, Islamic Republic of Iran

4:20 PM

Break

Iron & Steel Making Refractories - RH Snorkels

Room: Esquimalt

Session Chair: Carlos Pagliosa, Magnesita Refractories; Nathan Leicht, Shinagawa

4:40 PM

(UNITECR-104-2013) Theoretical and practical the temperature gradient of the refractory lining of the RH snorkel

Z. Czapka*, Zakłady Magnezytowe "ROPCZYCE" S.A., Poland, J. Szczerba, AGH University of Science and Technology, Poland; W. Zelik, Zaklady Magnezytowe "ROPCZYCE" S.A., Poland

5:00 PM

(UNITECR-105-2013) Development of degasser snorkel refractories and the effect of process parameters on wear rate

Y. Bi*, Tata Steel Europe, United Kingdom; I. A. Smith, Tata Steel Strip UK, United Kingdom; K. Andreev, Tata Steel Europe RD&T, Netherlands

5:20 PM

(UNITECR-106-2013) Development of High durability Hot Repair Spray and New Installation Method for the RH Snorkel

J. Lee*, C. Kim, D. Lee, B. Kim, POSCOCHEMTECH, Republic of Korea

Energy Savings Through Refractory Design II

Room: Sidney

Session Chairs: James Hemrick, Oak Ridge National Laboratory; Valeriy Martynenko, Ukrainian Research Institute of Refractories named after A.S. Berezhnoy

2:20 PM

(UNITECR-059-2013) Achievement of the reducing erosion for investigation of trough bottom angle in the semi pooling type main trough

H. Fujiwara*, NIPPON CRUCIBLE CO.,LTD., Japan

2:40 PM

(UNITECR-060-2013) New Insulating Lining Concepts Based on Calcium Hexaluminate

D. Zacherl*, Almatis Inc., USA; D. Schmidtmeier, A. Buhr, R. Kockegey-Lorenz, M. Schnabel, Almatis GmbH, Germany; J. Dutton, N/A, United Kingdom

3:00 PM

(UNITECR-061-2013) Energy saving in steel reheating furnaces of voestalpine (Austria) and ArcelorMittal (Germany) by a new concept for skid pipe insulation

M. Springer*, FBB Engineering GmbH, Germany; M. Gumpenberger, voestalpine, Austria; J. Heinlein, ArcelorMittal, Germany; A. Buhr, Almatis GmbH, Germany

3:20 PM

(UNITECR-062-2013) Energy savings of slab reheating furnaces by the improvement of refractories

M. Sato*, T. Takeuchi, K. Kohno, S. Akihiro, Nippon Steel & Sumitomo Metal Corporation, Japan

3:40 PM

(UNITECR-063-2013) Energy savings and improvement of productivity in continuous reheating furnaces

P. Tassot*, J. Fernau, H. Lemaistre, CALDERYS, Germany

4:00 PM

(UNITECR-064-2013) Novel generation of kiln furniture

U. Scheithauer*, K. Haderk, T. Moritz, M. Zins, A. Michaelis, Fraunhofer IKTS Dresden, Germany

4:20 PM

Break

Iron & Steel Making Refractories - General Session II

Room: Sidney

Session Chair: Jacques Poirier, University of Orleans - CNRS; Dilip Jain, Kyanite Mining

4:40 PM

(UNITECR-123-2013) Application and Development of Top Combustion Style HBS in China

D. Hongqin*, S. Gengchen, L. Fuchao, L. Jiantao, zhenzhou Annec Industrial Co., Ltd, China

5:00 PM

(UNITECR-124-2013) Development of active and reactive carbon-bonded filters for steel melt filtration

M. Emmel*, C. G. Aneziris, Technical University of Freiberg, Germany

5:20 PM

(UNITECR-125-2013) Influence of composition and processing on the microstructure of carbon bonded Al2O3-C filter materials and their behavior at high temperatures

Y. Klemm, H. Biermann, C. Aneziris*, TU Bergakademie Freiberg, Germany

Petrochemical

Room: Colwood

Session Chairs: Don McIntyre, ANH Refractories Co., USA; Ken Moody, Refractory System Solutions

2:20 PM

(UNITECR-179-2013) Engineered refractory castables with improved thermal shock resistance

A. Luz*, T. Santos Jr., Federal University of São Carlos, Brazil; J. Medeiros, Petrobras, Brazil; V. C. Pandolfelli, Federal University of São Carlos, Brazil

2:40 PM

(UNITECR-180-2013) Deterioration of Refractory Ceramic fibre lining in an Ethylene Cracking Furnace: A case study

M. K. Maity*, E. Al-Zahrani, Saudi Basic Industries Corporation, Saudi Arabia; M. Al-Thomali, M. Abdul Kareem, Eastern Petrochemical Company, Saudi Arabia

3:00 PM

(UNITECR-181-2013) The coke effect on the fracture energy of a refractory castable for petrochemical industry

D. Y. Miyaji, C. Z. Otofuji, M. D. Cabrelon, Universidade Federal de São Carlos, Brazil; J. Medeiros, Petrobrás - Petróleo Brasileiro S/A, Brazil; J. A. Rodrigues*, Universidade Federal de São Carlos, Brazil

3:20 PM

(UNITECR-182-2013) Avoid Cosmetic Repair of Refractory Lining in Critical Equipments

E. S. Al-zahrani*, M. M. Maity, SABIC, Saudi Arabia

3:40 PM

(UNITECR-184-2013) Sintering additive role on the performance of advanced refractory castables

A. Luz*, T. Santos Jr., Federal University of São Carlos, Brazil; J. Medeiros, Petrobras, Brazil; V. C. Pandolfelli, Federal University of São Carlos, Brazil

Friday, September 13, 2013

Plenary Session II

Room: Lecture Theatre

Session Chair: Dana Goski, Allied Mineral Products

8:00 AM

(UNITECR-003-2013) Trends for the World's Most Important, but least known Products

C. Semler*, Semler Materials Services, USA

Iron & Steel Making Refractories - Spinel Castables

Room: Lecture Theatre

Session Chair: Arnaud Lafaurie, ALTEO; Carl Zetterstrom, Kerneos

9:20 AM

(UNITECR-107-2013) Thermal shock resistance of alumina and alumina-rich spinel refractories using the decomposition of aluminum titanate

K. Moritz*, S. Dudczig, C. G. Aneziris, Technische Universität Bergakademie Freiberg, Germany

9:40 AM

(UNITECR-109-2013) Development of Alumina Magnesia Non-Cement Castable for Steel Ladle

M. Nishimura*, S. Nishida, H. Sasaki, M. Namba, Shinagawa Refractories Co,.Ltd., Japan

10:00 AM

(UNITECR-110-2013) Characteristics and Design of Spinel-containing Castables for Steel Ladle

R. Kim*, S. Lee, S. Jung, S. Lee, Korea Refractories Co. LTD, Republic of Korea

10:20 AM

(UNITECR-108-2013) Expansion under Constraint and its Effect on High-alumina Spinel-forming Refractory Castables

M. Braulio*, E. Sako, V. Pandolfelli, Federal University of Sao Carlos, Brazil

Monolithics VI

Room: Saanich

Session Chair: Randy Mauzy, Aluchem; Ted Huang, Allied Mineral Products

9:20 AM

(UNITECR-170-2013) Development of Light Weight Al2O3-CaO-MgO Castables Using Micro-pored CA6-MA Aggregates

C. Li, Y. Bi*, N. Zhou, Henan University of Science and Technology, China

9:40 AM

(UNITECR-171-2013) Effect of process parameters on phase growth in high purity alumina cements

S. Sengupta, T. K. Roy, N. Ramasubramanian*, CUMI Super Refractories, India

10:00 AM

Break

Refractories for Nonferrous Metallurgy II

Room: Oak Bay

Session Chairs: Rick Volk, United Refractories Co.; Angela Rodrigues-Schroer, Wahl Refractory Solutions

9:20 AM

(UNITECR-211-2013) Molten Aluminum Long-Distance Transportation: A Refractory Issue

M. Braulio*, D. Oliveira, Federal University of Sao Carlos, Brazil; J. Gallo, Alcoa, Brazil; V. Pandolfelli, Federal University of Sao Carlos, Brazil

9:40 AM

(UNITECR-212-2013) Chromium-Free Spinel Bonded Castables versus Rebonded Fused Grain Basic Bricks

G. Oprea*, H. Zargar, C. Oprea, R. Lodha, T. Troczynski, University of British Columbia, Canada; D. Verhelst, Teck Metals Ltd., Canada

10:00 AM

(UNITECR-213-2013) Development and Application of Improved Shotctrete Refractory for Aluminum Rotary Furnace Applications

J. G. Hemrick*, Oak Ridge National Laboratory, USA; A. Rodrigues-Schroer, D. Colavito, MinTeq International, Inc., USA; J. Smith, K. O'Hara, Missouri University of Science and Technololgy., USA

10:20 AM

(UNITECR-214-2013) Phosphate bonded monolithic refractory materials with improved mechanical and chemical resistance for applications in the aluminum industry

J. Decker*, Stellar Materials, USA

10:40 AM

(UNITECR-215-2013) Advances in No Cement Colloidal Silica Bonded Monolithic Refractories for Aluminum and Magnesium Applications

M. W. Anderson*, L. A. Hrenak, D. A. Snyder, Magneco/Metrel, Inc., USA

11:00 AM

(UNITECR-216-2013) Functional Coatings on Reticulated Porous Foam Ceramics made of Alumina for Aluminum Filtration

C. Voigt*, C. G. Aneziris, TU Bergakademie Freiberg, Germany

Raw Materials Developments and Global Raw Materials Issues III

Room: Esquimalt

Session Chairs: Shane Bower, Christy Minerals LLC; Bill Peschler, Minerals Technologies

9:20 AM

(UNITECR-194-2013) Development and Application of Bauxite-based Homogenized Grogs

T. Ge*, X. Zhong, Zhengzhou University, China; L. Wang, J. An, Yangquan JInyu Tongda High-temperature Materials Co., Ltd., China

9:40 AM

(UNITECR-196-2013) Influence of additives on phase transformation and morphology

L. Zhu*, G. Ye, A. Fu, S. Li, C. Yao, X. Song, Zhengzhou University, China

10:00 AM

(UNITECR-197-2013) Synthesis of High Purity Forsterite and Its Use in Magnesia Based Castable

N. Zhou*, L. Guo, Henan University of Science and Technology, China; H. Bai, Yanshi Zhongyue Refractories Co., Ltd, China

Global Education in Refractories I

Room: Sidney

Session Chairs: George Oprea, University of British Columbia; Yawei Li, Wuhan University of Science & Technology

9:20 AM

(UNITECR-065-2013) Enhancing Technology Transfer Capabilities: A German Perspective

A. Geigenmüller*, Ilmenau University of Technology, Germany

9:40 AM

(UNITECR-066-2013) Koblenz University of Applied Science, Department of Materials Engineering, Glass and Ceramics playing a key role in the science and education network for the refractory industry

O. Krause*, Koblenz University of Applied Sciences, Germany; P. Quirmbach, University of Koblenz-Landau, Germany

10:00 AM

(UNITECR-067-2013) Integrating education concepts: The Koblenz region offers a one-of-a-kind infrastructure to identify and qualify future specialists in order to ensure reliable and continuous provision of best-skilled employees to the Refractory Industry

P. Quirmbach*, University of Koblenz-Landau, Germany; O. Krause, University of Applied Science, Germany

10:20 AM

(UNITECR-068-2013) Graduate Programs in Refractory Engineering: What is duly needed?

M. Rigaud*, École Polytechnique, Canada

10:40 AM

Break

Iron & Steel Making Refractories- General Session III

Room: Colwood

Session Chair: Brian Kenyon, Vesuvius; Yong Lee, ArcelorMittal Research

9:20 AM

(UNITECR-126-2013) Refractory response for pig iron refining with KR-process

P. Tassot*, CALDERYS, Germany; J. Wang, CALDERYS TAIWAN, Taiwan; H. Lemaistre, CALDERYS, France

9:40 AM

(UNITECR-127-2013) Improvement of Refractory Castables for KR Desulphurization Impeller

S. Yeh*, C. Chen, W. Lin, H. Chen, Good Furnace Refractory Industrial Co., Ltd, Taiwan

10:00 AM

(UNITECR-128-2013) Study on Ladle Purging Plug with Gradient Composite Structure and Material

H. Zhang*, T. Yu, W. Yang, L. Chen, Luoyang Institute of Refractories Research, China; W. Yang, State Key Laboratory of Advanced Refractories, China

10:20 AM

(UNITECR-129-2013) Benchmarking of CAS-OB Refractory Bells

K. Subramaniam*, A. Kremer, GSB Group GmbH, Germany

10:40 AM

(UNITECR-130-2013) Effects of B4C Addition on High Temperature Properties of Al/Si Incorporated Low Carbon Al2O3-C Slide Plate Materials

X. Liu*, High Temperature Ceramics Institute, China; Y. Wang, Puyang Refractories Group Co.,Ltd., China; X. Zhong, High Temperature Ceramics Institute, China

11:00 AM

(UNITECR-131-2013) Improvement of the durability on SG Plate for steel ladle

Z. Ohmaru*, K. Akamine, K. Morikawa, J. Yoshitomi, Krosaki Harima Corporation, Japan

Iron & Steel Making Refractories - Blast Furnace and Troughs II

Room: Lecture Theatre

Session Chair: Mike Alexander, Riverside Refractories; Andus Buhr, Almatis

11:20 AM

(UNITECR-075-2013) Innovative Graphitic Castable Utilized as a Repair Material for Carbonaceous Refractory Systems

F. Van Laar*, Y. Ma, Allied Mineral Products, Inc., USA; A. Petruccelli, Allied Mineral Technical Services, Inc., USA

11:40 AM

(UNITECR-076-2013) Challenges to Improving the Environmental and Health Safety Characteristics of Tap Hole Clay

J. Stendera*, R. Hershey, G. Biever, Vesuvius, USA

12:00 PM

(UNITECR-078-2013) Invention Reaction Bonded Alumina bricks for BF Ceramic Cup

Y. Hong*, Chosun Refractories.,Co.Ltd, Republic of Korea

12:20 PM

(UNITECR-079-2013) Development and Application of Taphole Mud for 5800 m3 Large Scale Blast Furnace

P. Chen*, N. Lin, T. Lin, Sunward Refractories Co., Ltd., Taiwan

Iron & Steel Making Refractories - General Session IV

Room: Saanich

Session Chair: Vanessa Mazzetti-Succi, ArcelorMittal Dofasco; Rakesh Dhaka, US Steel

11:20 AM

(UNITECR-132-2013) Development of the monolithic refractory using spent refractories

N. Koji*, KOBE STEEL,LTD., Japan

11:40 AM

(UNITECR-133-2013) Strengthening mechanism of graphene oxide nanosheets for Al2O3-C refractories

Y. Li*, S. Sang, M. Luo, T. Zhu, Q. Wang, Wuhan University of Science and Technology, China

Safety, Environmental Issues and Recycling Solutions for Refractories

Room: Oak Bay

Session Chairs: Jason Canon, The Christy Refractories Co. LLC; Leonardo Curimbaba, US Electrofused Minerals/Electroabrasives LLC

11:20 AM

(UNITECR-222-2013) Analysis of Chemical Valence of Chromium in Magnesia-Chrome Bricks Used in Different High-temperature Furnaces

C. Yao, G. Ye*, X. Yang, Y. Mu, L. Chen, Zhengzhou University, China

11:40 AM

(UNITECR-223-2013) The issue of usage of refractory materials scrap

A. Kielski, ArcelorMittal Refractories, Poland; P. Wyszomirski, AGH University of Science and Technology, Poland; P. Blumenfeld, ArcelorMittal Fos-sur-Mer, France; L. Obszynska*, M. Sulkowski, ArcelorMittal Refractories, Poland

12:00 PM

(UNITECR-224-2013) Is there a viable alternative fiber to RCF?

S. Chernack*, Morgan Thermal Ceramics, USA

12:20 PM

(UNITECR-225-2013) An Attempt Towards the Development and Successful use of Eco Friendly Basic Refractory Product

P. Sengupta*, N. Gupta, S. Mondal, S. Mondal, SKG Refractories Ltd, India

Global Education in Refractories II and Facilitated Discussion on Global Education in Refractories

Room: Sidney

Session Chairs: George Oprea, University of British Columbia; Yawei Li, Wuhan University of Science & Technology

11:20 AM

(UNITECR-069-2013) Promoting Natural Science and Engineering at Freiberg University: Some outstanding tools and results

K. Haeussler*, TU Bergakademie Freiberg, Germany

11:40 AM

(UNITECR-070-2013) Visualizing the Invisible: How to Attract Students to Refractory Engineering

A. Geigenmüller*, S. Lohmann, Ilmenau University of Technology, Germany

12:00 PM

Facilitated Discussion on Global Education in Refractories

Wednesday, September 11, 2013

Opening Ceremony and Keynote Speaker

Room: Lecture Theatre
Session Chair: Dana Goski, Allied Mineral Products

9:00 AM

(UNITECR-001-2013) Minerals to Materials: The changing face of the global refractory industry

R. de Jong*, IMERYS, France

Not available

Monolithics I

Room: Lecture Theatre
Session Chairs: Dale Zacherl, Almatis Inc.; Goutam Bhattacharya, Kerneos, India

10:40 AM

(UNITECR-148-2013) Next generation alumina binder for cement-free castables

C. Tontrup, Evonik Industries AG, Germany; V. Lifton*, Evonik Degussa Corp., USA; T. von Rymon Lipinski, Institute of Applied Technology, Germany

Since some years cement-and silica-free castables find increasing interest in the academic research as well as industry. For the first time a castable bonded with a negatively charged, citric acid stabilized nano-structured alumina binder was presented by Lipinski et al. at Unitecr 2009. This binder found meanwhile its way into industrial application. The present work deals with the development of an improved second generation of that binder. Major scope was to preserve the benefits such as high solids content and long-term stability and improve the high temperature properties of the castable. First part of the study deals with the development and physico-chemical characterization of a new nano-structured alumina binder such as particle size distribution, zeta potential and impurity content. In the second part, alumina castables with and without microsilica were prepared using the new binder. It was possible to show that the new binder can significantly improve the hot properties (for instance hot crushing strength at 1400°C was increased by about 40% compared to the first generation). The improvement was majorly attributed to the reduced sodium content of the binder.

11:00 AM

(UNITECR-149-2013) Non-cement castable for blast furnaces troughs

A. Kusunoki*, K. Haraguchi, Y. Eguchi, KROSAKI HARIMA CORPORATION, Japan

The refractory castable for blast furnaces troughs has mainly two requirements. One is corrosion resistance, and the castable is widely used with ultra-low cement because it inhibits making low-melting liquid phase leading to the reduction of corrosion resistance. The other is drying explosion resistance due to the thickness of casting materials. As colloidal silica bonded castable doesn't contain calcium alumina cement, it has high corrosion resistance. It also has good drying ability because it doesn't make hydrogen phases. Although the castable has these advantages, it has disadvantages for crack during curing process because of shrinkage of sol-gel bond. In the case of deep cracks in the materials, the performance might become worse due to its delamination. Nevertheless there are few studies to consider suppressing cracks so far. This study details the development of colloidal silica bonded castable with minimize cracks due to shrinkage and high performance.

11:20 AM

(UNITECR-150-2013) No-Cement Alumina - Magnesia Castables

Y. Ohba*, Taiko Refractories Co., Ltd, Japan

High temperature properties of no-cement alumina - magnesia castables were investigated. The corrosion resistance of a ρ alumina bonded castables was higher than that of an alumina cement bonded castables. The high corrosion resistance was obtained by not using the alumina cement. On the other hand, the hot - modulus of rupture of the ρ alumina bonded castables with silica fume was almost same as that of general alumina cement bonded castables. We investigated the other binder systems with superior high temperature properties.

Iron & Steel Making Refractories - Coke Ovens

Room: Saanich
Session Chair: Gary West, Suncoke Energy; Thomas Schemmel, Refratechnik Steel GmbH

10:40 AM

(UNITECR-085-2013) Influence of thermal expansion behavior on adhesive strength of silica mortar

A. Kasai*, Sumitomo Metal Industries, LTD, Japan

Refractory mortar, which is used to connect refractory bricks, is a kind of monolithic refractory. It is important that thermal expansion curves of mortar resemble brick, because mortar will be separated from brick after being heated if these are not similar. It is well-known that silica brick's thermal expansion curve is very peculiar, so the authors are interested in the relation between silica mortar's thermal expansion behavior and adhesive strength. For 5 mortars, the thermal expansion curve was measured, and qualitative analysis by XRD and adhesive strength between silica mortar and bricks at room temperature and after being heated at 1200 or 1400 degrees centigrade for 3 hours was carried out. From these results, adhesive strength of the silica mortar, whose tridymite content was higher than other mortars, was the strongest after being heated. Thermal expansion curve of this mortar was different from silica brick's curve during heating, but it became similar to silica brick after being heated. Meanwhile the thermal expansion curve of the silica mortars whose tridymite content were low did not completely change into silica bricks after being heated. And the adhesive strengths of these mortars were weaker than the tridymite-rich silica mortar. So we concluded that it is important that expansion curve of silica mortar becomes similar to silica brick during heating for increased adhesive strength.

11:00 AM

(UNITECR-087-2013) Physical Properties of Used Bricks for Coke Oven

S. Hosohara*, H. Matsunaga, Y. Fukushima, JFE Steel Corporation, Japan

In Japan, many coke ovens were built from the middle of 1960 to late in 1970. Some ovens are working for 40 years or more. The reason why the silica brick is used for the coke oven is that the dimensional change in high temperature is small. As for the silica brick used under high temperature for a long time, the structure and physical properties are changing. The silica bricks of the coke oven which passed after construction for 44 years were investigated. The silica bricks sampled from the wall of the coke oven. Change of the structure of bricks and change of physical properties were investigated. Comparing these change by the carbonization side and combustion side was investigated. The phase of used brick was tridymite mainly. Moreover, compressive strength of used brick was increasing compared with that of new one.

11:20 AM

(UNITECR-088-2013) Evaluation of coke oven regenerator checkers after 40 years in service

M. Rimoldi*, S. Camelli, Instituto Argentino de Siderurgia, Argentina; D. Beltran, M. Labadie, Ternium Siderar, Argentina

The regenerators are located from pusher side to coke side under the cove oven chambers and the heating walls. The checker bricks form the regenerator packing above the sole flues. The majority of the checker bricks are manufactured from low alumina fireclay, but at higher temperature regenerator zones the upper four layers are manufactured from 40% alumina fireclay. In the case of Ternium Siderar coke oven battery #3, the first six layers of the regenerators from the oven sole were formed of three different fireclay checkers. After 40 years of operation, some of the regenerators were dismantled. The checkers of the first layer from the air and gas chamber presented different aspect, such as color and dimensional changes. In this way, it was performed a post mortem study to determine the causes of the different checker behaviors between chambers. The post mortem study included determination of the chemical and mineralogical composition, bulk density and apparent porosity and microstructure analysis by optical and electronic microscopy (SEM and EDS analyses).

11:40 AM

(UNITECR-089-2013) Development of zero expansion silica bricks for hot repair of coke oven

B. Prasad*, B. K. Panda, S. P. Das, J. Tiwari, N. Sahoo, OCL India Ltd, India

Conventional dense silica bricks are extensively used for refractory lining of coke oven walls. These bricks are made from quartzite & the finished brick contents mostly tridymite & cristobalite phases which are so called stable phases at the operating temperature of coke oven. However, these bricks are prone to crack at oven ends due to frequent opening of oven doors at both ends of coke ovens. To counter this problem, Zero Expansion silica brick is developed which is most suitable for hot repair of Coke ovens. These bricks are manufactured from amorphous silica having low Permanent linear change & low reversible thermal expansion & results very low volume expansion when undergoes sudden temperature change during hot repair. Thus prevents crack formation. This paper focuses on development of zero expansion silica bricks keeping special focus on selection of raw material, its granulometry & firing technique. Advantage & performance of these bricks have been highlighted with respect to use in actual practice for repair of coke ovens.

Advanced Testing of Refractories I

Room: Oak Bay

Session Chairs: Len Kreitz, Plibrico Co., LLC; Nigel Longshaw, Ceram Research Ltd.

10:40 AM

(UNITECR-009-2013) Thermo-mechanical characterisation of magnesia-carbon refractories by means of wedge splitting test under controlled atmosphere at high-temperature

E. Brochen*, C. Dannert, Forschungsgemeinschaft Feuerfest e.V., Germany; P. Quirmbach, DIFK Deutsches Institut für Feuerfest und Keramik GmbH, Germany

Due to their intrinsic properties and performance, Magnesia-Carbon refractories (MgO-C) are nowadays a key component of steel production. Especially the carbon bond/fraction accounts for their outstanding resistance to corrosion and thermal stress. However, this carbon fraction is also responsible for difficulties during testing the materials properties at typical service temperature (up to 1750 °C), which are nonetheless relevant and necessary for a sound performance evaluation. In presence of oxygen and at elevated temperature during testing, the carbon present in the matrix burns off, leaving behind a MgO skeleton with only minimal ceramic bond which is not representative for the complete MgO-C material. With a new testing system that operates under controlled atmosphere, wedge splitting tests according to Tschegg were successfully carried out to measure the fracture mechanical characteristics determine the nominal tensile strength and the specific fracture energy of MgO-C refractories at high temperature. The testing system is introduced and results from high-temperature wedge splitting tests of MgO-C specimens are shown and discussed.

11:00 AM

(UNITECR-010-2013) Characterization of magnesia and magnesia-chromite bricks by the use of different destructive and nondestructive testing methods

A. Ressler*, R. Neuboeck, C. Manhart, RHI AG, Austria

Magnesia and magnesia-chromite refractory bricks have a wide field of applications in the steel and non ferrous metal industry. Due to the use of these bricks in the highest wear areas, they are characterized by high refractoriness and good resistance to slag corrosion. For quality management purpose the physical properties (e.g. density, open porosity, cold crushing strength), which are measured at room temperature, are determined at high frequency. This characterization do not really allow conclusions to the behavior at applications temperature (1200°C up to 1750°C). Especially the characterization at operation conditions give a better understanding on wear resistance. Properties, which have a high impact on in-service performance, like thermal shock resistance, modulus of elasticity, hot modulus of rupture, wetting angle by slag and metals, are investigated in detail. The measurement methods are compared for specific magnesia and magnesia-chromite brick qualities. The correlation of all the tested destructive and non destructive properties at room and different application temperatures, helps to select the best lining concept for the different applications.

11:20 AM

(UNITECR-011-2013) The influence of in-sute formation spinel on the fracture energy of alumina-magnesia refractory castables

H. Qin*, University of Science and Technology Beijing, China; H. Li, Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China; J. Wang, University of Science and Technology Beijing, China; G. Liu, W. Yang, Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China; L. Xu, University of Science and Technology Beijing, China

The specific fracture energy is a important parameter in studying the non-linear fracture mechanics. The well known wedge splitting test (WST) method is used to test the fracture energy at 1100oC in this paper. The result is used for predicting the thermal shock resistance of the refractory castables. This study focused on an evaluation of several characteristics of four refractory castables with similar chemical compositions but with different materials component,. The results show that, the content of in-sute formation spinel added to the castables has a significant influence on the matrix/aggregate interaction, to form different microstructure in the castables, which caused the maximum load and fracture energy of the refractory castables have the same changing trend, increasing first and decresing afterward. It also proves by the experiment that the thermal shock resistance of the castables shows the opposite trends with fracture energy. However, a relationship between the thermal shock resistance and the specific fracture energy was noted.

Developments in Basic Refractories I

Room: Esquimalt
Session Chairs: Dominick Colavito, MINTEQ International Inc.; Andrie Garbers-Craig, University of Pretoria

10:40 AM

(UNITECR-042-2013) Reactant Particle Size Effects on Spinel Expansion

F. Cunha-Duncan, R. C. Bradt*, The University of Alabama, USA

When magnesia and alumina powders react to form the magnesium aluminate spinel there is a volume expansion because of the density differences of the structures. This expansion occurs for the reaction of single crystals and for powder reactions. The same occurs when the two reactants combine to form the spinel in-situ within a refractory structure such as A-M-C refractories. This expansion has been observed under many different circumstances and for many different applications. This paper reports experiments which address the changes in the amount of expansion for different particle size combinations of pure alumina and pure magnesia powders. It compares those expansions with the theoretical values and relates it to the particle sizes of the powders.

11:00 AM

(UNITECR-043-2013) Thermal Properties in the $MgAl_2O_4$-Al_2O_3 System

K. R. Wilkerson*, J. D. Smith, Missouri University of Science and Technology, USA; J. G. Hemrick, Oak Ridge National Laboratory, USA

Compositional effects on the thermal diffusivity in the $MgAl_2O_4$-Al_2O_3 system were studied. The lowest thermal diffusivity, 0.0258±5% cm/s, was measured between 79.8 and 83.9 wt% Al_2O_3 quenched from various temperatures between 1500°C and 1700°C. All of the chemistries in this range extend past the solvus, but still form a single phase super-saturated spinel solid solution, regardless of quenching temperature. A super-saturated metastable solid solution region was observed at 1500, 1600, and 1700°C extending to 83.9, 85.2, and 87.1 wt% Al_2O_3, respectively. Beyond 83.9 wt% Al_2O_3 a significant increase in the thermal diffusivity, 11.7%, was observed and is attributed to precipitation of Al_2O_3 through spinodal decomposition.

11:20 AM

(UNITECR-044-2013) Development of MgO-C NanoTech.Refractories aimed at 0% Graphite content

S. Tamura*, T. Ochiai, S. Takanaga, Nanotech.Refractories Institute, Japan; O. Matsuura, H. Yasumitsu, M. Hirashima, Kyushu Refractories Co.,Ltd., Japan

MgO-C refractories with graphite are widely used in the high temperature refining process. Although higher thermal conductivity of MgO-C refractories was equipped by increasing the content of graphite to improve the thermal shock resistance moreover, the problems are that the thermal energy is lost, the emission of environmentally hazardous CO2 increases and the deformation of the vessel steel shell arises from temperature up. In addition graphite resources are unevenly distributed on earth and have the exhaustible problem. Consequentially thermal shock resistant MgO-C NanoTech.Refractories with energy saving and excellent corrosion resistance are targeted under the condition of reducing graphite content remarkably. In this study MgO-C NanoTech.Refractories without graphite was aimed at and finally has been developed by microstructural control around the interface of MgO grains in applying carbon nano particles, and by sintering behavior control in applying nano particles of hybrid graphite blacks.

11:40 AM

(UNITECR-227-2013) Influence of Solid-Solution Formation on the Solid-State Sintering of MgCr2O4 Spinel

H. Zargar*, G. Oprea, T. Troczynski, University of British Columbia, Canada

The MgCr2O4 spinel (MCS) has a poor sinterability and it is attributed to the oxidation of Cr+3 to Cr+4 and Cr+6, where Cr+3 is the most stable form of chromium and has a major roll during sintering. The objective of this study was to reduce the sintering temperature of MCS by stabilizing chromium in +3 oxidation state through incorporating it into a solid-solution. A series of the sintering studies was performed to elucidate the effect of solid-solution formation on the sinterability of MCS. The experimental compositions contained MCS and tetravalent oxides, trivalent oxides and combinations of them. For comparison purposes, oxide nano-powders were also used, in order to improve the sintering process at low temperatures. The results showed that the solid-solution formation enhanced the densification of MCS at temperatures lower than 1500°C, in comparison with compositions without sintering additives, although the densities were less than 65% of the theoretical density of the experimental compositions, implying the inefficiency of solid-solubility mechanism for sintering of MCS. The nano-sintering additives accelerated the solid-solution formation, but their effect on the final density was negligible. It was concluded that the sintering atmosphere is the controlling parameter in the densification process of MCS and could affect also the performances of sintering additives.

Advanced Installation Techniques and Equipment

Room: Sidney
Session Chairs: James Stendera, Vesuvius R&D Center; Hirohide Okuno, Taiko Refractories Co. Ltd.

10:40 AM

(UNITECR-004-2013) Development of Automatic Repair Technology by Continuous and Quick Mixing Technology

Y. Furuta*, H. Itoh, K. Seki, J. Tsukuda, Krosaki Harima, Japan; S. Nakai, NS engineering, Japan; S. Hanagiri, Nippon Steel & Sumitomo Metal, Japan; T. Uchida, S. Itoh, Nippon Steel & Sumitomo Metal, Japan; S. Asoh, Nippon Steel & Sumitomo Metal, Japan

Conventional wet gunning systems were not enough as durability of the gunning body by addition water increase in quantity to do pumping. Gunning repair technology by continuous and quick mixing without the need for pumping, into a low water content is possible newly developed. As a result, this system could get an execution gunning body of the quality superior to the wet gunning execution. In addition, the washing after the execution is convenience at the same level as dry gunning. Report on the development status and life circumstances of this system.

11:00 AM

(UNITECR-005-2013) Gunning Robots for the hot repair

C. Wolf*, Velco GmbH, Germany

For many years the gunning procedure is used for the repair of refractory linings. Depending on the case of application and the gunning capacity different kinds and sizes of gunning machines are utilized. In combination with a gunning manipulator furnaces, tundishes or ladles can be repaired in hot condition. The advantages of the hot repair are : higher gunning rates, giving shorter repair times. Higher quality of application. Less physical strain on the operators. This paper will give an overview in different designs of gunning robots and the use at different customers.

11:20 AM

(UNITECR-006-2013) Tapholes repair on CSN's Blast Furnace 3: Core & Cast and Core & Plug

P. C. da Silveira Sousa*, Companhia Siderúrgica Nacional, Brazil; T. Talaat, TRE Services, USA; T. I. Souza, A. L. Saraiva Junior, E. S. Neves, P. R. de Oliveira Cordeiro, E. G. Fernandes, Companhia Siderúrgica Nacional, Brazil

The main purpose of this work is present the repair carried out in tap holes areas at CSN's Blast Furnace 3 to preserve the hearth wall and ensure the campaign until 2021 according to original project. In 2001 the Blast Furnace 3 was relined and installed a new hearth, but in 2008, CSN verified high temperatures and degradation signs in the carbon blocks at tap holes area. The evaluation of tap holes condition was done in partnership with TRE Services trough core drilling the adjacent areas. According to core drilling results, was proposed the repair method named Core & Cast and Core & Plug. The concept of Core & Cast is drill with a core bit. This is a temporary repair that preserve the refractory around the tap holes. The concept of Core & Plug is the same as Core & Cast but deeper, and after remove the damage refractory are installed several micropore carbon plugs interconnected to restore the refractory wall inside the shell at tap hole and hearth area. The repair were carried out in two steps, the first being in October 2008 with Core & Cast in Tap Holes 1 and 4, and Core & Plug in Tap Holes 2 and 3. The second step was in August 2009 with Core & Plug in Tap Holes 1, 3 and 4. The tap holes performance has been as expected. After Core & Plug repairs the tap holes reached an average of 30 months of operation without general repairs and every 8 months is done a partial repair.

11:40 AM

(UNITECR-007-2013) The Next Generation of Monolithic Application Technology: Continuous Mixing of Low Cement Castables for Wet Shotcreting

J. Pelletier*, C. Alt, Kerneos, Inc., USA; C. Parr, Kerneos SA, France; J. Farrell, T. Farrell, Blastcrete Equipment Company, USA

Lengthy mixing times, when extrapolated over the full volume of material to be installed, can contribute significantly to the overall timeline of a refractory installation. By reducing or eliminating residence time inside the mixer, overall installation time can be reduced. One method of reducing mixing time on the jobsite is to simply add more water. However, this apparent time-saving convenience comes at the expense of installed properties. This paper will examine the use of new technology – a two-stage continuous mixer. In the first stage, this equipment pairs a high-shear colloidal type continuous mixer with advanced water-metering technology to ensure properly-mixed low cement castables with little or no residence time. The second stage is a more passive mixing phase for additional homogenized blending just prior to placement. Commercially available refractory castables based on high-quality calcium aluminate cement are prepared two ways: (1) in a traditional batch mixer and (2) in the new continuous mixer. When the castables' physical properties are compared, the results show that material of comparable quality and performance can be produced on a continuous basis at a feed rate up to 25 t(short)/h. By providing material in an as-needed manner, significant cost savings can be realized in several aspects of the refractory installation.

12:00 PM

(UNITECR-008-2013) Development of Continuous Quick Mixing & Repairing Technology

S. Itoh*, S. Hanagiri, T. Uchida, H. Takeuchi, H. Nakamura, S. Asoh, Nippon Steel & Sumitomo Metal, Japan; H. Itoh, Y. Furuta, K. Seki, J. Tsukuda, Krosaki Harima, Japan; S. Nakai, NS engineering, Japan

Conventional repairing technology is that the dry powder conveyed by the air flow is mixing with added water in the gun nozzle, and gunned for refractories. Therefore, the dry powder is not mixed with water sufficiently, the gunning body becomes uneven, and there is a problem of poor durability. This time, a new, continuous quick mixing and repairing technology (H-QMI; Hot-Quick Mixing & Mist Injection) has developed. This technology is that the dry powder fed from the material precision feeder is conveyed by the air flow, after the addition of mist water, is mixing through quick mixing mixer, and then is gunned for BOF or ladle. And in the introduction of mixing function, the dry powder is mixed with water sufficiently, adheres to the surface of refractories enough , and high quality construction of the gunning body is achieved. As a result, the improvement of life was observed in the hot repairing of BOF and ladle.

Refractories for Glass

Room: Colwood

Session Chairs: M. Patil, Corning Incorporated; Matt Lambert, Allied Mineral Products

10:40 AM

(UNITECR-204-2013) Research of Refractories from Aluminaboronsilicate Fiberglass Production Furnace Lining after 88 Months Service

V. V. Martynenko*, V. V. Primachenko, P. P. Kryvoruchko, Y. E. Mishnyova, N. G. Pryvalova, O. I. Synyukova, Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine

Aluminaboronsilicate glass «E» for fiberglass production causes an active corrosion action on refractories, therefore studying of their wearing character at service in glass melting furnaces is the purpose of this work. The standard methods of chemical, petrographic and electron microscopy analyses, as well as determination of open porosity, apparent density and cold crushing strength have been used. The researches of chrome oxide (Cr), alumina-zirconia-silica (AZS) and alumina-chrome oxide (ACr) refractories from fiberglass production furnace lining after 88 months campaign has been realized. The most intensive wear of Cr refractory takes place at the level of glass mirror, AZS – in the area of bubbling and ACr – in the arches of doghouse. It is ascertained that the chemical interaction of Cr refractory with «E» glass does not occur. Its wear is realized by mechanical washing-up of recrystallized Cr refractory particles by the stream of glass mass. The wear of AZS and ACr refractories is carried out by their interaction with penetrating glass melt, formation more easy melted compositions and subsequent washing off it from superficial layers of refractories. The results of these researches will be used at improvement of refractories technologies and constructions of glass furnaces linings.

11:00 AM

(UNITECR-205-2013) New materials and improvements for the glass industry

S. C. Frasson*, M. F. Guerra, S. M. Justus, V. P. Ramos, E. Y. Sako, Saint-Gobain do Brasil Ltda, Brazil

This paper shows the development and improvement of new materials for the glass market. Materials are based on fused silica, fused mullite, fused alumina, tabular alumina and 70% grog. The mullite/alumina product is used in the market of hollow glass(expendables) as well in lipstones for rolled glass. Fused silica products are used in crown hot repairs and blocks for float flat arches. Mullite/grog/alumina castables are used in superstructure of feeder channels for container glass furnaces. This paper will show the development of materials and details of its use in the glass industry.

11:20 AM

(UNITECR-206-2013) Understanding microstructure/properties relationships related to the thermomechanical behaviour of high zirconia refractories

C. Patapy, LMDC INSA, France; F. Gouraud*, SPCTS UMR CNRS 7315, France; N. Gey, M. Humbert, A. Hazotte, LEM3 UMR CNRS 7239, France; D. Chateigner, CRISMAT UMR CNRS 6508, France; R. Guinebretière, M. Huger, T. Chotard, SPCTS UMR CNRS 7315, France

High zirconia materials (HZ) constitute important part of furnaces structures for the manufacturing of glasses. The development of new

compositions requires an increased control of the elaboration process.These materials exhibit specific thermo mechanical properties related to a microstructure containing monoclinic zirconia dendrites embedded into a silica-alumina glassy phase. The present study deals with the understanding of microdamage phenomena at a low scale during the cooling process applied to the sample. Mechanical characterizations are carried out to identify the chronology of the microdamage. The coupling between microstructural texture of the material and the cooling process will also been investigated thanks to heavy experimental device (neutron diffraction facilities). Microstructure observations will complete thermal experiments and allow identifying the main characteristics of such internal mechanisms.

Monolithics II

Room: Lecture Theatre
Session Chairs: Dale Zacherl, Almatis Inc.; Goutam Bhattacharya, Kerneos, India

1:40 PM

(UNITECR-152-2013) Novel Calcium Magnesium Aluminate bonded castables for steel and foundry ladles

C. Woehrmeyer*, J. Auvray, B. Li, H. Fryda, M. Szepizdyn, Kerneos SA, France; D. Poerzgen, Beck + Kaltheuner GmbH & Co., KG, Germany; N. Li, W. Yan, Wuhan University of Science and Technology, China

Extensive laboratory trials have demonstrated that ladle castables bonded with the novel calcium magnesium aluminate binder (CMA) have excellent corrosion and penetration resistance. The micro spinel inside CMA facilitates the design of new castable microstructures and improves penetration and corrosion resistance. This paper investigates how thermo-mechanical properties of alumina spinel and alumina magnesia castables can be positively influenced with CMA. In alumina spinel castables higher strength at equivalent CaO content can be achieved with CMA versus a reference calcium aluminate cement. Furthermore, CMA based alumina magnesia castables can be designed with a reduction of free magnesia and less silica fume additions which results in better thermo-mechanical properties. However, inside steel and foundry ladles, several destructive phenomena occur. Slag penetration, dissolution, abrasion, and thermo-mechanical phenomena happen at the same time which is difficult to simulate in classical laboratory tests. Therefore this paper investigates how CMA based castables behave under real conditions inside steel and foundry ladles. Microstructure investigations of samples taken from ladle linings together with macroscopic observations during the ladle operations will give an in-depth understanding of the mechanisms that lead to the improved performance of CMA based ladle castables

2:00 PM

(UNITECR-153-2013) Influence of phase evolution and microstructure on mechanical properties of basic castables

J. Szczerba, R. Prorok*, AGH University of Science and Technology, Poland; Z. Czapka, Zaklady Magnezytowe ROPCZYCE S.A., Poland; D. Madej, E. Sniezek, AGH University of Science and Technology, Poland

The aim of this study was to evaluate and relate the phase evolution and microstructure in MgO-SiO2-H2O phase system with the mechanical properties of basic castables based on this system. The basic castables are based on MgO-SiO2-H2O phase system and maintain with magnesium silicate hydrate gel (MSH phase), the phase which is creates during the reaction magnesium oxide with microslica and water. The examined castables were composed of burnt magnesium oxide and microsilica in three different additives: 3%, 6%, 9%. The castables after preparation were subjected to heat treatment operations in different temperatures up to 1500° C. The phase and microstructure examination were performed by XRD analysis in the range 5-90° 2θ, DTA-TGA-EGA analysis in the range 20-1000° C, as well as SEM-EDS analysis. The mechanical properties of the samples were evaluated by cold crushing and bending strength. Performed analysis reveals that depending from the temperature of heat treatment and amount of microsilica, the microstucture and the mechanical properties were changed. This work is supported by the grant no UDA-POIG.04.04.00-18-010/09-00 of the Polish Government.

2:20 PM

(UNITECR-154-2013) Synthesis of Nano MgO from natural raw Magnesite and its application in High alumina castable products

N. Sahoo*, P. Rauta, L. Padhi, Dalmia Institute of Scientific & Industrial Research, India; J. Tiwari, OCL India Limited, India

A process has been developed to produce nano MgO from natural raw magnesite through spray pyrolyser route. The nano MgO particles obtained were comprehensively characterized by X-ray diffraction, particles size, Scanning electron microscope and chemical analysis. The developed nano MgO has 99% MgO content and its average particle size is 80 nm. The nano MgO was used as an additive for manufacture of precast high alumina castable refractory. The physical, chemical, thermo-mechanical and mineralogical properties of the castable products with and without nano MgO addition were compared. It was observed that addition of nano MgO enhances the thermo-mechanical, corrosion and erosion resistance of the precast high alumina products.

2:40 PM

(UNITECR-155-2013) Advanced understanding on in situ spinel formation and corrosion performance of spinel-containing refractory castables

E. Y. Sako*, Saint-Gobain Cerâmicas e Plásticos, Brazil; M. A. Braulio, V. C. Pandolfelli, Universidade Federal de São Carlos, Brazil

The in situ formation of magnesium-aluminate spinel (MgAl2O4) is usually followed by a positive volumetric change and a resulting pore generation after the reaction. However, when compared to castables containing synthesized spinel grains, in situ spinel-forming castables usually present excellent corrosion performance in both laboratorial tests and industrial applications, even presenting such expansive reaction and apparently a more porous microstructure. Considering this scenario, the objective of the present work is to shed some light on these two main questions: a) what does really rule the spinel formation in spinel-forming refractory castables?, and b) if this phase formation reaction is followed by expansion and pore generation, why do spinel-forming castables present excellent corrosion resistance in industrial applications? The results suggested that the faster Mg2+ migration during the spinel formation led to vacancy accumulation and, consequently, to pore generation, as a direct result of the Kirkendall effect. Nonetheless, its performance was less affected by such mechanism then by the location of CA6 crystals in its microstructure, which results in a suitable physicochemical protection of both, the tabular alumina aggregates and the matrix, during the experiment.

3:00 PM

(UNITECR-156-2013) Study on the hydration behavior of MgO powders

Q. Jia*, R. Wu, T. Ge, X. Sun, Zhengzhou University, China; X. Qian, J. Zhan, Chengdu Futian New Materials Technology Co., Ltd, China

Comparing to Al2O3-spinel castables, Al2O3-MgO refractory castables have been widely used as working-line in steel ladle due to its superior slag corrosion resistance, however, hydration of MgO powder limits the application of MgO based castables. In this paper, effects of temperature, hydration time and additives (cement and microsilica)on the hydration behavior of MgO powders were investigated in this paper. The results show: (1) The intensity of brucite (Mg(OH)2) diffraction peaks is noticeably increased with the increase of hydration time and temperature, the amount of hydrated product Mg(OH)2 is 2.4%, 6.79%, 14.2%, 18.0%, at 250C, 500C, 750C, 950C for 24h, respectively. With 5% microsilica or cement addition, the amount of hydrated product Mg(OH)2 is noticeably decreased from

18.0% to 11.4% and 2%. The reasons about hydration behavior of MgO powders were discussed.

Monolithics III

Room: Lecture Theatre
Session Chairs: Dale Zacherl, Almatis Inc.; Goutam Bhattacharya, Kerneos, India

4:20 PM

(UNITECR-157-2013) Cement free MgO castables: Part I: Flow, setting and slaking

B. Myhre*, Elkem Silicon Materials, Norway; M. Luo, Wuhan University of Science and Technology, China; H. Peng, Elkem Silicon Materials, Norway

Cement free MgO based castables have been made with different additives to study the flow and set as well as inhibition of cracking (slaking). The results showed that a minimum amount of microsilica must be added in order to effectively prevent the cracking of MgO based castables during drying. Using the proper dispersing additives, good flow, set and high resistance to slaking can thus be obtained on castables basically composed of MgO.

4:40 PM

(UNITECR-158-2013) Cement free MgO castables: Part II: Strength and explosion resistance

B. Myhre*, Elkem Silicon Materials, Norway; M. Luo, Wuhan University of Science and Technology, China; H. Peng, Elkem Silicon Materials, Norway

Cement free MgO castables presented in part I of this paper were submitted to further investigations. Both cold and hot properties were studied. The results show that it is not indifferent what additives one apply and a single component like the dispersing additive can have a pronounced effect on the strength, both cold and hot, as well as the explosion resistance. The cement free MgO castables excel having a high resistance to explosive spalling, which would render them suitable for many applications where fast firing is important.

5:00 PM

(UNITECR-159-2013) Influence of Dispersants and Bonding Methods on Properties of Alumina Based Castables without Microsilica Addition

Z. Wang*, Z. Li, X. Cao, S. Wang, L. Zhou, State Key Laboratory of Advanced Refractories, Sinosteel Luoyang Institute of Refractories Research, China

Alumina based castables are widely used in high temperature industries by adding some SiO2 micro-powder to improve flowability, the performance related to installation, which makes low melting point phases such as melilite and anorthite produce at a lower temperature, and affect the performance of the castables in high temperatures. Influences of 4 kinds of dispersants on rheological parameters of the matrix slurry and on physical properties of alumina based, microsilica free castables bonded by alumina cement, hydratable alumina and their combination were investigated and discussed in present work. The conclusions are summarized as: (1) Compared with dispersants HAD-1, FDN and SM, the castables with dispersant FS10 addition give the lowest water demand and relative better physical properties. (2) Besides a slight expansion after heat treatment at 1500C for 3h, the castables bonded by alumina cement indicate favourite physical properties compared with the other bonding modes. Higher strength after drying is attained while the other physical properties are not so goodish for the castables bonded by hydratable alumina.

Iron & Steel Making Refractories - Magnesia-Carbon I

Room: Saanich
Session Chair: Patrick Tassot, Calderys; Helge Jansen, RE-FRACTECHNIK Steel

1:40 PM

(UNITECR-096-2013) Effects of Nano Boron Carbide as additive for MgO-C for BOF

C. Pagliosa*, N. Freire, G. Cholodovskis, MAGNESITA Refractories, Brazil

MgO-C refractories are widely used as working lining for BOF vessel. Combination of top and bottom blowing are often used and bricks are exposed to severe oxidation and corrosion by gases and slags, erosion and thermal shock. Improved technology in MgO-C bricks included high quality raw materials, new binding systems and different additives combinations. The addition of several metals prevents oxidation, increases hot mechanical properties and also results in better physical and corrosion properties. Boron carbide (B4C) is a kind of a key additive. B4C has excellent oxidation properties and has been proved able to speed up the crystallization from resin. With combination with Al metal accelerates the formation and growth of MgO.Al2O3 spinel crystals between graphite in the matrix. Nano-B4C was synthesized to replace commercial boron carbide. A comparative evaluation between these two B4C sources was performed to show the effects of nanotechnology to MgO-C bricks additives. Raw materials characterization and product properties are presented in this paper.

2:00 PM

(UNITECR-097-2013) Development of Al2O3-MgAl2O4-C Refractories for steel ladle: Effect of MgO and Al2O3 reactivity

H. S. Tripathi*, A. Ghosh, CSIR-Central Glass & Ceramic Research Institute, India

MgO and Al2O3 of different reactivity were used to develop magnesium aluminate spinel. This composition was utilized as in-situ spinel former in Al2O3-MgAl2O4-C refractory. Properties like permanent linear change on reheating (PLCR) at increasing heating cycles and microstructure of this refractory was evaluated. It was observed that rate of spinel formation and associated volume expansion is very much related to the reactivity of raw materials. Magnesia and alumina of moderate reactivity develops the optimum PLCR value, which will be suitable for the refractory application in ladles.

2:20 PM

(UNITECR-099-2013) Properties of MgO Based Refractories with Synthetic MgO-SiC-C Powder

Y. Wei*, X. Li, N. Li, Wuhan University of Science and Technology, China; X. Li, B. Wu, L. Wang, L. Ma, Zhejiang Zili Co.,Ltd.,, China

With the development of high quality steel making, more and more second refining equipments were put into used, so the residence time of steel melt and slag in steel ladle is prolonged and sometimes the steel is treated under high temperature. Thus cause a serious problem, for example, the severe damage on the slag line refractories. The low carbon content MgO-SiC-C refractories has developed and successfully used as ladle slag lining in low carbon steel making process for more than 5 years already. The use of MgO-SiC-C refractories can reduce the recarburization of steel with satisfied performance. In order to optimize the composition and microstructure of the MgO base refractories. MgO-SiC-C powder was synthesized first according to the proper compound and then used as the fine powder in MgO refractories fabrication. The properties of MgO refractories with MgO-SiC-C synthesized powder were investigated in this paper, including physical properties, microstructure, slag resistance and thermal shock resistance.

Iron & Steel Making Refractories - Magnesia-Carbon II

Room: Saanich
Session Chair: Patrick Tassot, Calderys; Helge Jansen, RE-FRACTECHNIK Steel

4:20 PM

(UNITECR-100-2013) Influence of Zinc catalysis on in-situ reaction of metal composite MgO-C refractories

C. Ma*, H. Ma, Z. Ren, D. Meng, Zhengzhou University, China

With clean steel production increased year by year, low carbon MgO-C refractories become the new hot spot. The preliminary study of author found that Zinc have unique catalytic effect on in-situ reaction of metal composite MgO-C materials matrix. In this paper the influence mechanism of Zinc to in-situ reaction and performance of non-burned MgO-C materials have been studied. The study Object focus on metal Al / Zn composite low carbon MgO-C materials with the use of chemical kinetic theory, the physical and chemical changes of Zn, Al, MgO, C and other in heating process of MgO-C materials, the activation energy of related chemical reaction was estimated, And combined with high temperature service performance experiments, material phase and microstructure analysis, the Influence law of Zinc gas-phase catalysis on in-situ reaction was discussed.

4:40 PM

(UNITECR-101-2013) The comprehensive studies of magnesia carbon bricks' anisotropy

H. Zhu*, Puyang Punai Refractories Group Co.,Ltd., China

Flake graphite and magnesia are the main compositions of magnesia carbon bricks, and the inherent anisotropy of flake graphite has great effect on bricks' performances. In this paper, all of the physical and chemical properties were carefully and comprehensively researched in a new method of sampling taking ladle slag line magnesia carbon bricks as the research object. Detailed testing results show that the compressive strength, modulus of rupture and high temperature of bending strength of forming direction's samples is obviously larger than vertical direction' samples in both after drying and baking at 1000 centigrade. The interesting results of dynamic elastic modulus were gradually enlarging from the center to the surface of the same brick. In the center of bricks, gas permeability had the biggest value, that is to say, the amount of pores which diameter was larger than 0.01um was also the most, and this conclusion was confirmed by the tests of pore distribution using mercury as carrier and so forth. Key words: magnesia carbon bricks, graphite, anisotropy

5:00 PM

(UNITECR-102-2013) Improvement and Maintenance of MgO-C Bottom-Blowing Tuyer in BOF Converter for Prolonging Service Life

L. Li*, X. Peng, H. Ding, F. Gao, China Central Iron and Steel Research Institute Group, China

With improvement of steel quality and increase of service life of converter campaign, a great attention has been paid to extend the service life of tuyeres in order to satisfy the need of steel process. Because of the life of tuyers is far less than that of MgO-C lining of converter in general, it is absolutely necessary to maintain and repair the tuyrers frequently. In this paper, several effective methods including structure improvement, repair way, replacement and bottom-blowing gas volume control for prolonging the service life of tuyeres were introduced.

Advanced Testing of Refractories II

Room: Oak Bay
Session Chairs: Len Kreitz, Plibrico Co., LLC; Nigel Longshaw, Ceram Research Ltd.

1:40 PM

(UNITECR-014-2013) Temperature dependent thermo-mechanical behavior of novel alumina based refractories

A. Böhm*, E. Skiera, J. Malzbender, Forschungszentrum Juelich GmbH, Germany; C. G. Aneziris, Technical University Bergakademie Freiberg, Germany

Novel developed alumina based refractories are investigated to determine thermo-mechanical properties within the framework of the DFG SPP "FIRE". The refractories are produced for application as slide gates or entry nozzles. Experiments were performed from RT - 1000° C. The wedge splitting test was used to determine R-Curve behavior and thermal shock resistance. Crack growth was observed in situ at RT in a SEM chamber. Elastic behavior was investigated using impulse excitation technique and four point bending tests. The influence of different additives (TiO2, ZrO2, MgAl2O4, C) and maximum grain size on elastic behavior, crack propagation and thermal shock resistance is investigated. Addition of small amounts of oxides leads to huge changes of elastic modulus and has therefore a strong influence on thermal shock resistance. For instance the addition of 2.5 % TiO2 and 2.5 % ZrO2 lowers the elastic modulus drastically in comparison to pure alumina. The elastic behavior of the doped material shows a hysteresis at elevated temperatures whereas the pure alumina shows linear behavior. This effect is related to a phase transition of ZrO2 which was observed using high temperature x-ray diffraction.

2:00 PM

(UNITECR-015-2013) Contribution of different bonding agents and amounts to Young's modulus of elasticity at elevated temperatures of carbon-bonded alumina determined by Impulse excitation technique

J. Werner*, C. G. Aneziris, TU Freiberg, Germany

Carbon-bonded refractories are widely used in steel industry as functional components and as lining material (e.g. BOF). They are well known for their outstanding thermal shock behavior. The knowledge of the elastic properties at high temperatures will provide simulation of thermal shock resistance with unknown data or supports the understanding of the material micro-structure. In this work we present results regarding the Young's modulus of elasticity (E) of carbon-bonded alumina refractories at high temperatures with variation in binder content, binder type, graphite content and porosity. Using the proposed method one can accurately determine E up to 1450 °C in air and inert gas atmosphere. Therefore a sample is excited by a projectile, resulting in an oscillation. From this the resoncance frequency of the material can be obtained. According to ASTM 1876 E can be calculated from this frequency. As bonding agents were used resin type novolac and carbonaceous resin. The samples were coked at 1000 °C. As a result one can model the thermal shock and thermo-mechanical behavior of carbon-bonded materials according to the available temperature depending Young's modulus of elasticity. Furthermore the influence of binding matrix on the thermal shock behavior can be evaluated.

2:20 PM

(UNITECR-016-2013) Influence of the Cabores content on the damage parameters of carbon bonded alumina obtained by means of the Small Punch Test

S. Soltysiak*, M. Abendroth, M. Kuna, TU Bergakademie Freiberg, Germany

The material investigated is used for the production of open cell foam filters. These filters are used for the filtration of metal melts. All material compositions contain 30 wt% residual carbon after coking. The Cabores content is varied from 10 wt% to 30 wt%. The mechanical

tests were carried out by means of the Small Punch Test. The main advantage of this test method is the small amount of material necessary for the tests. The thickness of the samples is in the same range as the thickness of the struts of the filters. The specimens are exhibit to a biaxial state of stress. This test setup therefore provides conditions which are close to the in-service conditions of a filter during casting. The specimens for the tests could be manufactured by a slip casting process route. A comparison to results obtained by 3-point-bending tests, where the specimens were uniaxial pressed, showed that it essential to keep the specimen production route close to the way of the filter production. The results showed that the reliability and the strength of the carbon bonded alumina is increasing with an increasing Cabores content.

2:40 PM

(UNITECR-017-2013) Dry out simulation of castables containing calcium aluminate cement under hydrothermal conditions

J. Auvray, C. Zetterstrom*, C. Wohrmeyer, H. Fryda, C. Parr, C. Eychenne-Baron, Kerneos SA, France

The permeability of refractory concretes is an important parameter in assessing the safe dry out of castables. Experimental data has shown that the permeability of castables decreases under hydrothermal conditions which are often experienced inside castables during dry out. This has been attributed to the formation of specific hydrates and is confirmed through the post mortem analysis of dry out failures. These analyses have also shown that permeability alone is insufficient to predict the ability to successfully dry out dense deflocculated castable types. This paper investigates the relationship between castable properties and the risk of explosion during the dehydration phase. Experimental simulations of explosion during dry out under safe conditions with one-sided heating as well as the more traditional furnace based approach are conducted. Hydration and de-hydration are performed under ambient as well as hydrothermal conditions using an autoclave. These methods are coupled with a 'macro'-TGA apparatus as well as permeability and the measurement of other traditional properties. The results reveal significant differences in dry out ability as a function of formulation parameters as well as external conditions such as the water addition, temperature and time during curing and heat up rates. Conclusions suggest optimisation routes to ensure safe dry out.

3:00 PM

(UNITECR-018-2013) Corrosion of corundum-mullite refractories in gaseous HCl/H2O atmosphere at elevated temperature

M. Jafari, M. Ghanbari, F. Golestani-fard*, R. Naghizadeh, Iran University of Science and Technology, Islamic Republic of Iran

The improvement of refractory life campaign in Iranian petrochemical incinerator is becoming an ever increasing issue due to fast development. In this article we will report the gashouse corrosion of corundum-mullite refractories with aim of selection a more resistant material. The samples were tested in H2O/HCl gas stream in a tube furnace at 1000-1200 C. The weight loss, phase evolution and microstructure were studied by microbalance, XRD and SEM respectively. It was found that the most dominant corrosion mechanism could be based on evaporation of SiCl4 and Si(OH)4 from Mullite phase. The Mullite, then was mainly converted to corundum and non-stoichiometric with lower thermal shock resistance followed by spalling. The rate of corrosion and activation energy was calculated and mechanism of corrosion was proposed.

Advanced Testing of Refractories III

Room: Oak Bay

Session Chairs: Len Kreitz, Plibrico Co., LLC; Nigel Longshaw, Ceram Research Ltd.

4:20 PM

(UNITECR-019-2013) Microstructural processes in the wake region of the crack in castables containing eutectic aggregates at high temperature thermal shock

J. Schnieder*, N. Traon, T. Tonnesen, R. Telle, RWTH Aachen, Germany

Like in engineering ceramics the crack tip was held responsible for the damage through thermal shock in refractories in the last decades. In the last years the area behind the advancing crack front was more and more the focus of attention. The strengthening taking place in this wake region is essentially due to crack bridging and friction between aggregates and matrix. These effects depend strongly on the aggregates size, properties and shape. To understand and improve the thermal shock behavior of castables, different grain fractions (a small range between 100 μm and 6 mm, for example 2.24 – 3.0 mm) of tabular based castables were substituted by different kinds of fused eutectic aggregates (Al2O3-ZrO2-SiO2, as in-situ fiber reinforcement) and afterwards examined (thermo-mechanical properties). . Thermal shock experiments between two high temperatures, namely between 1600°C and 1100°C, could reveal different resulting effects in the wake region of the crack than those observed during standardized thermal shocks.

4:40 PM

(UNITECR-021-2013) Thermal shock on the lower slide gate plate when closing: Test development and post-mortem investigations

R. Grasset-Bourdel*, C. Manhart, J. Pascual, RHI AG, Austria

Thermal shock is known to be one of the factors limiting the service life of slide gate refractories, especially for large plates. Closing a slide gate produces a thermal shock at the closing position and on the stroke path. Especially in alumina-carbon rotary gates some spalling/damage can be observed which may limit the service life of the plate. Laboratory thermal shock trials were conducted in order to simulate this thermal shock. The tests consisted in pouring an amount of molten steel (1650°C) on the plate to be tested. The steel is contained by zirconia rings placed on the plate. Therefore the region of the plate in contact with the steel is heated very rapidly and suffers a thermal shock. Damage was observed on the alumina-carbon plates after the test. Several methods have been used to characterize the damage level: results obtained by ultrasonic methods, before and after the test, were compared and exhaustive microstructure analyses were carried out by microscopy and X-ray tomography.

Developments in Basic Refractories II

Room: Esquimalt

Session Chairs: Dominick Colavito, MINTEQ International Inc.; Andrie Garbers-Craig, University of Pretoria

1:40 PM

(UNITECR-046-2013) Thermal cycling resistant MgO based monolithic linings

C. Dromain, Calderys, France; P. Malkmus, Calderys, Germany; J. Soudier*, Calderys, France

Magnesia based refractories are widely used in lime and cement production industry - especially in rotary kilns with magnesia-spinel bricks ; but also in steel industry, such as in electric arc furnaces and secondary steel fields. These applications require suitable refractories, exhibiting in particular a high resistance to thermal cycling or thermal shocks. Formulation design of MgO based refractory castable has been investigated - particularly the incorporation of alumina, AM spinel or zirconia grains – and resulting improvement of thermal cycling resistance has been assessed. Micro-cracks formation during

first heating up or first cooling down is recognized as responsible for the observed thermal cycling resistance increase. These micro cracks result from thermal dilatation difference and expansion mismatch between incorporated grains and magnesia matrix. The micro-crack network formed has been identified to both dissipate the energy of macro-cracks propagation and to enhance the accommodation of thermal strain in the matrix.. The paper presents such properties in dense, cement free and MgO based refractory castables depending on nature, amount and size of incorporated grains.

2:00 PM

(UNITECR-047-2013) Effect of Magnesia Dissolution in Non-Stoichiometric Chromium-Free Complex Spinel

R. Lodha, C. Oprea*, T. Troczynski, G. Oprea, The University of British Columbia, Canada

This work investigated the synthesis and sintering of magnesia-rich chromium-free complex spinels and their solid solutions, prepared at much lower temperatures (1350-1550°C) than the Cr3+ bearing versions, which usually require firing at 1720-1800°C, in order to achieve equivalent properties. The aim of this work was to understand the effects of sintering temperature on structural changes in spinel-bonded chromium-free basic refractories. It has been determined that the synthesis and sintering at low temperatures is due to the formation of distorted spinel phases at temperatures below 1350°C which could activate the cationic diffusion, leading to enhanced synthesis and sintering rates. The volume expansion due to spinel formation, which usually retards densification, was also overcome by the volume shrinkage due to sintering, in the range of temperatures where they take place simultaneously. The calculated lattice parameters (from theoretical considerations) were correlated to the experimental lattice parameters through whole pattern fit (WPF) Rietveld analyses of the X-ray diffraction patterns of experimental samples fired at various temperatures. The changes in lattice parameters with firing temperature were correlated to the level of inversion and magnesia dissolution in the complex spinel phase.

2:20 PM

(UNITECR-048-2013) Microstructural and physico-chemical evolution of Al2O3 and Fe2O3 nanoparticles doped magnesia (MgO) sintered at 1600 °C

C. Gomez Rodriguez*, T. K. Das Roy, A. G. Castillo Rodriguez, S. Shaji, E. A. Rodriguez Castellanos, L. V. Garcia Quinonez, Universidad Autonoma de Nuevo Leon, Mexico

The high demands by the extraordinary steel consumption worldwide have led to the refractory industry to explore new fields of science. The newest advances in the nanotechnology have awakened the refractory industry interest. In this context, basic refractories of magnesia (MgO) were doped with 1, 3 and 5 wt. % of nanoparticles (Fe2O3, Al2O3, and SiO2) and then sintered at 1300, 1500 and 1600 °C for 4 h in an electric furnace. The physical properties and microstructural characteristics were reported in terms of density and porosity as well as its morphology and crystalline phases, using Archimedes method, X-ray diffraction (XRD) and scanning electron microscopy (SEM) with energy dispersive X-ray (EDX). In general, the addition of 5 wt. % of Fe2O3 nanoparticles at 1500°C reached the maximum increase in density (3.42 g/cm3) as well as refractory samples sintered at 1600°C with Al2O3 and SiO2. These samples were tested by a static chemical attack method with electrical arch slag and subsequently, it was evaluated their chemical properties by SEM-EDX and XRD. The final results showed that the corrosion resistance depends on the formation of crystalline phases which were promoted by the addition of nanoparticles in the MgO matrix.

2:40 PM

(UNITECR-049-2013) Studies on the Effect of Nano-Carbon in MgO-C: A New Generation Refractories

M. Bag, R. Sarkar, National Institute of Technology, India; R. P. Rana, S. Adak*, A. K. Chattopadhyay, TRL Krosaki Refractories Limited, India

Abstract The Magnesia-Carbon Refractories are widely used in steel making mainly the working lining of BOF Vessel, Steel ladle and EAF. The problems with conventional MgO-C brick are carbon pick up by steel and increase in heat loss, which has resulted in demand for low carbon MgO-C bricks. It's a challenge for the scientists to develop an eco-friendly low carbon MgO-C bricks with good thermal spalling resistance. The present work discusses the role of Nano-Carbon for the development of low carbon MgO-C brick with superior properties. The amount of Nano-C has been varied from 0.2 to 1wt% along with pitch and liquid resin as other source of Carbon. The test results of the newly developed MgO-C were evaluated in comparison with conventionally prepared MgO-C (12%) bricks and it was observed that the mechanical and thermo-mechanical properties such as CCS, HMOR etc. are better for MgO-C bricks prepared with Nano-C. A detailed micro-structural evaluation has also been carried out using Optical Microscopy as well as SEM. Also elemental mapping of carbon was done to study the distribution of the nano-carbon in the matrix of the Refractories.

3:00 PM

(UNITECR-050-2013) Magnesia-Carbon Bricks Made in Europe, Challenges and Solutions

G. Buchebner*, A. Kronthaler, W. Hammerer, RHI AG, Austria

Strong competition from Chinese magnesia-carbon bricks and a high dependency on raw materials sourced from China has initiated a series of actions and developments in the past years to make magnesia-carbon brick production in western countries "fit for the future". The main topics have focused on backward integration of raw material supply, environmental impact, performance, and providing special product solutions. To address alternative raw material supply, a new plant to produce fused magnesia became operational in Norway in October 2012. Additional activities have concentrated on processing recycled material in order to maximize the proportion of secondary magnesia available. This new raw material situation has resulted in a new series of magnesia-carbon bricks. Concerning performance and environmental aspects, major steps have been taken towards achieving strong carbon bonding without the need for metallic additives. This is an important issue because recycling magnesia-carbon materials with metallic additives causes severe problems in the brick manufacturing process and requires a cost-intensive pretreatment of the magnesia-carbon scrap. Quality control has also been improved and automated following the installation of ultrasonic and X-ray equipment, with the possibility for nearly 100% production control.

Developments in Basic Refractories III

Room: Esquimalt
Session Chairs: Dominick Colavito, MINTEQ International Inc.; Ben Markel, Resco Products

4:20 PM

(UNITECR-051-2013) The effects of rare earth oxides on the structures and properties of MgO-CaO ceramics

Y. Yanwen*, Baosteel Metal Society, China

In recent years, with the steady growth of steel-output, the refinement process also became popular. The main processes include Argon-Oxygen Decarburizations (AOD),Vacuum Oxygen Decarburizations (VOD), Secondary Refining Process. No matter what kind of process, the usage of magnesia- calcia materials is best, taking account of the technique and economies. There is much literature concerning the slag corrosion resistance of magnesia-calcia materials, however, most of these focused on the synthetic slag corrosion to the magnesia-cal-

cia materials and few reports were found for refining slag corrosion. The additives of Y2O3 were studied on microscopic structure and properties of mechanic and sintering as well as anti-hydration for MgO-CaO ceramics. The product with additives Y2O3, to which was added 1.0a wt%Y2O3 in matrix, sintered at 1650 centigrade for 5 hours, which cold and hot modulus of rupture are respectively 110Mpa,14MPa and hydration rate of MgO-CaO product (CaO≥50%) is superior to that without additives Y2O3, is developed.

4:40 PM

(UNITECR-052-2013) Development of planar and cylindrical refractories with graded microstructure

U. Scheithauer*, T. Slawik, K. Haderk, T. Moritz, A. Michaelis, Fraunhofer IKTS Dresden, Germany

At the Fraunhofer Institute for Ceramic Technologies and Systems the principle of manufacturing of refractories with graded properties is investigated. The manufacturing of multilayer composites by aqueous ceramic tape technology allows an environmental-friendly production of components with large dimensions and gradient structures regarding porosity and phase composition. Within the framework of the SPP 1418 "Fire" funded by the German Research Foundation (DFG) carbonless refractories with different porosities in each layer are developed. The used material systems are Ca-aluminate/Al2O3 and MgO-stabilized ZrO2. The graded pore structure shall result in improved thermal shock properties of the materials. Not only planar structures, but also cylindrical structures with a radial gradient of the microstructure and the resulting properties can be realized by applying a winding technology known from the paper technology. The presentation will show the production of planar and cylindrical refractories with a selected microstructure and graded porosity. Computer tomography allows searching for possible delaminations between the different tapes after the sintering process. SEM-images of the sintered components show the perfect connection between the single layers and the produced structures.

5:00 PM

(UNITECR-053-2013) Development of magnesia refractories with higher slaking resistance

K. Shimizu*, T. Nakamichi, Y. Sadatomi, J. Yoshitomi, Krosaki Harima Corporation, Japan

Autoclave tests revealed that slaking resistance of MgO bricks after heat treatment at 1673 K deteriorates remarkably than that of MgO bricks without heat treatment. It is probable that heat treatment damages MgCO3 layer on surface of MgO bricks, which is formed by exposure to atmosphere and which suppresses interaction of MgO surface and water particles and which improves slaking resistance. Slaking resistance after heat treatment is hardly improved by pretreatment with liquid impregnation, e. g., MgSO4 solution and molten pitch. It is probable that heat treatment also damages impregnant layer on surface of MgO bricks. Addition of glass frit, especially borosilicate glass frit, in the mixture of a conventional burnt MgO brick significantly improves slaking resistance. It is probable that the glass frit is molten in manufacturing process, covers MgO surface and suppresses interaction of MgO surface and water particles.

Refractories for Waste to Energy Processing and Power

Room: Sidney

Session Chairs: Ben Markel, Resco Products, USA; Steve Chernack, Morgan Thermal Ceramics

1:40 PM

(UNITECR-217-2013) Vapor Phase and Melt Corrosion of Refractory Castables in Biomass Gasification and Incineration Processes

T. Tonnesen*, R. Telle, RWTH Aachen University, Germany

The demand of new energy resources increases the amount of industrial gasification and incineration processes of biomass. Apart from process stability corrosion of the refractory lining is a limiting factor for such boilers and vessels. In this study the corrosion mechanisms for different castables based on andalusite, calcium aluminates, spinel and SiC were examined in contact to slags and ashes of biomass incineration processes with its high alkaline, phosphate and sulfate concentrations. A thermodynamic model using the FactSage software package was worked out and applied on the different refractory compositions to predict phase formation, dissolution and corrosion behaviour. Vapor phase corrosion experiments between 1000 and 1400°C with changing chemical compositions due to different biomass feedstocks of crucibles and in a special tube furnace were performed to work out the gaseous corrosion in regard of condensation of aggresive vapors into a refractory with a thermal gradient. Slag and post-mortem analyses were achieved to define dissolution behaviour. The corrosion were applied on the matrix materials (CA-cement, spinel-cement, CA6, SiC fines) as well as on grog aggregates. Finally the impregnation and the microstructural change is discussed in regard of changing thermal properties such as expansion, permeability and strength.

2:00 PM

(UNITECR-218-2013) Improvement of the physical properties in Al2O3-SiO2-bricks by sol- impregnation

G. Monsberger*, K. Santowski, RHI-AG technologie Center Leoben, Austria

Due to their different mineral composition and extended range of properties, alumina-silica refractory bricks have a wide field of application in the cement, petrochemical, glass and non-ferrous industries. Especially in furnaces with high corrosion - areas, where alkali-load, chemical attack, high abrasion resistance and high refractoriness are required, sol- impregnated A2O3-SiO2 bricks are recommended. The sol-impregnation improve in refractory brick based on e.g. fireclays, andalusite, bauxite and also fuse alumina up to 99% Al2O3 the physical properties with a reduction the open porosity and gas permeability but also an increase the cold crushing strength and the abrasion resistance. Additionally sol-impregnated bricks showed a rising of the refractoriness under load temperature. The improvement all these properties extend the service life of the A2O3-SiO2 refractory bricks for the new corrosion demands in different customer processes. The present study evaluates the corrosion resistance in different alkali and alkali vapor cup test and compare the physical properties between sol-impregnated and no- impregnated Al-Si refractory bricks.

2:20 PM

(UNITECR-219-2013) The Improvement of Al2O3-Cr2O3 Bricks for Waste Melting Furnaces

H. Hoshizuki*, H. Tanida, S. Ota, Y. Yoshimi, MINO CERAMIC CO., LTD, Japan

Waste melting furnaces make it possible to incinerate and melt industrial and general wastes at high temperature, contributing to volume reduction, and also to be harmless to environment. They are classified depending on the kind of wastes treated and disposal process and the properties required for the lining refractories differ according to

the furnaces. For rotary kiln type waste melting furnaces, the refractory bricks are required to possess both corrosion resistance to molten slag and spalling resistance to mechanical stress during rotation and thermal shock at a high level. In this study, we report the developed Al2O3-Cr2O3 brickfor rotary kiln type waste melting furnaces and applied it in actual kilns, showing excellent performance. Moreover, Al2O3-Cr2O3 brick having different Cr2O3 content with improved spalling resistance is also reported.

2:40 PM

(UNITECR-220-2013) Recent lining concepts for thermal treatment of hazardous wastes

K. Schwickert, U. Frohneberg, J. Sperber, R. Burgard, F. Duennes, D. Schweez*, STEULER-KCH GmbH, Germany

The aim of this process is the disintegration of toxic components… We will discuss lining systems for different types of incinerators for halogenated and alkaline residuals… Mixed waste technology – rotary kiln …where slag can appear chromium oxide containing lining material is recommended… …low viscosity and high iron content of the slag is in most cases the condition which results in an extremely high wear… Mixed waste technology – post-combustion chamber …recommend a lining with chromium oxide containing andalusite or andalusite-corundum bricks. … this is the reduced thermal expansion which will relate to a lower stress in the arch lining compared to a lining with corundum based… High alkaline contaminated waste … the resident time in the cylindrical part the reaction to disintegrate toxic components is fulfilled and in the outlet area the flue gas is quenched with water… … a chemically bonded brick is well established. For severe abrasive conditions a special high fired andalusite brick… Incineration of halogenated waste …the incineration of halogenated carbon hydrates like e.g. CFC or FC containing residuals.. Standard aluminium silicate material is attacked increasingly with the electro negativity of the halogens. Conclusions The generation of low silica, chromium oxide containing corundum bricks for the lining of rotary kilns will lead to a significant improvement of…

Refractories for Nonferrous Metallurgy I

Room: Sidney
Session Chairs: Rick Volk, United Refractories Co.; Angela Rodrigues-Schroer, Wahl Refractory Solutions

4:20 PM

(UNITECR-207-2013) Processing and Characterization of MgAl2O4 – Calcium Aluminate Refractories by Reaction Sintering of Alumina-Dolomite

R. P. Rana, A. S. Bal, B. P. Padhy, S. Adak*, P. B. Panda, A. K. Chattopadhyay, TRL Krosaki Refractories Limited, India

Reaction sintering of dolomite with alumina forms MgAl2O4 and calcium aluminate phases depending upon the ratio of the reactants and temperature. The phase formation and densification of the alumina-dolomite mixer as a function of temperature was studied. The brick was fired at 1520°C and different properties e.g. porosity, density, crushing strength, hot modulus of rupture and thermal conductivity were determined. The wetting of the refractories and physical properties including Al resistance against pure Al (A-7 grade) were carried out in the similar condition (850°C/72hrs). The detailed phase analysis has been characterized using XRD and microscopy. The spinel-calcium aluminate brick showed non-wetting characteristics and no impurity pick up from the brick to the Aluminum metal after the test. The phase analysis and pore size distribution of the metal treated surface and the outer surface were compared to ensure the metal penetration. Thermal spalling resistance and thermal expansion behavior of the brick was determined for the confirmation of application in Aluminum Industry.

4:40 PM

(UNITECR-208-2013) Calcium zirconate refractories for titanium melts

S. Schaffoener*, TU Bergakademie Freiberg, Germany; B. Rotmann, RWTH Aachen, Germany; H. Berek, TU Bergakademie Freiberg, Germany; B. Friedrich, RWTH Aachen, Germany; C. Aneziris, TU Bergakademie Freiberg, Germany

This contribution investigates the possibility of melting titanium and titanium aluminide alloys in a crucible made of calcium zirconate (CaZrO3). CaZrO3 exhibits a remarkable thermodynamic stability and is therefore very interesting for its potential use for vacuum induction melting (VIM) of extraordinary corrosive metals like titanium. The crucibles are produced by cold isostatic pressing (CIP) on laboratory scale. The main focus of this contribution is the reaction between the crucible material with Ti and TiAl alloys. Preliminary results already showed the stability of crucibles. To limit the infiltration and corrosion by molten metal the pore size distribution and composition of the refractory matrix is optimized by the combination of sintered and fused CaZrO3 qualities. The used crucibles are investigated by scanning electron and light microscopy. Especially the investigation of the corrosion process of the crucible by the melted metal with electron backscattering diffraction (EBSD) is to the knowledge of the authors the first of its kind. Because oxygen worsens the mechanical properties of titanium the oxygen takeup by the melt is also investigated in order to study the quality of the refractories.

5:00 PM

(UNITECR-209-2013) Chromium-Free Complex Spinel Bonded Basic Castables

R. Lodha*, H. Zargar, T. Troczynski, G. Oprea, The University of British Columbia, Canada

This study presents the experimental results of processing and sintering of chromium-free spinel bonded basic castables through the use of ultra-fine particles and spinel forming oxides that can create metastable phases leading to the formation of complex spinel solid solution. The metastable phases formed during the low temperature reactions lead to an activated synthesis of complex spinel. The subsequent reaction of the formed spinel matrix bonding to the basic aggregates was achieved, which resulted in lower temperatures of synthesis and sintering of the spinel phases. The binder system based on in-situ spinel forming technology allows the matrix of castables to sinter at 5% open porosity, when fired below 1500°C. The effects of commercial dispersants on flow and setting behavior of castables were studied. The effect of aggregate hydration on green properties of castables was also studied in order to understand the impact of brucite formation on the flow and working time of castables and their subsequent fired properties. Castables using our novel chromium-free spinel bonding system, fired at as low as 1450°C, have been scaled up to industrial size and tested in an industrial non-ferrous Bottom Blown Oxygen Furnace (BBOC). They showed similar properties and behavior in use to industrial rebonded fused grain (RFG) grade of magnesia-chrome basic bricks, which are considered at this time the best for non-ferrous applications.

5:20 PM

(UNITECR-210-2013) Influence of corrosive attack by AlMg5 on the hot abrasion resistance of refractory materials for the use in the secondary aluminum industry

R. Simmat*, C. Dannert, Forschungsgemeinschaft Feuerfest e.V., Germany

The refractory linings installed in melting furnaces of the secondary aluminum industry are concurrently subjected to corrosive attack from molten aluminum and to mechanical wear. For a reliable prediction of the refractories performance during industrial use, it is vital to consider the interaction of those two different degradation processes. Therefore, a laboratory testing procedure that generates corrosive attack by molten AlMg5, followed by mechanical wear by particle impingement at 850 °C on the same sample specimen, was established

and applied on two different refractory brick materials and four different refractory castables. The influence of the corrosive attack on the mechanical wear resistance was investigated by comparing the remaining erosion resistance of the samples after interaction with AlMg5 with their erosion resistance in their original condition. The mechanisms by which corrosive attack of the aluminum alloy affects the erosion resistance of refractories were investigated extensively by microscope and SEM/EDX. The results will help to optimize the wear resistance of refractories for use in critical zones like the belly band or charging areas in melting furnaces.

Modelling and Simulation of Refractories I

Room: Colwood
Session Chairs: Bill Headrick, MORCO, USA; Harald Harmuth, Montanuniversitaet Leoben

1:40 PM

(UNITECR-135-2013) Marangoni convection as a contribution to refractory corrosion - CFD simulation and analytical approaches

S. Vollmann, H. Harmuth*, Montanuniversitaet Leoben, Austria

One purpose of the study was to improve and extend the methodology available to quantify Marangoni convection with respect to refractory corrosion. Moreover for the setup of a simple corrosion test it should be verified whether it is possible to assess the significance of Marangoni convection as a contribution to corrosive wear by a relation between a critical Reynolds and a Marangoni number. For this purpose computational fluid dynamics (CFD) and an analytical approach have been applied. Especially the case of a rotating silica refractory slab in a fayalite slag was investigated for three different slags and compared with experimental results reported in literature. A significant impact of Marangoni convection on the mass transfer coefficient especially for low Reynolds numbers was observed and a critical Reynolds number was determined. Simulation results showed good agreement with experiment, nevertheless analytically calculated mass transfer coefficients seem to overestimate mass transfer and therefore corrosion at least in the example investigated here. It was concluded that CFD simulations are suitable to quantify the impact of Marangoni convection on refractory corrosion, and they may be helpful to improve the accuracy of analytical calculations. Moreover a critical Reynolds number helps to judge significance of Marangoni convection.

2:00 PM

(UNITECR-136-2013) Thermomechanical computations of refractory linings accounting for chemical swelling

M. Tarek, B. Eric*, PRISME Laboratory - University of Orléans, France; S. Nicolas, LMT Cachan - ENS de Cachan / CNRS UMR 8535 / UPMC, France; D. Emmanuel, CEMHTI, UPR3079 CNRS - University of Orleans, France; G. Alain, PRISME Laboratory - University of Orléans, France

The design of refractory linings is mainly based on thermal computation, thermochemistry and strong workman know-how. The numerical design is often limited to simple thermo-elastic computations. Sometimes they are refined considering non-linear mechanical behavior, but without any link with corrosion which often induces large swelling and strong evolution of the mechanical behavior. The aim of this presentation is to demonstrate current possibility to develop fully 3D finite element simulations accounting simultaneously for thermal, mechanical and chemistry phenomena. Illustrations are focused on the case of SiC-based refractory lining used in Waste to Energy plant. A multi-physical coupled analysis is proposed to elaborate degradation roots. Then, a dedicated thermo-chemo-mechanical model is built. This model accounts for the reactive transport of oxygen through the gases within the porosity, and for the swelling and porosity clogging up induced by SiC oxidation. Different real geometries of the lining are modeled and a computation of one year in service is done. Two materials are also considered. Results reproduce well the localization of the degradations and allow highlighting the geometry and material effects on the lining behavior.

2:20 PM

(UNITECR-138-2013) Dissolution rate of solid oxide into molten slag

N. Maruoka, IMRAM, Tohoku University, Japan; F. Huang, J. Liu, University of Science and Technology, Beijing, China; S. Kitamura*, IMRAM, Tohoku University, Japan

To reduce the refractory damage of BOF, precise control of slag composition during the blowing is important. Although the slag composition is affected by the dissolution rates of fluxes and refractory, the dissolution rates of these oxides are influenced by the slag composition. In many cases, a solid solution layer is formed at the interface and the formation and decomposition rates of this layer are considered as rate controlling steps. In this research, the influence of the interfacial layer on the dissolution rate is investigated by the fundamental experiment. The reagents were mixed in various proportions and sintered to make pure oxides and solid solutions at about 1773 K. The sintered rod was added into the molten slag which is stirred by Ar gas and the dissolution rate was measured by the change in slag composition. As pure oxides CaO and MgO and as the solid solution 2CaO-SiO2 which formed at the interface of lime and MgOFeO which formed at the interface of MgO based refractory were chosen. The results revealed the importance of the density and toughness of the interfacial layer on the dissolution rate.

2:40 PM

(UNITECR-139-2013) Finite element analysis for thermal stress of stopper

Y. Wengang*, L. Guoqi, M. Tianfei, Y. Jianbin, Q. Fan, Sinosteel Corporation Luoyang Institute of Refractories Research, China

The critical parts of stopper is head that decides the flow conrol function and service life of stopper in continuous casting process. As the head of stopper is erossed by the rapid flow of molten steel, the head shape is irregular, and the flow can not be controlled. So the key to improve the life of stopper is to solve the erosion and spalling resistance in the moleten steel. In this paper, three different structure stoppers were designed, the structure of stopper A is the head in direct contact with the body, the structure of stopper B is that has 2 cm transition layer between the head and body, and the structure of stopper C is that not noly has 2 cm transition layer between the head and body, but also the head has a composite layer with lower carbon materials. The thermal stress of different structure stoppers in continuous casting process were analyzed by finite element software ANSYS, and all stoppers were tested in factory. The results show that, the thermal stress of stopper acutely varies at the initial stage of steel-irrigating, and this can be a main reason causing these rapture.When the stoppers were used in practice, a part of stopper A ruptured on the face of body contact with head, the erosion of stopper B is more serious, and stopper C had a best work.

Iron & Steel Making Refractories - Continuous Casting

Room: Colwood
Session Chair: Xiaoyong Xiong, Imerys Refractory Minerals; Olaf Krause, Forschungsgemeinschaft Feuerfest e.V

4:20 PM

(UNITECR-112-2013) Development of Aluminous Nozzles reinforced with SiAlON

C. M. Galinari*, P. R. Dutra, Magnesita, Brazil

SiAlON is a compound formed by tetrahedral structured in a kind of arrangement similar to mineral silicates. Characteristics such as high strength at high temperature, good thermal shock resistance and low wettability by slag and molten steel, were verified in sialon bonded re-

fractories used for blast furnaces and awakened interest in applications related to steel continuous casting. Aiming to replace the small zirconia nozzles used in jet open casting for the production of steel billets, studies were done seeking to develop an aluminous material reinforced with SiAlON in its matrix. For this, it was correlated different compositions, production processes, microstructures and properties. In this study, was used an aluminous base with metal powders and additives such as zirconia, magnesia and kaolin. There was formation of SiAlON matrix into all of them, but presenting very different structures, such as whiskers rod-like, whiskers wool-like, overlapping layers. These materials showed high mechanical strength with CCS around 300MPa, bulk density around 3.20 g/cm3, apparent porosity around 10% and distinct hot properties. The best combination of properties was selected for testing with Customers, showing promising results.

4:40 PM

(UNITECR-113-2013) Properties of self-glazing Al2O3-C-refractories influenced by the graphite content and nanoscaled additives

S. Ludwig*, V. Roungos, C. G. Aneziris, TU Bergakademie Freiberg, Germany

Components based on carbon bonded alumina refractories are widely used in the steelmaking industry in terms of submerged entry nozzles, monobloc stoppers and ladle shrouds. According to the state of the art, such components are glazed to inhibit the oxidation process of the carbon contained in the refractory bodies. Carbon oxidation leads to a deterioration of the components properties, risking even a detrimental failure and should therefore be prevented. In the present paper alumina-graphite refractories were produced according to standard commercial practice and mechanical, as well as physical properties were tested taking into account the carbon content and the application of nanoscaled additives. The investigations showed a correlation between the porous structure and the generation of a self-glaze after the heat treatment in air, effectively inhibiting the oxidation process. Moreover, the mechanical and thermo-mechanical behavior of the tested samples was comparable to commercial components. These newly developed self-glazed Al2O3-C refractories could have the potential to replace the currently used components in the near future.

5:00 PM

(UNITECR-115-2013) Effects of viscosity and surface tension of Free fluorine fluxes on the wear mechanisms of Al2O3-C nozzle

E. Brandaleze*, M. Avalos, V. Peirani, Universidad Tecnológica Nacional-Facultad Regional San Nicolás, Argentina

Fluoride emissions during continuous casting could cause health problems and equipment corrosion. Nowadays free fluor mould fluxes are developed, using other oxides in order to substitute fluoride compounds. Flux physical properties must be guaranteed to prevent operation problems and to avoid product defects. Nevertheless, it is so relevant to understand the effect of the new fluxes on nozzle wear mechanisms. In this paper, fluxes with B2O3 and Li2O were selected for a corrosion study on Al2O3-C nozzle. The study includes static and dynamic corrosion tests developed at 1400C. Also, viscosity and surface tension of the fluxes were determined in order to correlate with results obtained using light and electron microscopy (ESEM) including EDS analysis. The EBSD technique contributes to increase the knowledge on wear mechanism information. Finally, the results were correlated with a thermodynamic study carried out with the software Fact Sage.

Poster Session

Room: Palm Court

(UNITECR-P002-2013) Development of High Performance Alumina-Chrome-Zirconia Brick for Multiple Applications

A. Chakrabarti, B. Ghosh, S. Adak*, P. B. Panda, A. K. Chattopadhyay, TRL Krosaki Refractories Limited, India; S. Chattopadhyaya, B. Das, Sterlite Industries Limited, India

Alumina-Chrome-Zirconia system is well known for its outstanding thermo-mechanical properties and corrosion resistance towards various metals and slag. Binary Phase Diagram of alumina-chrome system shows a complete solid solution (hence, excellent corrosion resistance) and presence of zirconia in alumina-chrome system improves thermal shock resistance of the refractory by virtue of creation of micro-cracks within the matrix. The present work describes the development of alumina-chrome-zirconia refractory having some unique characteristics for application in copper smelters, incinerators, pelletization furnace, glass tank furnaces etc. High purity raw materials like fused corundum, reaction bonded chrome oxide and specially designed monocilinic zirconia with optimum granulometry were selected for design of the product. The developed products were thoroughly characterized for AP, BD, CCS, RUL, HMOR and chemical analysis. The final product with optimum properties was tested for XRD, SEM, slag corrosion resistance and thermal shock resistance.

(UNITECR-P003-2013) Optimum Quantity of Gas blown into the Bore of Tundish Upper Nozzle

A. Mizobe*, J. Kurisu, K. Furukawa, T. Tsuduki, M. Yamamoto, T. Oouchi, K. Oki, KrosakiHarima Corporation, Japan

Inert gas(Ar) is blown into the bore of tundish upper nozzle for continuous casting of steel in order to avoid adhesion of inclusions to its inner surface by forming gas-protection-layer(curtain-like gas film) to it. In case of less quantity of blown-gas, the gas-protection-effect would be ineffective. Conversely in case of excess quantity of blown-gas, although the gas-protection-effect would be effective, turbulent flow would generate inside the nozzle bore because of gas floating power(buoyancy force). In respect to suppressing turbulent energy, the optimum geometry of nozzle inner surface has been already reported. The decision of the optimum quantity of gas blown into nozzle bore by theory construction, computational fluid dynamics(CFD) and water modeling examination with applying the above mentioned optimal nozzle bore profile is described in the present report.

(UNITECR-P004-2013) Nanostructured self-flow refractory castable to long-life melt aluminum contact lining

F. L. Ziegler*, F. D. Valenzuela, ZTECH Refractories Industry, Brazil

This work shows the development route of a nanostructured no-wetting zero-cement refractory castable. To characterize the chemical, physical, thermomechanical and non-wetting properties were used X-ray difratometry, mass spectrometry, water cyclic thermal shock and liquid metal cup-test. Industrial tests are carried too. This work showed comparative form to some commercial high-performance concretes, and indicates that improvement of microstructure through the selection of raw materials, chemicals additives, particles packaging and nanostructured binder, let develop refractory castable to contact with liquid aluminum with lower cleaning and maintenance rates, reaching higher durability in service.

(UNITECR-P005-2013) Thermo-mechanics of ceramic filter structures

J. Storm*, M. Abendroth, M. Kuna, C. Aneziris, TU Bergakademie Freiberg, Germany

Ceramic open-cell foams are used for the filtration of metallic melts. Thermo-mechanical simulations of such structures are complex and therefor often simplified by using beam models. This talk shows detailed studies of the influence of geometrical properties on the

thermo-mechanical behaviour. For this purpose realistic volume models are used. Computer generated models are used due to some disadvantages of volume models derived from computer tomography (CT) data. The method to generate such complex structures is versatile and can also be used for other structures (e.g. close-cell foams). It allows to study diverse geometrical properties like strut and node shapes, cavities and coatings, which are neglected by more simple approximations of the geometrical model. The geometry of the open-cell foam can be further optimised to reduce maximal stresses or strains. The results will be compared with those of beam models and empirical solutions from literature. The simulations show the limitations of beam models and improve the understanding of the thermo-mechanical behaviour of open-cell foams.

(UNITECR-P006-2013) Tape Casting of Coarse-Grained Oxide Powders for the Manufacture of Advanced Refractory Multilayer Composites

D. Jakobsen*, I. Götschel, A. Roosen, University Erlangen-Nuremberg, Germany

In this work, the ceramic multilayer technique, which is based on tape cast green sheets, was applied to generate advanced refractory composite structures. High purity refractory oxides like alumina, magnesia and Mg-Al-spinell were used for casting tapes with thicknesses of several mm. Tapes of different porosity and microstructure were obtained using multi-modal slurries of grain sizes up to 1 mm. Via lamination of the green tapes and co-firing, multilayer structures were formed. To improve the thermal shock behaviour of the carbon-free compos-ites, specific multilayer designs have been realized. The processing route as well as the me-chanical and thermo-mechanical properties of the sintered tapes and composites will be de-scribed and the interrelation between processing, design and properties will be discussed.

(UNITECR-P008-2013) Microstructure and properties of porous ZrO2 ceramics prepared by foaming combined with gelcasting methods

G. Wang*, J. Han, B. Yuan, H. Li, Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China

Porous calcium stabilized zirconia ceramics with ultra-high porosity and ultra-low thermal conductivity were prepared by direct foaming methods combined with gelcasting. The phase composition of the sintered ceramics was detected by X-ray diffraction (XRD). The microstructure of sintered ceramics prepared with different foaming agent was observed by scanning electron microscope (SEM). Its forming mechanism was also analysed. The porosity of ZrO2 ceramics varied from 66.4% to 84.4% with the addition of foaming agent increasing, while the compressive strength descended from 75.32 MPa to 16.39 MPa and the bending strength descended from 25.84 MPa to 4.79 MPa. The thermal conductivity of the ZrO2 ceramic with the 80.0% porosity was 0.180 Wm-1K-1 at 400 °C and 0.220 W m-1K-1 at 1200 °C. The ZrO2 ceramics can be applied as insulating refractory at high temperatures due to their excellent mechanical and heat insulation properties.

(UNITECR-P009-2013) Influence of the additive of cordierite on the properties of mullite-andalusite-cordierite brick

D. Hongqin*, L. Fuchao, L. Jiantao, S. Gengchen, Z. Guolu, G. Nan, G. Shijian, zhenzhou Annec Industrial Co., Ltd, China; L. Suping, Y. Fangbao, Zhengzhou University, China

1.Preface: Andalusite is the top choice for the ceramic burner of HBS for its good TSR, high RUL and low creep. Influence of addition and way of cordierite and andalusite on TSR of mullite-andalusite-cordierite brick is studied. 2.Procedure: The bricks with cordierite are fired at 1390°C and the bricks without cordierite at 1450°C. XRD and SEM have been tested. 3. Results and discussions: The addition of cordierite is 0, 10% and 15%. RUL decreases and TSR increases with the increase of cordierite, and the reasonable addition is 10%. The brick with cordierite of 1-0mm has higher RUL than that with cordierite of 180 meshes. The negative influence of mullite particle on the RUL and TSR attributes to the microstructure of mullite with more pores. TSR of bricks added with cordierite is good, which because andalusite grains have more micro-cracks. The second reason is because of difference thermal expansions (cordierite of 2×10-6, andalusite 5×10-6 and mullite of 7×10-6) and the unmatched coefficients lead to micro-cracks in matrix during the cooling process after firing. 4.Conclusion: For the mullite-andalusite-cordierite brick with high TSR and high RUL, the reasonable adding quantity of cordierite is 10%, and the reasonable particle size is 1-0mm.

(UNITECR-P010-2013) Development of measuring method of torpedo car brick thickness using commercial 3D laser scanner

R. Otake*, T. Ozato, N. Sakaguchi, K. Nakanishi, K. Kobayashi, KOBE STEEL, LTD, Japan

In Kakogawa works, dephosphorization and desulphurization treatment has been performed in torpedo car and refractory brick used in the torpedo car has been damaged severely by high basicity slag and oxidization gas. Wearing rate of brick has been changed depending on its treatment. Moreover it is difficult to estimate the thickness of brick visually because of the complicated shape of torpedo car shell. In order to evaluate the damaged position with good accuracy in a short time and to visualize the damaged area, we developed a measuring method for torpedo car brick thickness in room temperature using commercial 3D laser scanner. In this method, only a commercial 3D scanner and some target spheres and an analysis computer is used. This method has achieved a good accuracy of the torpedo brick thickness data actually. Using this method, the life of torpedo car refractory brick has been prolonged by appropriate repairing and the usage amount of torpedo car refractory brick has been reduced.

(UNITECR-P012-2013) Chemical wear of Al2O3-MgO-C bricks by air and basic slags

L. Musante, P. G. Galliano, Center for Industrial Research-TENARIS, Argentina; E. Brandaleze, Universidad Tecnológica Nacional, Argentina; V. Muñoz, A. G. Tomba Martinez*, INTEMA, Argentina

Al2O3-MgO-C (AMC) refractory bricks maintain their high consumption level in steelmaking plants due to their excellent properties: the high thermal conductivity, thermal shock and slag attack resistances and the spinelization that induces an expansion counterbalancing the wear of the brick joint by reducing slag penetration. In this work, the oxidation and the corrosion resistance to a basic ladle slag of commercial AMC refractories were evaluated. Techniques as XRD, XRF, ICP-OES, DTA/TGA, density, porosity and permeability measurements, mercury intrusion porosimetry, and SEM/EDX were employed for the refractories characterization. The oxidation tests were performed in air between 700 and 1400°C (2 h) on cylinders (diameter: 27 mm, height: 25 mm). Static corrosion tests were carried out on cubes (length: 50 mm) with a hole (diameter: 35 mm, height: 30 mm) at 1400°C (2 h) in air. The weight loss of oxidized samples was determined. Both types of specimens were transversally cut. Decarburized areas by image analysis and mineralogical composition by XRD were determined on the surface of oxidized samples. The corroded surfaces were ground and polished for image and SEM/EDS analyses for determining the worn area and the microstructure of the slag-refractory interface. Differences between the oxidation and slag resistance of the studied materials were related to the composition and microstructure of each refractory.

(UNITECR-P013-2013) Alumina-Magnesia-Carbon bricks for steel ladle

M. Klewski*, M. Sulkowski, ArcelorMittal Refractories, Poland; P. Blumenfeld, ArcelorMittal Fos-sur-Mer, France

The properties of alumina-magnesia-carbon refractories applied in steel ladles have been analyzed. It is essential to obtain proper volume stability within a wide range of temperature. Our extensive experience in the use of A-M-C bricks in numerous steel plants shows how important it is to control the changes of the linear dimensions for the

life of ladle refractory linings. The permanent linear change of A-M-C bricks depends mainly on the quantity of the magnesium- aluminium spinel formed 'in situ'. It has been found that the content of spinel depends not only on the content of MgO, Al2O3, grain size, temperature and the heating time, but also on the content of impurities in the major raw materials. The article presents the test results of these bricks, which were manufactured with the use of various types of major raw materials of Al2O3 group: brown and white corundum, bauxites, brown sintered alumina.

(UNITECR-P014-2013) Role of design and application in refractory performance

P. Saha*, B. Sarkar, P. P. Lahiri, Engineers India Limited, India

Performance of a refractory lining system primarily depends on design and application. Appropriate selection of material, anchoring system and provision for adequate thermal expansion are the key elements in a refractory design. This paper highlights select case studies, where performance has been enhanced by small changes in the design. Change of anchor design from fixed to floating type increased refractory life from 6 months to 4 years in CCU cooler. Refractory life increased to almost double by modification of air mixer nozzle in a secondary reformer. Effectiveness of a refractory design largely depends on the application. Some case studies of the refractory failure analysis undertaken by authors are presented in the paper, which reveals wrong application is a major reason of refractory failures in many instances. Case study of a tail gas combustor refractory failure in a carbon black industry and bridge wall refractory failure in a multi cell CCR heater are typical examples of refractory failure due to wrong application. In oil and gas processing furnaces like crackers, reformers, FCCU, SRU etc, refractory performance becomes vital for smooth operation of these process units. In most cases, licensor's specification adequately defines the essential requirements concerning design but, effective implementation of the same requires review of the detail engineering and application supervision by an independent agency.

(UNITECR-P015-2013) Application of multi-hole stopper for mould level stability

S. Choi*, I. Lee, D. Choi, K. Choi, S. Lee, S. Sunwoo, Chosun refractories, Republic of Korea

Achieving high surface quality steel in the continous casting process requires optimal mould level control. The main objective of a flow control stopper is to keep the steady molten steel level in the mould. However,non metallic deposition is commonly attached to the nose part in conventional stopper, which leads to significant stopper position raise and mould level fluctuation. To improve mould flow stability,multi hole stopper with several holes around nose at specific positions has been developed.Ar gas injection through multi holes prevents the non metallic deposition to the nose and the Ar gas bubble make floating the non metallic inclusion in the mould to the surface.Through the water model experiment, the number of holes and its position has been optimized. In the plant trial,developed multi hole stopper have been applied successfully. By the absence of deposition on the stopper nose,the stopper position is not fluctuated anymore and the uniform Ar gas injection back pressure has been confirmed during the casting which results stable mould level control.

(UNITECR-P016-2013) Improvement of the thermal shock resistance on lower nozzle for tundish and ladle

K. Iwamoto*, H. Kamio, K. Morikawa, J. Yoshitomi, Krosaki Harima Corporation, Japan

The lower nozzle (LN) applied to tundish and ladle are suffered severe thermal loads, the damages are itemized as, slag corrosion, molten steel abrasion, and thermal/ structural spalling in the casting of the molten steel. It is often reported that the operating trouble of the LN is occurred by air aspiration through the cracks by the thermal spalling. Generally the unburned materials of Al2O3-C or Al2O3-ZrO2-C systems are applied to the LN with addition of pitch/ graphite carbon and ZrO2 system raw material in order to improve the thermal shock resistance. In order to improve further the durability against the thermal shock resistance without these raw materials, it was successfully applied by controlling both the particle size composition and diameter distribution of pore in the organization of the LN.

(UNITECR-P017-2013) Effects of Particle Size and Impurities on Mullitization of Andalusite

S. Li, G. Ye*, Y. Zhang, X. Song, J. Ma, C. Zhang, Zhengzhou University, China

Andalusite is a kind of high-quality natural refractory raw material, and andalusite-based refractory has good high-temperature mechanical properties and thermal shock resistance, which grant it a wide use range in iron and steel industry and other high temperature industries. In this work, different sources of andalusite from France, South Africa, Peru and China are used as experimental raw materials. The phase composition and microstructure of the raw materials during firing at different temperatures are analyzed by XRD, SEM and DSC, with aim at establishing the dependence of decomposition and transformation on particle sites and impurities of andalusite.

(UNITECR-P018-2013) Study on Erosion Mechanism of Cr2O3-Al2O3-ZrO2 Bricks for Coal-water Slurry Pressurized Gasifier

Y. Li*, Luoyang Lier Refractories Co., Ltd., China; C. Ke, Y. Zhang, Wuhan University of Science and Technology, China; Y. Zhang, J. Zhao, Luoyang Lier Refractories Co., Ltd., China; G. Ye, Zhengzhou University, China

The microstructure of used Cr2O3-Al2O3-ZrO2 bricks in different positions of coal-water slurry pressurized gasifier has been investigated by using SEM and EDS, and the erosion mechanism is discussed. The results showed that, under the operating conditions of coal-water slurry pressurized gasifier, the coal slag infiltrates into Cr2O3-Al2O3-ZrO2 bricks mainly through pores and cracks; the main reason of the erosion of Cr2O3-Al2O3-ZrO2 bricks is the strength weakening and the structure spalling of the bricks caused by the composition change and the destruction of the initial network mosaic structure resulted from the penetration of slags and the reaction between strongly reducing gases and bricks.

(UNITECR-P019-2013) Calcium Hexaluminate Distribution and Properties of Calcium Alumina Cement Bonded Castables with Addition of Magnesium Chloride Addition

C. Zhang, G. Ye*, L. Zhu, Q. Wang, Y. Mu, Zhengzhou University, China; C. Wang, Henan University of Technology, China

In-situ calcium hexaluminate ($CaO\ 6Al_2O_3$, CA_6) formation is beneficial to the properties of corundum-based castables bonded with calcium alumina cement (CAC). But formation and distribution of In-situ calcium hexaluminate influences volumetric stability and mechanical strength of the castables at high temperatures. In this work, different contents of magnesium chloride were added in the castables to investigate CA_6 distribution effect on the volume stability and thermal shock resistance of the castables. Calcium hexaluminate formation with different additions of magnesium chloride was analyzed by using powder X-ray diffractometry and calcium hexaluminate distribution in the castables observed with scanning electronic microscope.

(UNITECR-P020-2013) New Developments on Refractory Hollowware Materials for Ingot Casting

R. de Paula Rettore*, E. Gueguen, G. Zieba, Magnesita Refractories, Germany

Refractory products for ingot casting normally require good thermal shock and high erosion and corrosion resistances. A high thermal shock resistance and erosion resistance is normally achieved by Refractories of the high alumina to silica systems, in which corundum and mullite, are the main mineral phases. To increase hot strength, however, it is necessary to lower the level of impurities, e.g. Fe2O3, TiO2 and alkali, which are normally present in natural raw materials. In this way, a new high alumina material, composed by a special syn-

thetic aggregate and a pure matrix was developed. This new refractory material presented 150oC higher T05 refractoriness under load when compared with fired bauxite bricks (84% Al2O3). Superior thermal shock was also obtained, observed by the higher residual mechanical strength after 10 thermal cycles. To address the corrosion resistance, a novel approach was found by introducing 3% to 5% carbon into the refractory matrix. No matter the carbon source type used, practically no corrosion and no sticking between the refractory material and steel was observed. These new developments for refractory hollowware materials can be installed whenever strong operational conditions take place, like high casting temperature and high Mn containing steels. Some real cases of the utilisation of these new refractory hollowware materials will be presented and discussed.

(UNITECR-P021-2013) How do steelmakers pick refractories? A supplier's perspective

I. Prendergast*, ANH Refractories, USA

Review of materials, products and operations and the interactions between them all, to enable the steelmaker to be able to select the most cost-effective solution.

(UNITECR-P023-2013) Improving Maintenance at Direct-Reduction Plants Using Infrared Thermography

Y. J. Giron, E. J. Estrada, Siderurgica del Orinoco - Sidor, Venezuela, Bolivarian Republic of; D. Gutierrez*, Universidad Simon Bolivar, Venezuela, Bolivarian Republic of

Direct-reduction process is a fundamental link into the steel industry because their products (DRI) could directly affect the productivity of Electric Arch Furnaces (EAF). Therefore, proper operation and appropriate scheduling for maintenance are key parameters to increase efficiency at any steel plant. On the other hand, infrared thermography allows the evaluation of refractory lining for operating equipment and, thus, it can be used to detect and monitor problem areas. In this regard, the present work documents actual cases of infrared inspection at the direct-reduction plant in the iron and steel industry of Venezuela. By means of this system, the preventing maintenance in the reforming, reduction, recuperation and associated ducts was improved. Also, out-of-scheduled shutdowns were reduced and, a systematic program for better maintenance was developed.

(UNITECR-P025-2013) Steel Cleanliness and Sequence length Improvement through Tundish Configuration and Black Refractories Quality Optimization and by Introducing the Concept of Management at JSW Steel Vijaynagar Works , INDIA

A. K. Sarkar*, JSW Steel INDIA, India

Performance of a steel making shop is governed by the productivity of its caster . The productivity of continuous caster depends on its utilization which in turn determined by its sequence length and yield . Longer casting sequence avoid time loss in repeated cast start preparation and also result in higher yield as start up and tail out loss are minimized . Casting sequence length is restricted by SEN (Submerged Entry nuzzle) Stopper Rod , shroud and Life of tundish . It thus become necessary and indespensible to enhance the utilization of existing facility and adopt new modulus to increase the sequence length . Emperical models for control of super heat , mould level fluctuation , dams and wire design , turbo stop and Clogging and argon flow rate were prepared to control the flow dynamics in the tundish and inside the mould and modify the process parameter during casting.

(UNITECR-P026-2013) Present Trend of Pre-cast Shape and Refractory Castable uses in Vizag Steel Plant, India: Challenges Faced and Success Stories

A. Datta, P. Paul*, Rastriya Ispat Nigam Limited, Visakhapatnam Steel Plant, India

Refractory castable mixes, often called refractory concrete, have been known for approximately last 40 years. These developments include a better understanding of the principles governing the strength at service temperatures, different ideas on the optimum application and curing methods, the introduction of improved bonding media, and the use of improved refractory aggregates in the castable mixes. In turn this has allowed refractory castables to accelerate their use as most dependant material for refractory solution in many types of furnaces, kilns and other equipments in integrated steel plants. In RINL, Vizag Steel Plant, India, refractory castable has wide range of application in the areas like repair of stacks and lining of iron and slag runners in blast furnace, steel ladle and tundish linings, hearth and skid/posts of rolling mills furnace, charging and discharge areas of rotary kilns etc. In this paper attempt has been made to discuss different areas for castable applications & pre-cast shapes in Vizag Steel, its challenges and technical requirements from the suppliers and R&D organization regarding the quality improvement, assuring the quality consistency, innovation in application technique and hot repairing measures.

(UNITECR-P028-2013) Optical Microscopy and its Contribution to The Control of Applied Submerged Entry Nozzle - SEN in Continuous Casting of Steel

S. Devic*, Institut IMS, Serbia; M. Cocic, M. Logar, Technical Faculty, Serbia

The aim of this paper is to present some results using optical microscopy in control of SEN. Simultaneous display of test results that show the contribution of this method in the process of continuous casting of steel. In the long run was monitored and tested a large number of SEN, and to show the most interesting results of the respondents selected SEN. SEN tested parts are molded refractory materials based alumografita manufactured by isostatic pressing. For examination by optical microscopy was used a polarizing microscope Neophot 32. The crystallizer SEN is in contact with steel, but with casting powder that is sprinkled on steel to protect the steel from oxidation. Steel operates on the inner wall of SEN, while casting powder on the outer side of the wall. The destructive effect of steel and casting powder and reduce the life of SEN, it is his durability. In the present paper, microphotography and look at the contact structure formed steel - SEN wall and touch casting powder – wall SEN. Appearance, structure and minerals as a result of examination by optical microscopy indicate influence of various factors on the process of continuous casting of steel. Based on the obtained results SEN, if necessary adjustments can be made in the management process. This correction is done depends on the cause and reduce the life of SEN.

(UNITECR-P030-2013) Volume expansion of SiC-based refractories induced by salts corrosion

E. de Bilbao*, Cemhti, France; P. Prigent, TRB, France; C. Mehdi-Souzani, LURPA, France; M. Bouchetou, Cemhti, France; N. Schmitt, LMT, France; J. Poirier, Cemhti, France; E. Blond, Prisme, France

Corrosion tests of SiC-based refractory cylinders with oxide bonding by molten salts (mainly $CaSO_4$, K_2SO_4) were performed at high temperature (860°C) at the lab scale in order to better understand the corrosion mechanisms. One or several salt pellets were putted on the upper surface of the cylinders. After melting, the corrosive product soaked into the porosity of the refractory and partially corroded the SiC phase. SEM-EDS analyses showed that pseudo-wollastonite ($CaSiO_3$) was the main new phase formed, growing from SiC aggregates in the porosity. As the formation of pseudo-wollastonite from SiC produces a swelling, after local filling the initial voids, the corrosion product pushed the walls of the solids phases so that an overall heterogeneous volume change of the sample was observed. The geometry of the initial and corroded cylinders were measured by means of a 3D coordinates measuring machine equipped with a laser-plane sensor. They permitted to characterize local volume expansion due to the phase change and to establish the evolution of the residual radial deformation versus the depth from the surface in contact with salt pellets. Coupling SEM-EDS analyses with 3D digitizing enabled to link the corrosion product to the volume expansion.

(UNITECR-P031-2013) Effects of Mg Addition on Phase Composition, Microstructure and Properties of Al2O3-C Material

X. Liu*, X. Zhu, L. Feng, High Temperature Ceramics Institute, China

The Al2O3-C material with Mg addition has been prepared by tabular alumina, ultra fine alumina, graphite and Mg as starting materials and resin as binder. The effects of Mg addition on phase composition, microstructure, physical and mechanical properties of Al2O3-C material at different temperatures have been studied. The results show that Mg begins to react with CO to form nano-sized MgO crystals at about 600C which causes some expansion and consequently increases apparent porosity slightly, but cold and hot strength increases noticeably which is attributed to MgO crystals interspersed in the corundum skeleton structure creating strengthening effect. MgO initially reacts with Al2O3 to form granular MgAl2O4 at about 1000C, the amount and size of MgAl2O4 increase with temperature from 1000C to 1400C. Due to strengthening effect of the granular and tabular MgAl2O4, cold and hot strength increase notably; but strength somewhat decreases after heating at 1400C possibly due to micro-cracks resulting from expansion accompanying MgAl2O4 formation.

(UNITECR-P032-2013) Specific material properties for the evaluation of the thermal stress resistance of refractory products: Compendium and new investigation methods

E. Brochen*, C. Dannert, Forschungsgemeinschaft Feuerfest e.V., Germany

The capacity of a refractory component to sustain thermal stresses, for instance caused by thermal shock, is a crucial characteristic for the quality and lifetime of refractory linings. However, the thermal stress resistance (TSR) is not a material-specific parameter, but rather depends on a large number of factors, including mechanical and thermal properties (fracture strength, E-Modulus, thermal expansion coefficient and conductivity), the geometry of the component and the heat transfer conditions (heat transfer coefficient, temperature of the surrounding medium(s), thermal flux…). The impact of those factors on the TSR and new testing systems to investigate them will be presented and discussed. Though the qualitative impact of each factor is quite well known, when several factors interfere concurrently, their impact on the TSR is however much more complicated to assess. The classical models and theories to depict the thermal stress resistance of refractories and their limitations will be introduced, and improvements to these models proposed.

(UNITECR-P034-2013) Properties Improvement of Light Weight Al2O3-SiO2 Castables by Andalusite Addition

N. Zhou*, S. Hu, H. Wang, Henan University of Science and Technology, China; X. Xiong, X. Liu, Damrec-Imerys, France

High performance light weight castables (LWC) in Al2O3-SiO2 system are increasingly needed for energy saving, for which concerns in terms of shrinkage, insufficient strength, etc must be eliminated by improving properties. This work investigated the role of andalusite addition in improving properties of two series LWC using mullite based hollow balls and micro-pored mullite as aggregates respectively. The effect of andalusite additions up to 30% at an interval of 6% was investigated on bulk density, permanent linear change (PLC), hot modulus of rupture (HMOR), refractoriness under load (RUL), thermal shock resistance (TSR) and thermal conductivity (TC). By means of SEM and EDAX, microstructure of the samples was also characterized. The in situ mullitization effect of the added andalusite leads to improved PLC, HMOR and RUL of the LWC. For the hollow balls LWC, andalusite adding can improve TSR, while affects TC little. For the micro-pored mullite LWC, with increased addition of andalusite, TC decreases. The improvement effect by andalusite addition is attributed to the favorable matrix microstructure featured by interlaced mullite derived from andalusite, dotted with SiO2-rich liquid phase within the mullite based network.

(UNITECR-P035-2013) Influence of process conditions on the crystallization of calcium silicates in the stirring autoclave and their impact on thermal stability

B. Schickle*, R. Telle, T. Tonnesen, Institute of Mineral Engineering, Germany; A. Opsommer, Promat Research and Technology Centre N.V., Belgium

The thermal stability of calcium silicates is limited by the phase transformation of its main phases xonotlite and tobermorite and other calcium silicate hydrates (C-S-H) containing more crystal water into wollastonite at higher temperatures. To improve the thermal stability, it is necessary to decrease the amount of amorphous or poorly crystalline phases which are mainly responsible for high shrinkage values. In addition to reasons related to raw materials, the process conditions play an important role for the crystallization of the calcium silicates. In the present work, several trials were carried out on a laboratory scale stirring autoclave to show the effects of changing process parameters like ramp and dwell time, temperature / pressure and stirring speed on the formation of calcium silicates. The synthesised powder was analysed with use of quantitative and qualitative XRD, specific surface area measurements and SEM. Furthermore, in a second step, the filter pressed products were investigated to find out the influence of the phase composition and micro structure on the thermal stability behaviour which was determined by using thermomechanical analyses (TMA).

(UNITECR-P036-2013) Influence of aluminates of evaluation thermomechanical properties refractory materials from the MgO-CaO-Al2O3-ZrO2 system

J. Szczerba, AGH University of Science and Technology, Poland; M. Szymaszek, Zaklady Magnezytowe ROPCZYCE S.A., Poland; E. Sniezek*, D. Madej, R. Prorok, AGH University of Science and Technology, Poland

The MgO-CaO-Al2O3-ZrO2 tetrahedron is composed of four high refractory simple oxides. The potential phase compositions for refractories in the MgO-CaO-Al2O3-ZrO2 system would be refractories from the MgO-CaZrO3-MgAl2O4, MgO-CaZrO3-CaAl2O4 or MgO-CaZrO3-CaAl2O4-MgAl2O4 systems. MgO-CaZrO3 refractories with the aluminium bond would be the good alternative in relation to the MgO-CaZrO3 refractories with the silicate bond. The thermo mechanical properties (CMOR, HMOR – 1250°C and 1450°C, CCS, elastic modulus, refractoriness under load, creep in compression, thermal shock resistance) of the composites were investigated. The samples were prepared by ceramics method under industrial conditions. Masses of magnesia-zirconia refractories were prepared using model of Dinger and Funk grain size distribution. As based raw material with low admixture content, the sinter magnesia clinker and calcium zirconate were used. Moreover, the microstructure of refractory composites was investigated. This paper presents that aluminate phases in significance way improve of application properties. The work was supported by the grant of The National Centre for Research and Development.

(UNITECR-P037-2013) Basic understanding of physical properties of carbon bonded refractory composites

D. Dupuy*, SPCTS UMR CNRS 70315, France; S. Zhu, D. DeBastiani, P. Guillo, C. Dumazeau, Vesuvius, USA; C. Peyratout, GEMH, France; M. Huger, T. Chotard, SPCTS UMR CNRS 70315, France

Advance in continuous steel casting process is related to the progress in the knowledge of thermomechanical behavior of carbon bonded refractories. Better understand the interactions between components of such materials and their influence on the macroscopic thermophysical properties is vital in order to keep a reliable control of their industrial elaboration. To achieve this comprehension, carbon based model materials using organic precursors for the carbon matrix and different oxides as fillers were elaborated to understand the interactions between the carbon matrix and the oxide particles. They were studied with different characterization methods such as Scanning Electron Microscopy and thermal expansion analysis. Depending on

the load, two types of composites were obtained: 1)an amorphous carbon matrix containing dispersed oxide particles, 2)a network with connected oxide particles linked by amorphous carbon. Due to the thermal expansion coefficient mismatch between the carbon and oxide particles, microcracks were developed in the microstructure. The presented results revealed that the thermomechanical properties can be engineered by tailoring the microstructure. Such fundamental understanding of carbon bonded refractory composites will enable the development of next generation of refractory materials to offer improved safety, reduced carbon footprint, and more energy efficient practices.

(UNITECR-P038-2013) Spinel Inversion and Lattice Parameters in Chromium-Free Spinel Solid Solutions

R. Lodha*, G. Oprea, T. Troczynski, The University of British Columbia, Canada

The objective of this work was to investigate the amount of inversion in complex spinel solid solutions in order to understand the synthesis and sintering of magnesia-rich chromium-free complex spinels and their solid solutions. It has been observed that chromium-free spinels can be sintered at much lower temperatures (1350-1550°C) than the Cr3+ bearing versions, which require firing at 1720-1800°C, in order to achieve equivalent properties. We have determined that the low temperature synthesis is due to the low temperature defect structure, leading to activated synthesis and sintering of the complex spinels. The inversion of the spinel was calculated using theoretical considerations and correlated to the observed inversion for experimental samples fired at various temperatures. The inversion in the complex spinel phase versus firing temperatures and composition were correlated to the densification of the ceramic specimens fired in air at temperatures ranging from 1350°C to 1550°C for 3 hours, in order to understand the effect of crystallographic changes in terms of the values of the lattice parameters of the complex spinel phase and their effects on the bulk density, open porosity and compressive strength of this new type of chromium-free basic refractory ceramics.

(UNITECR-P041-2013) Challenges of Blast Furnace Casthouse: Failure Analysis of Main Runner Refractory Castable

V. Domiciano*, A. R. Ollmann, E. I. Clemente, A. K. Duarte, A. M. Brito, Magnesita Refratários S.A., Brazil

The Brazilian iron making scenario has experienced major changes in recent years as a result of the huge competition in the global steel market. In Blast Furnace, the use economically competitive raw materials (iron ore, coke, alternative fuels, etc.) have allowed to reduce production costs of pig iron. In the meantime, it has been noticed frequent fluctuations in the Blast Furnaces operating conditions (casting temperature, slag-rate, slag composition, etc.) which has shown a direct impact on the performance of main runner refractory castables. The need to adjust the products to increasingly severe operational conditions has been a major challenge for refractory's' suppliers in order to guarantee the safety and availability of runners for operation. This paper presents the results of a post-mortem study carried out with a main runner Al2O3-SiC-C refractory castable, which showed a remarkable wear in the metal line zone resulting in an accident. The physico-chemical characterization, ceramografy and scanning electron microscopy have identified something unusual in the samples: the presence of significant amounts of alkalis (K2O and Na2O) dissolved in the slag-hot metal interface and infiltrated slag suggests a synergy of wear mechanisms and illustrates the severe conditions to which the main runner working line could be subjected in today's Blast Furnace casthouse operation.

(UNITECR-P042-2013) Rotary Kilns: Lining, Design and Energy Savings

P. Trane, N. Jacobsen*, C. Bach, Skamol A/S, Denmark

Rotary kilns are used in a wide range of industries for Drying, Sintering and Calcination of raw materials. This paper will focus on the use of rotary kilns in mineral processing industries, how to improve the energy efficiency of kilns, service life of the refractory lining and auxiliary mechanical equipment, trough a dual lining insulating concept. As energy prices are soaring high efficiency is increasingly becoming an important factor in an ever more competitive business environment globally. CO2, NOX, SOX and other noxious gas-emissions are gaining political awareness, it is therefore important to address alternative and improved designs of rotary kiln linings. By installing good and efficient insulation and refractory materials in kiln linings, massive savings in energy costs can be achieved. The paper will include thermal, calculations based on Rotary Kiln producing light weight aggregate. A description of benefits/drawbacks of dual lining design, and what a rotary kiln owner should take in to consideration when choosing refractory design. In addition examples of installation methods will be described.

Thursday, September 12, 2013

Plenary Session I

Room: Lecture Theatre
Session Chair: Dana Goski, Allied Mineral Products

8:00 AM

(UNITECR-002-2013) How Do Steel Makers Pick Refractories - Logic, Emotion or Dartboard?

T. Vert*, ArcelorMittal Dofasco, Canada

not available

Monolithics IV

Room: Lecture Theatre
Session Chair: Bjorn Myhre, Elkem; Christos G Aneziris, Technical University Bergakademie Freiberg

9:20 AM

(UNITECR-161-2013) Cement Hydration and Strength Development – How Can Reproducible Results be Achieved?

D. Schmidtmeier, A. Buhr*, Almatis GmbH, Germany; G. Wams, S. Kuiper, Almatis B.V., Netherlands; S. Klaus, F. Götz-Neunhöfer, University Erlangen, Germany; D. Zacherl, Almatis Inc., USA; J. Dutton, N/A, United Kingdom

The consistency of high alumina cements, with regard to setting and strength development, is a key quality feature which distinguishes different brands available in the market. The quality testing of cement must take into account inherent variation of the cement setting behavior which occurs, for example, in neat cement testing. When testing in castables the ambient conditions such as temperature, humidity, and a covering of the samples can have an influence on the strength development. The paper discusses results obtained in calorimetric testing of different cement test grogs and of castable testing under practical laboratory conditions with different cement content and additives in the test castables.

9:40 AM

(UNITECR-162-2013) Mixing optimization of an alumina based LC castable by applying variable power inputs and the effect on the rheology during molding, the setting and hardening behavior as well as the derived mechanical properties

J. Kasper*, O. Krause, University of Applied Science Koblenz, Germany

The mixing conditions are a key issue for molding highly dispersed refractory castables. Up to now there is only poor understanding about the interactions of mixing energy and microfillers as well as the applied dispersing agent and its concentration. The tests were carried out by using an EIRICH R05 mixing device, being capable of altering the mixing power. During mixing the engine power was recorded to determine power input and the progression of the mixing process. The rheological properties of the resulting mix were analyzed by applying a ball measuring system (BMS). The resulting setting and

hardening properties were investigated by simultaneously measuring sonic velocity and electrical conductivity. Furthermore the influence on the dry strength was analyzed. The end of the mixing process can be determined exactly by evaluating power-time-diagrams. By applying an optimized mixing procedure it is shown that the rheological and hardening properties change distinctly. BMS-measurements exhibit a reduction of viscosity and the hardening time is reduced for several hours. The results promise an enhanced understanding of castable technology and therefore the resulting properties are more predictable.

10:00 AM

(UNITECR-163-2013) Rheological & Dispersion behaviour of reactive aluminas in matrix formulation

A. Lafaurie*, E. Chabas, C. Ulrich, ALTEO, France

This study aims understanding key paramaters in Aluminas that leads to different behaviour in early stage of castable formulation. High aluminas castable formulation is made to get the lower amount of water with enhanced workability and optimized setting time depending on cement amount. Basically, to achieve these behaviour, reactive aluminas/cement/additives interactions optimisation is a key to success. In this study, we first start by studying the alumina itself in water suspension, we study the impact of concentration, pH, type of aluminas (impurities; surface area, PSD, crystal size & shape…) and additives on some simple flowability tests and deeper investigation like potential zeta and rheological behaviour to assess dilatancy of aluminas. Then deeper investigations were made on the influence of calcium aluminate cement (CAC) addition on rheological behaviour and stability of suspensions. To confirm results in suspensions, we carried on a study on a full matrix system containing different type of alumina, CAC amount (from regular to ultralow content) and fines under 100µm from aggregates (tabular or white fused aluminas). Rheological development in early stage is investigated.

10:20 AM

(UNITECR-164-2013) Effect of Minor Elements on Solid-liquid Interactions in Calcium Aluminate Cement Refractories

J. Alex*, L. Vandeperre, Imperial College London, United Kingdom; B. Touzo, C. Parr, Kerneos Ltd., France; W. E. Lee, Imperial College London, United Kingdom

The role of various oxides on the solid-liquid interactions in calcium aluminate cements (CACs) at high temperatures is being examined using phase and microstructural characterisation (SEM, TEM, XRD and TGA) and Gibbs energy minimisation computational modelling. In light of recent trends in the refractory industry to replace bricks by higher purity CAC-based monolithics for enhanced durability, performance and novel applicability, improved mineralogical control is of growing significance. The effect of minor elements on the development of a microstructure within these systems during processing and application is being examined with emphasis on potential mineralisation effects of liquid formation linked to these elements as well as the grain growth which occurs through dissolution/precipitation reactions. Furthermore, threshold values were determined above which the presence of minor elements leads to a deterioration of desirable refractory castable properties.

10:40 AM

(UNITECR-P027-2013) Methods to assess the drying ability of refractory castables

P. Ermtraud, CALDERYS, Germany; P. Meunier*, J. Soudier, CALDERYS, France

Refractory castables of different types are more or less sensitive to steam spalling during drying. The main castable properties which control the drying ability of these castables are on one hand, water desorption / dehydration isotherms and permeability and on the other hand, strength required to resist the steam pressure build up. However the assessment of the sensitivity to steam spalling is not so easy since these properties are not independent, steam pressure being a common parameter. So simulation tests are used. Non directional heating of small samples in dry atmosphere hardly take into account the cross- influence of steam pressure. Unidirectional heating of larger samples allow a more realistic comparison of the drying rates. In addition, temperature measurements throughout the thickness of the samples can be used to assess the pressure build up. Unidirectional heating of large samples can also be used as spalling test for castables with a low strength, provided that lateral and rear water and steam losses are prevented. For stronger castables, the heat flux with unidirectional laboratory set ups is usually too small to maintain a high vaporisation rate deep inside the castable and consequently to reach explosion.

Monolithics V

Room: Lecture Theatre
Session Chair: Dave Bakshi, C-E Minerals; Jens Decker, Stellar Materials

11:20 AM

(UNITECR-165-2013) The Effect of Aging of Blast Furnace Trough Castables Due to Storage Conditions on Performance in Service

S. Bonsall*, W. Gavrish, Vesuvius USA, USA

Cement bonded refractory castables for blast furnace troughs play an important role in the overall blast furnace refractory system. However, the installation and operational properties of these critical refractories can be severely compromised by improper storage of the materials prior to installation. Material degradation can happen without obvious signs to the casual observer. Laboratory experiments will be reviewed that show the effects of water ingress into bags of castables during storage. Packaging the cement separately from the castable has been successfully implemented as a countermeasure. Not only are safety issues (hard lumps) avoided, but several other benefits such as more consistent installation and improved service life have been observed.

11:40 AM

(UNITECR-166-2013) Practical experience of time stable calcium aluminates in low cement castable applications

F. Simonin*, C. Parr, H. Fryda, J. Mahiaoui, M. Szepizdyn, KERNEOS, France; O. Pawlig, KERNEOS, Germany

A key factor for improving the reliability of deflocculated dense low calcium content castables is to increase their resistance to ageing. This means offering much longer shelf-life and providing predictable placing and hardening properties, irrespective of the storage time. Ageing is a generic name used to describe interactions between a cement or a castable and the atmosphere, and consequently the impact this interaction has on the cement reactivity and the castable properties as a function of dry mix storage time. Ageing on job sites manifests itself as a change in placing properties such as delayed hardening and demoulding time. This paper presents results and analysis of different ageing stories, when either the cement alone or the full dry mix castable travel over the world with different climatic conditions and duration. An original method consists of following the evolution of temperature and relative humidity by means of sensors embedded in the cement or in the full dry mix castable. They point out the specific and severe climatic conditions the materials have to withstand and reinforce the improved resistance to ageing that the new time stable calcium aluminate cements can provide as a "travelling cement".

12:00 PM

(UNITECR-167-2013) Influence of alumina parameters on formulation characteristics and mechanical properties of refractory castables: A new added value range of reactive aluminas

E. Chabas*, A. Lafaurie, C. Ulrich, ALTEO, France

The properties of ceramic materials and by consequence refractory materials depend strongly on the homogeneity of their microstructure. Indeed the defects generated during the manufacturing process will not be corrected during the firing process and remain present in the final materials. The control of the microstructure is direct correlated with the properties of formulation, and more precisely with the characteristics of raw materials and some of their dispersion characteristics. The conventional refractory castables are composed of heterogeneous aggregates of tabular alumina and a cement matrix, this one consisting of clinker and fine alumina. The aim of these studies is to link parameters of formulation and refractory castables properties and highlight parameters of alumina (specific surface area, morphology, and impurities) having an influence on the microstructural parameters improving reactivity and mechanical strength of the castable. A first way to reach these correlations is to control and have a good understanding of powder dispersion in aqueous environment. We evaluated a new range of reactive aluminas developed by ALTEO.

12:20 PM

(UNITECR-168-2013) High Performance Gunning Mix With CT10SG as a Plasticizer

D. Zacherl*, Almatis, Inc, USA; B. Long, Qingdao Almatis, China; Z. Wang, Wuhan University of Science & Technology, China; A. Buhr, Almatis, GmbH, Germany

High purity calcined alumina product CT10SG, and the American equivalent A13 -325, has the proper particle size distribution and surface area required to achieve the water retaining properties which makes it ideal for use in gunning mixes. CT10SG was compared to conventional plasticizers such as soft clay and silica fume in a high performance gunning mix. The matrix study showed that the slurry containing CT10SG had an equivalent rheological behavior as compared to that made with traditional plasticizers. The alumina-based gunning mix with CT10SG displayed exceptional adhesion, minimal rebound, good consistency and nominal linear change. The CT10SG mix also exhibited a superior hot modulus of rupture and increased slag resistance.

12:40 PM

(UNITECR-169-2013) Time, energy and cost saving during monolithic refractory lining installation by combining Quick Dry technology and gunning technics

P. Malkmus, Calderys, Germany; P. Meunier*, J. Soudier, Calderys, France

A new monolithic refractory concept - based on a no-cement innovative bonding system called QD NCC for Quick Dry No Cement Castables - and permitting extreme rapid and safe dry-out and heating up, has been recently introduced and has become a standard solution. In order to extend primary advantages of QD NCC technology, this concept has been applied to monolithic installation technics such as Low Porosity Dense Gunning and Shotcreeting in order to further reduce overall installation time and related cost of monolithic linings. It is detailed how a pump-able, alkali resistant QD NCC product was designed and characterized at laboratory and industrial scale compared to state of the art cement bonded product. A special focus is given on behaviour during installation by shotcreeting (rheology, stick-ability and open time for surface flattening) and during drying (gas permeability and internal vapour pressure generation measurements during fast heating up). It is also presented how the QD NCC bonding system has been implemented in Low Porosity Dense Gunning dedicated products, and how drying ability of resulting lining has been improved.

Iron & Steel Making Refractories - Submerged Entry Nozzles

Room: Saanich

Session Chair: Arupk Chattopadahyay, TRL Krosaki Refractories; Farhad Golestanifard, Iran University of Science & Technology

9:20 AM

(UNITECR-116-2013) Main mechanisms of SEN slag band corrosion as observed by post mortem investigations

H. Harmuth*, N. Kölbl, Montanuniversitaet Leoben, Austria; B. Rollinger, RHI AG, Austria; G. Xia, voestalpine Stahl GmbH, Austria

The study aims to reveal the main mechanisms of SEN corrosion and erosion in dependence of the steel grade, the mold powder composition and the mode of operation for zirconia graphite materials. For this purpose post mortem investigations have been performed on worn specimens after service and after a laboratory test based on a rotating specimen in a steel/slag bath. Erosion is prepared by oxidation of the carbon bond and the graphite as well as by dissolution and destabilization of zirconia. For the latter one both liquid infiltration and transport via the gas phase are decisive. Results show how the relation of oxidative to corrosive attack depends on the steel grade and the mold slag composition. Moreover when the SEN is lifted during service in order to distribute the wear more evenly this ratio usually increases for a fixed area of the SEN and is lowest close to the liquid steel. Nevertheless also here oxidation of the carbon bond seems to be a necessary condition for following erosion. It is concluded that - contrary to other refractory applications - here graphite is not able to prevent slag infiltration in the same way. Oxidation of graphite and the carbon bond is reduced in the case of TRIP steel grades due to the lower oxygen partial pressure but is still regarded to be the weak link with respect to later erosion. Stabilized zirconia is more prone to disintegration.

9:40 AM

(UNITECR-117-2013) Critical Evaluation and Optimization of the Li2O-ZrO2 and Li2O-ZrO2-SiO2 systems

W. Kim*, I. Jung, McGill University, Canada

In the continuous casting process of steel, the submerged entry nozzle (SEN) typically made of the stabilized ZrO2-graphite can interact with mould flux and molten steel. In particular, the significant corrosion of the SEN by mould flux (CaO-SiO2-Na2O-Al2O3-K2O-Li2O-F) is commonly reported. In order to understand the corrosion mechanism accurately, thermodynamic database for the system are required. As part of a large thermodynamic database development for the mould flux in the continuous casting process, the thermodynamic modeling of the Li2O-ZrO2-SiO2 system was carried out in the present study. All thermodynamic property data and phase diagram data related to binary Li2O-ZrO2 and ternary Li2O-ZrO2-SiO2 systems in literature were critically evaluated and optimized to obtain one set of optimized model parameters. The liquid solution was in particular described using the Modified Quasichemical Model which takes into account the short range ordering in molten slag. The model parameters with thermodynamic models can be used to calculate any thermodynamic properties and phase diagram section using the FactSage software.

10:00 AM

(UNITECR-118-2013) Studies and optimization of various types of Zirconia to minimize crack propagation and improve corrosion and erosion resistance of slag band of Subentry nozzle

J. K. Sahu*, B. Prasad, A. Sen, J. Tiwari, OCL India Ltd, India

Zirconium dioxide (ZrO2) popularly known as Zirconia in combination with carbon used in slag band of Subentry nozzle.It has high refractoriness & excellent corrosion resistance properties.Pure zirconia exists in three crystalline phases. Cubic(>2370°C),tetragonal(1170-2370°C)&below1170°C,transforms to monoclinic phase with volume

expansion of 3-5%.This causes large stress & cracks on cooling. Oxides like MgO,CaO,Y2O3 dissolve in the zirconia crystal structure slow down or eliminate these crystal structure changes & maintains stable cubic structure even at room temperature is called "Cubic stabilized /partially stabilized cubic Zirconia".It does not go through destructive phase transitions during heating and cooling.On the other hand monoclinic Zirconia shows better corrosion resistance because of its purity but very prone to crack because of phase transformations at higher temperature.Studies have been made with different types of zirconia,its puritiy,particle size,mixed ratio with carbon & compared with corrosion/erosion,spalling behaviour.Products of different combinations are made & its physico-mechanical properties are discussed. This paper also throws some light on design part for slag band with field performance.

10:20 AM

(UNITECR-119-2013) Evaluation methods of the corrosion resistance of ZrO2-C material used for SEN slag line

K. Moriwaki*, K. Yamaguchi, M. Ogata, Shinagawa Refractories CO.,LTD., Japan

ZrO2-C material is applied for slag line of submerged entry nozzle (SEN) which is corroded by mold flux. Corrosion resistance of slag line ZrO2-C material is one of factor to decide durability of SEN. Corrosion resistance of ZrO2-C material is generally evaluated using molten iron and mold flux at high frequency induction furnace. However, Due to composition change of molten iron and mold flux by mutual reaction during test, the results are not agree among corrosion test under different conditions We investigated the condition of corrosion test for ZrO2-C material. (i.e. the composition of molten iron, atmosphere and the sample) We prepared the ZrO2-C material samples which contain different carbon contents and have different apparent porosities. Samples after corrosion test were observed the hot face microstructure by optical microscope and were analyzed by electron probe micro-analyzer. As the result, influence of carbon contents and apparent porosities for corrosion resistance differs among different test conditions. We consider how test conditions have effect on the corrosion mechanism of ZrO2-C material in this report.

Iron & Steel Making Refractories - Ladles

Room: Saanich

Session Chair: Ningsheng Zhou, Henan University of Science and Technology; Steve Mangin, Magnesita

11:00 AM

(UNITECR-090-2013) Development of Alternative Solutions for Iron Ladle Refractory Lining

S. M. Justus*, V. P. Ramos, S. C. Frasson, D. Galesi, A. Bortolotti, M. Fadel, E. Sako, P. S. Delgado, L. Souza, J. Machado, M. Melo, C. F. Leao, D. Bomfim, G. Silva, C. Salsa, Saint Gobain, Brazil

The main wear mechanisms of the Iron Ladle working lining refractory are governed by Thermal Shock Damage in the Walls and Pig Iron Erosion in the Impact Zone. In parallel, the volumetric change suffered by the conjugation of the permanent linear change with the reversible thermal expansion result in the generation of thermal-mechanical stress, that once superiors to the fracture strength of the bricks drive the flaw, by spalling (mechanical thermoclase) and/or by the pig iron erosion facilitated by the weakness of the refractory due to the Thermal Shock Damage. This way the solution for wear reduction of the Iron Ladle refractory lining should consider: 1. Adaptation of the Design of the refractory lining to compensate the Volumetric Change during operation; and 2. Adaptation of the refractory lining to the Thermal Shock Damage and Pig Iron Erosion. In this way, it was developed and selected new ACS brick recipes for Impact Zone application due excellent pig iron erosion resistance and superior Thermal Shock Damage Resistance; and new AC brick recipes for Wall application due superior Thermal Shock Damage Resistance and good Pig Iron and Slag Corrosion Resistance. As results of the industrial application , they were obtained better performance in different customers signaling increase of the campaign.

11:20 AM

(UNITECR-091-2013) Insulation Board Investigation and Trials in 300 tonne Steel Ladles at ArcelorMittal Dofasco

V. Mazzetti Succi*, ArcelorMittal Dofasco, Canada

Analysis and results of different types of insulation board; specifically investigating properties balancing strength and thermal conductivity in steel ladles for Steelmaking applications to improve the safety lining life, determine their effect on shell temperatures and maintain the insulation board integrity throughout. ArcelorMittal Dofasco introduced insulation board into their safety linings in 2010. This paper compares theoretical calculations of the effect of different types of insulation board's strength and heat transfer to practical readings using infrared camera shots of steel ladles and examining the insulation board upon refractory tear-out of the safety linings. ArcelorMittal Dofasco relines safety linings with shotcrete once a year enabling this report to highlight the results and findings for the past three years.

11:40 AM

(UNITECR-092-2013) Preparation of microporous corundum and its lightweight alumina-magnesia castable for ladle

H. Gu, A. Huang*, M. Zhang, State Key Lab Breeding Base of Refractories & Ceramics, Wuhan University of Science & Technology, China; B. Du, Zhejiang Zili Co., Ltd., China; Z. Li, Jiangsu Jingxing High-Temperature Materials Co., Ltd., China; Q. Wang, Zhejiang Zili Co., Ltd., China

In this paper, based on the α-Al2O3 powders as raw materials, wet grinding process was applied, a microporous corundum aggregate was prepared by sintering. Then the properties of its lightweight alumina-magnesia castable and general alumina-magnesia castable with tabular alumina were compared. The results show that: with α-Al2O3 powders as the alumina source, the microporous corundum aggregate, of which the bulk density is 3.31g/cm3, apparent porosity is 4%, closed porosity is 12%, average pore size is 0.5~1 μ m, can be obtained under the condition of sintering temperature at 2103K. Compared with the general castable, the lightweight castable, of which the apparent porosity is higher, the bulk density is lower, but the strength differences after heat treating in 383K and 1273K are very small, even the strength after heat treating at 1773K is enhanced, the linear change rate is low, shows obvious advantages. The thermal conductivity of lightweight castable is less than general castable, especially the thermal conductivity in 1073K is reduced by 19%. The lightweight castable has basically the same corrosion index and 14% higher penetration index than general castable, but any crack doesn't appear on its surface. Keywords: Microporous corundum aggregate, Lightweight alumina-magnesia castable, Ladle

12:00 PM

(UNITECR-093-2013) Steel Ladle Lining: A proven technique to achieve 3.0% productivity in transported volume while reducing refratory cost using a smart lining

L. C. Simao*, Unifrax, Brazil

New insulation materials for steel ladle safety linings bring huge benefits to the molten metal transportation process. A new and revolutionary thermal insulation material capable of withstanding high hot compressive strength , high refractoriness, and very low thermal conductivity allows up to 2/3 of the working lining to be consumed without compromising the safety temperature of the metallic casing. In addition, because of the aforementioned characteristics of the insulating material, it may be possible to reduce the original thickness of the working lining without harming the performance of the campaign. In one case study, working lining thickness reduction translated into an 8% increase in throughput per trip.

12:20 PM

(UNITECR-094-2013) Troubleshooting in Steelmaking Areas including Steel Ladles with various Refractory Solutions

S. Bharati*, Tata Steel Limited,, India; S. Bose, Tata Steel Limited,, India; A. R. Pal, Tata Steel Limited,, India; B. Singh, Tata Steel Limited,, India

Ever increasing demand for steel with stringent quality requirements and higher productivity has compelled the steel manufacturers to explore different technological options including use of superior quality refractories to improve the availability of steel ladles. As a part of continuous improvement process, a similar exercise was carried out at Tata Steel Ltd., Jamshedpur at various stages of the process. Steel ladles were prematurely discarded due to abnormal hot erosion at the lower metal zone and bottom near the well block side. By certain changes in the quality of refractory and brick laying design, the average life of steel ladle could be improved from 78 heats to 84 heats. A higher turn-around-time due to recurring damage of the lip-plate and top course of steel ladle during steel/slag jam cleaning could be lowered down by installing wedge shaped top-tight bricks enveloped with special steel foil. Coating of LF roof with a special silica based gunning material eliminated the jam build-up phenomenon during secondary refinement process of liquid steel and helped in self removal of the jam at high temperature.

Advanced Testing of Refractories IV

Room: Oak Bay

Session Chairs: J. Willi, Sunset Refractory Services; Bob Fisher, Consultant / Nock & Son Co.

9:20 AM

(UNITECR-022-2013) Characterization Methods of Zirconia and the Impact of Stabilizing Agents on its Functionality

C. Bauer*, B. Rollinger, J. Pascual, G. Krumpel, O. Hoad, N. Rogers, RHI AG, Austria

Isostatically pressed products used for flow control in the continuous casting of steel commonly combine the thermal shock resistance of an alumina graphite main body material grade with the enhanced chemical resistance of a zirconia graphite slag band grade. In order to optimize both thermomechanical properties as well as chemical corrosion performance, it is of prominent importance to suitably characterize raw materials. Detailed insights into the microstructure in combination with an understanding of the crystallographic phase transformations of zirconia provide predictive capabilities pertaining to the material performance. We present characterization methods for PSZ, including the in situ trace element analysis of grains in combination with the characterization of the physical properties of zirconia-bearing materials. The crystallographic transformations of the zirconia grains during operation is demonstrated by elemental distribution mapping. Recrystallization and exsolution phenomena are fundamental and also limiting factors regarding thermal shock resistance; chemical wear resistance changes with ongoing recrystallization. These wear patterns can be linked with the varying specific casting conditions; chemical and structural processes within the material are central to a superior understanding and the continuous optimization of refractory materials.

9:40 AM

(UNITECR-023-2013) High Temperature Characteristics of Refractory Zirconia Crucibles used for Vacuum Induction Melting

A. Quadling*, L. J. Vandeperre, Imperial College, United Kingdom; P. Myers, Morgan Ceramics, Commercial Rd, United Kingdom; W. E. Lee, Imperial College, United Kingdom

Zirconia crucibles are used for the vacuum induction melting of precious metals and superalloys but there is evidence for alloy contamination by crucible and thermal shock resistance remains a challenge. Zirconia refractories are composite materials in which naturally occurring flaws mean easy infiltration of liquid metal oxides. This presentation is part of a larger study to investigate how infiltration of corrosive liquids reduces the thermal shock resistance of these materials. Previous cold shock experiments in this group have shown that crack propagation is exacerbated by the modified temperature and stress profiles associated with liquid ingress in ceramics. In this work, thermal stresses arising at working temperatures of 1500-2000°C have been studied by combining a temperature distribution (obtained from heat flow simulations) with experimental high temperature data for the thermal expansion coefficient and Young's modulus of partially stabilised zirconia. Results of microstructural characterization using XRD, SEM/EDS after high temperature treatments will be tied into the modeling results.

10:00 AM

(UNITECR-024-2013) Influence of the Pore Shape on the Internal Friction Properties of Refractory Castables

N. Traon*, T. Tonnesen, R. Telle, RWTH Aachen University, Germany

Non-destructive methods for the evaluation of elastic properties are nowadays rightfully used on a large scale to estimate the depletion of the toughness of refractory materials following progressive thermal shocks. Challenging studies are therefore conducted to better understand crack formation and crack propagation phenomena through Resonant Frequency Damping Analysis. However, as heterogeneous materials, refractory castables present microstructural defects namely the porosity, which may have a more influential impact on the damping properties than the resulting defects from thermal shock experiments. From this standing point, pore forming agents of different nature were added in a refractory castable formulation based on tabular alumina. This survey aims to bring the same volume of porosity in the tested composition by incorporation of carbon containing additives by expecting the formation of pores with different geometry. Among other things, carbon fibres, carbon flakes and sphere like carbon were added to increase at different scale the degree of internal friction. This study will lay the emphasis on the difficulty to correlate the damping behaviour with the apparent porosity. The experimental values will be also compared to that of the literature in order to criticize the prediction of the elastic properties evolution with increasing porosities.

10:20 AM

(UNITECR-025-2013) Development of a new spalling test method for bottom blowing tuyeres for BOFs

M. Kakihara*, Shinagawa Refractories, USA; H. Yoshioka, M. Hashimoto, K. Inoue, Shinagawa Refractories, Japan

Recently multi hole plugs (MHP) are becoming more widely used as a bottom tuyere for BOF and EAF, having an integral role in steel making refinement. Bottom blowing tuyeres including MHP often experience high wear in actual furnace conditions because they are subjected to thermal spalling by the influence of gas cooling. For this reason, we thought it important to evaluate the spalling resistance of MHP based more closely to actual using conditions for improving the performance of MHP. However most conventional test methods could not test a large sample bound by other bricks under conditions in which the sample brick was cooled from the inside. Therefore we developed a new spalling test method by constructing a large heavy oil heating furnace in which a special frame can bind a sample with actual water cooling pipes placed within the inside of the brick samples. We investigated the spalling resistance of many samples with different material properties in conjunction with numerous stainless pipe configurations using this new method. As a result, we were able to reproduce samples that under testing methods experienced similar cracking to product used in an actual steel furnace. This report will explain the development of this new spalling test method for bottom blowing tuyere and sample test results.

10:40 AM

(UNITECR-026-2013) Current status and development of Chinese standards on refractory products

X. Peng*, Sinosteel Luoyang Instute of Refractories Research, China

China is the biggest manufacturing country of refractories in the world. In order to standardize the production and trade, China has established a complete and complicated standard system for refractory products including national standards (GB) and industrial standards. The industrial standards can be divided into metallurgical standards (YB), building materials standards (JC), nonferrous standards (YS), electric power standards (DL), etc. In recent years, Chinese standards of refractory products have changed a lot along with the entrance of foreign refractory companies into China and the development of refractory products export. The current status and developing trend of Chinese standards on refractory products were introduced in this paper.

Advanced Testing of Refractories V

Room: Oak Bay

Session Chairs: J. Willi, Sunset Refractory Services; Bob Fisher, Consultant / Nock & Son Co.

11:20 AM

(UNITECR-027-2013) Refractory industry suffers financial damages through imprecise test procedures for the determination of the CO-Resistance of refractory materials: Time to review ISO 12676 and ASTM C 288

O. Krause*, University of Applied Science, Germany; C. Dannert, Forschungsgemeinschaft Feuerfest e. V, Germany; L. Redecker, University of Koblenz-Landau, Germany

The intention of the presented work is to define more precise test parameters, as there are time, gas flow rate, furnace design and the processing gas. To identify distinct effects CO tests were performed in a standard testing device, where CO critical refractory products were tested. The C-grow rate was determined in a tube furnace with Fe2O3 as precursor. It turned out that in particular the gas flow rate in the CO furnace plays an important role for the emplacement velocity of carbon. Furthermore, the influence of hydrogen in the atmosphere is examined and stated to be an accelerator, because it has the ability to reactivate the catalyst. The magnitude of destruction of prismatic samples depends on the size and on the location of the reactive impurity. Therefore the classification in "A" to "D" is in random coincidence with the position of the reactive impurities. In summary it turned out that current test methods are improper to determine reliable and reproducible results and it is necessary to define the test condition more strictly than they are today. At this particular time it is indispensable to perform round robin tests in order to evaluate the impact of the measures. It is necessary to discuss the detailed test conditions within the participating experts.

11:40 AM

(UNITECR-028-2013) Implementation of a standard test method for abrasion resistance of refractory materials for testing at elevated temperatures

R. Simmat*, C. Dannert, Forschungsgemeinschaft Feuerfest e.V., Germany; P. Quirmbach, DIFK Deutsches Institut für Feuerfest und Keramik GmbH, Germany; O. Krause, Hochschule Koblenz, Germany

ASTM C 704 and ISO 16282 are commonly in use to determine the abrasion resistance of refractory ceramic surfaces against highly accelerated particles at room temperature. The aim of the presented work is the transfer the test to elevated temperatures at conditions as close as possible to those specified in the standards. The paper reports on the test setup, plausibility tests and on the 6 years of experience as a testing device for the industry. For the implementation of test conditions up to 1400 °C the standard setup is supplemented with a ring shaped natural gas burner in which a coaxial abrasion nozzle made of silica glass is situated. The gas burner flame is focused and mixed into the accelerating pressured air that exhausts from the nozzle and carries the specified SiC particles. A safety mechanism stops the gas supply in case of flame interruption. The device also allows testing samples at RT with best correlation to the standard facility. The change of abrasion as a function of temperature is highly reproducible and can be correlated with the tests performed at RT. The method is well accepted by the industry and the test setup is easy to construct. Consequently, the method is capable to be implemented in the international standardisation system.

12:00 PM

(UNITECR-029-2013) Studying the non-linear mechanical behavior of refractories thanks to digital image correlation

Y. Belrhiti*, GEMH ENSCI, France; A. Germaneau, P. Doumalin, J. Dupré, PRIME INSTITUTE, France; A. Alzina, O. Pop, M. Huger, GEMH ENSCI, France; T. Chotard, SPCTS UMR CNRS 70315, France

Large strains to rupture are essential, for refractory materials, to improve their thermal shock resistance. In fact, the non-linear comportment under loading of specific developed ceramics associated to their type of microstructure (micro-cracked) leads to the possibility to increase their strain-to-rupture level. This limit allows a better accommodation of a high level of strain induced by thermal shock solicitations. This study is devoted to stress the mechanical behavior of these materials thanks to kinematics fields measured by digital image correlation from the experimental tests. By coupling the experimental data with the numerical models, finite element method updating has been used so as to have access to the non-linear stress-strain laws. The experimental tests are based on different refractory materials such as aluminum titanate, magnesia-spinel and magnesia carbon. These non-linear materials are characterized by a mechanical behavior strongly dependent on their microstructure. Indeed, this behavior can vary from a fragile one to a large non-linear one according to the degree of microcracking present within the material. Results highlight the nonlinear asymmetric mechanical behavior of these micro cracked materials, the evolution of damage, the different mechanisms of crack propagation besides the presence of crack branching phenomenon.

12:20 PM

(UNITECR-030-2013) Investigation on reliability of refractories via Weibull distribution

W. Yuan*, Q. Zhu, C. Deng, H. Zhu, Wuhan University of Science and Technology, China

Refractories are key materials in high temperature industry including steel making, cement and glass manufacturing. Because of its poor plasticity, refractories are sensitive to several parameters including pores and phase compositions, and the random of the parameters leads to great scatter of strength data. In this study, the flexural strength of different kinds of refractories including magnesia-carbon, magnesia-chrome and high alumina has been statistically analyzed by Weibull distribution based on the data of twenty-nine to thirty-five bending tests for every kind of samples. The reliability of the flexural strength of refractories was evaluated. The phase composition and fracture surface morphology of samples was characterized by X-ray diffraction and scanning electron microscope respectively. The results demonstrated that the difference of Weibull modulus value of different kinds of bricks is obvious because of the different chemical and phase composition. The ranges of failure probability were determined using the Weibull estimates.

Cement and Lime Refractories I

Room: Esquimalt
Session Chairs: Fielding Cloer, SPAR, Inc.; Christoph Woehrmeyer, Kerneos

9:20 AM

(UNITECR-031-2013) The Performance of High Quality Magnesia Raw Materials in Cement Applications

F. Goorman*, J. Visser, M. Ruer, Nedmag Industries, Netherlands; C. Aneziris, J. Ulbricht, Technical University Freiberg, Germany

In terms of this contribution synthetic as well as natural dead burned magnesia raw materials have been investigated according to their performance for high temperature applications, such refractory materials in the sinter zone of cement rotary kilns. The raw materials have been grinded in fine coarse grains sizes in order to meet the demands of same reactivity as a function of the grain size. The fine powders have then been pressed to different kind of samples in order to identify their thermo mechanical and chemical performance. The first experiments included high temperature mechanical properties such RUL, hot bending strength, high temperature Young's modulus of elasticity etc. Thermal shock tests in air and water were performed, and the thermal shock behavior was evaluated as a function of residual Young's modulus of elasticity at room temperature. The chemical behavior was carried out with the disc approach by measuring the change of the diameter of the disc samples as a function of temperature and different corrosive slag agents. The specific micro structure as well as the kind of distribution of the impurities lead to different kind of performance.

9:40 AM

(UNITECR-032-2013) The processes of new phases formation in the Al2SiO5-ZrSiO4 refractory material during industrial test in cement kiln preheater

D. Madej*, J. Szczerba, AGH University of Science and Technology, Poland

The study of the Al2SiO5-ZrSiO4 refractory material corrosion in the corroding medium of the external heat exchanger of cement kiln (cement kiln preheater) was carried out at the temperature of 1000±100°C. The main corrosive agents in cement kiln preheater were agents in solid, liquid and gaseous form. Gaseous corrosion of Al2SiO5-ZrSiO4 refractories was related mainly to K+/K2O attack. The new phases such as K2O-Al2O3-SiO2 (K-A-S) compounds were formed as a result of chemical reaction between potassium and Al2SiO5 according to the XRD and SEM/EDS results. Moreover, when ZrSiO4 grain was attacked by K+/K2O, decomposition of ZrSiO4 and formation ZrO¬2 oxide took place. Calcium oxide from the solid particles of a hot kiln meal reacted in the microareas of Al2SiO5 and ZrSiO4 grains in a solid state. Reactions of Ca2+ ions with Al2SiO5 resulted in the formation of CaO-Al2O3-SiO2 (C-A-S) compounds. SEM observations have also shown that zircon was decomposed according to CaO-SiO2-ZrO2 phase diagram and high refractory CaZrO3 (tmp = 2345°C) was formed. This process was preceded by formation of an intermediate phases of the CaO-SiO2-ZrO2 system. Acknowledgement The research was performed at Faculty of Materials Science and Ceramics of AGH within the confines of the project no 11.11.160.603

10:00 AM

(UNITECR-033-2013) Development of an electrofused MgO-CaZrO3 Refractory with Addition of Hercynite for the Cement Industry

G. Castillo*, F. Davila, T. K. Das Roy, B. Krishnan, A. M. Guzman, S. Shaji, Universidad Autonoma de Nuevo Leon, Mexico

An innovative chrome-free basic refractory brick, which is based on electrofused MgO-CaZrO3 using as ceramic bonding spinel of hercynite to improve their properties, is presented. Microstructural, physical, mechanical, and thermal properties of new refractory brick were determined. Static and dynamic resistance tests by chemical attack of cement raw constituents were carried out. The results showed that thermo-mechanical properties of new brick improved when the hercynite content is increasing. Microstructural analysis revealed that the hercynite phase aided to develop a strong bond between the magnesia and calcium zirconate refractory phases. Finally, this new refractory brick exhibits good refractory properties at high temperature and excellent chemical resistance against cement raw meal.

10:20 AM

(UNITECR-034-2013) Hybrid spinel technology for basic bricks in chemically highly loaded cement rotary kilns

G. Gelbmann*, S. Joerg, R. Krischanitz, RHI AG, Austria

For brittleness reduction in basic bricks for cement rotary kilns different flexibilising agents are used. Here, minerals from the spinel group AB2X4 are mainly used. State of the art are magnesia-alumina-spinel (spinel, MgAl2O4), iron-Alumina-spinel (hercynite, FeAl2O4) and manganese-alumina-spinel (galaxite, MnAl2O4). Due to the increasing use of secondary fuels, the refractory material in cement rotary kilns is increasingly contaminated by volatile compounds like K2O, SO3 and Cl. This causes a densification of the brick's microstructure and even spallings of hot face brick parts. Since this chemical attack leads to a shorter service life of the refractory material, it was the target to develop brands with an outstanding thermo-mechanical behavior within the whole temperature range even under strong densification by alkali salts. At tests of Young's Modulus by ultrasonics bricks with spinel and hercynite showed quite diverging characteristics. Based on these trials it was possible to develop bricks with hybrid spinels technology, which did not only show excellent thermo-mechanical properties but also an outstanding performance in chemically highly loaded cement rotary kilns.

10:40 AM

(UNITECR-035-2013) Influence of Andalusite Composition and Particle Size Distribution on Properties of Bauxite-Silicon carbide Brick

J. Ding, G. Ye*, Zhengzhou University, China; L. Yuan, X. Liu, J. Wang, H. Zhao, Ruitai Matetails Technology Co., Ltd., China

The conditions of refractories used by the cement kilns are increasing severe with the enlarging production scale the kilns, which demands that the refractories have high refractoriness under load and thermal shock resistance, low thermal conductivity, good wear resistance and corrosion resistance. In this work, andalusite was added to bauxite-silicon carbide bricks which are commonly used in the transition zone of cement kilns and the influences of andalusite particle distribution, composition and content on thermal shock resistance and refractoriness under load of the bricks are investigated. The phase composition and microstructure of the fired bricks with addition of andalusite are examined by XRD and SEM, with aim at exploring effect of andalusite on the properties of the bricks.

Raw Materials Developments and Global Raw Materials Issues II

Room: Esquimalt
Session Chairs: Shane Bower, Christy Minerals LLC; Philip Edwards, Imerys

11:20 AM

(UNITECR-190-2013) Studies on sintering behaviour and microstructural characteristics of Indian magnesite in presence of additive

M. K. Haldar*, CSIR-Central Glass & Ceramic Research Institute, India

The importance of basic refractories has increased considerably over the years due to rapid expansion of iron & steel industries. The increase in production of iron & steel is expected to increase the demand of magnesite for manufacturing of magnesia based refractories.

India, has major deposits of natural magnesite in the Salem region of Tamilnadu which had been previously examined without using additive to assess their usefulness as refractory raw materials. In the present study, an attempt has been made to see the effect of TiO2 on the sintering behavior of magnesite in the temperature range of 1550C - 1650C. B.D. And A. P. is found in the range of 3.27 to 3.44 g/cc and 2.26-5% respectively. The percentage densification is achieved upto the level of 98%. The micro structural characteristics is also studied. It is found in presence of TiO2 , MgO reacts to form MgTiO3 .

11:40 AM

(UNITECR-191-2013) Preparation, thermal stability and oxidation resistance of Ca-α/β-sialon powders by reaction nitridation method

H. Zhang*, Y. Cao, S. Du, S. Zhang, Wuhan University of Science and Technology, China

Abstract: The phase composition and microstructure of Ca-α/β-Sialon prepared from Si, Al, CaCO3 and Al2O3 by reaction nitridation method have been studied. The prepared Ca-α/β-Sialon powders are characterized by scanning electron microscopy, energy dispersive X-ray spectrometer, thermogravimetric analysis and X-ray diffraction. The results show that using Y2O3 as additive is more effective than that of Fe2O3 for promoting synthesis of Ca-α/β-Sialon. The oxidation resistance and the thermal stability of the prepared Ca-α/β-Sialon powders have also been investigated. The prepared Ca-α/β-Sialon powders show good thermal stability even under heat treatment at 1300-1550 degree centigrade for 20h. The prepared Ca-α/β-Sialon powders possess good oxidation resistance at 1250-1300 degree centigrade because the nature of its oxidation is in protective type, characterized by a dense oxidized layer which would impede the infiltration of O2. Anorthite and cristobalite are observed to be the oxidation products of the Ca-α/β-Sialon. Keywords: Ca-α/β-Sialon; reaction nitridation; preparation; thermal stability; oxidation resistance

12:00 PM

(UNITECR-192-2013) Effects of Fe2O3 and SiO2 on the MgAl2O4-SiC composite powders by forsterite, alumina and carbon black

H. Zhu*, H. Duan, W. Yuan, C. Deng, Wuhan University of Science and Technology, China

MgAl2O4 spinel and SiC was added to MgO-C refractory for improving slag erosion, penetration resistance and oxidation resistance. The MgAl2O4-SiC refractory composite powders have been fabricated by forsterite, alumina and carbon black. The effects of Fe2O3 and SiO2 on the MgAl2O4-SiC refractory composite powders were discussed. The samples were calcined under argon atmosphere at 1873 K for 3 hrs respectively. The phase compositions and microstructure of the synthesized powders were investigated by X-ray diffraction and scanning electron microscope. The result shows that the enhancement of the formation of SiC by adding Fe2O3 and SiO2 is significant.

Raw Materials Developments and Global Raw Materials Issues I

Room: Sidney

Session Chairs: Shane Bower, Christy Minerals LLC; Philip Edwards, Imerys

9:20 AM

(UNITECR-186-2013) Raw materials for refractories: the European perspective

A. Volckaert*, PRE - European Federation of Refractories Producers, Belgium

Raw material developments have topped the agenda of the European Commission for the past years. Europe's Raw Materials Initiative aims to foster both domestic and international access to raw materials and to promote recycling opportunities. To this end, a list of critical raw materials has been established and the EU, together with other countries, launched already two WTO legal cases against Chinese export restrictions on raw materials. In addition, the new European Innovation Partnership on Raw Materials will set the strategic agenda to secure access to raw materials for the next decade. Against this background, European refractory companies are aiming to advance the use of secondary raw materials and to improve their access to domestic supply. In this respect, European legislation is still too often a burden rather than a solace. PRE, the European Federation of Refractories Producers, presents the European perspective to raw materials as well as the achievements of the European refractory industry in this field and gives an outlook to the challenges and opportunities which lie ahead.

9:40 AM

(UNITECR-187-2013) Andalusite, An under-utilized Refractory Raw Material with undeveloped High Potential

C. De Ferrari*, Andalucita S.A., Peru

Without refractories, this earthly world as we now know it, would come to a standstill. That small industrial segment that works quietly behind the scenes produces heat resistant containment furnace facilities for the molten heart of the industrial world. Refractory andalusite, typically containing 58-60% Al203, is among the few heat-resistant materials that are capable of resisting the molten high temperatures of today's industrial furnaces. Unlike essentially all other refractory raw materials, andalusite is unique in that it requires little or no prior calcination. When the mined, cleaned, and sized andalusite is formed into brick shapes, the result is high Al203 with high bulk density. Andalusite-based refractories provide high resistance to: thermal shock, abrasion, alkalis, have a volume expansion under 5%, are particularly resistant to high temperatures under load, and have high dimensional stability. In a growing world market, andalusite refractories are presently used effectively in the steel, glass, copper, and cement industries, electric arc furnaces, and pitch-impregnated bricks in torpedo ladles and others. Andalusite has become a cost-effective raw material in the iron-steel industry, now with strategic sourcing in the western hemisphere. In the refractory world, interest is growing significantly today for andalusite - based materials.

10:00 AM

(UNITECR-188-2013) Refractory grade graphite: Seeking Chinese independence day

S. Moores*, Industrial Minerals, United Kingdom

Refractories producers have become over-reliant on natural graphite from China. In the last 23 years China's dominance of supply has risen to 77% for all graphite and 67% for flake. There is now a push to reduce this dependence on Chinese sources and look elsewhere for secure, consistence, long-term supply. Exploration in Canada has boomed and refractories producers are now looking at developing new mines for a 100% captive supply. But many challenges and risks remain including new competition from the electric vehicle battery sector which competes head on with refractories for the same raw material. The industry is looking to act before graphite becomes an even higher risk raw material. This presentation is part of continuing studies into graphite prices and trade at Industrial Minerals Data and as part of the Natural Graphite Report 2012: Data, Analysis and Forecast to 2016, published by Industrial Minerals Research in 2012.

10:20 AM

(UNITECR-189-2013) Phase transformation impact on the iron diffusion in olivine raw material refractory

R. Michel*, M. Ammar, P. Simon, J. Poirier, CNRS, France

Natural olivine is a refractory raw material, abundant in the earth crust. It is composed of solid solution of magnesium silicate and iron silicate, mainly with forsterite configuration Mg2SiO4 and a small amount of fayalite Fe2SiO4. This raw material is used in refractory

applications. For instance, it is used in tundish as material for steelmaking. It is also used in the fluidized bed reactors to produce a high calorific fuel-rich synthesis gas (CO + H2) from biomass. During calcination at high temperature, olivine undergoes phase transformations, which affect the chemical processes. Among these phase transformations, iron oxide is produced and contributes to the sintering of particles and to the reactivity of refractories. During the steelmaking process, iron oxide reacts with aluminium to form inclusions in steel. In gasification/combustion reactor, the agglomeration of the fluidized bed is induced by the reactions between olivine and biomass ashes. The phase transformations of olivine subjected to high temperature are not clearly understood. Therefore, the objective of this paper is the microstructural analysis and the mineral characterization of phase transformations. The material is analysed by optical microscopy, XRD, SEM and Raman microspectrometry with its mapping mode. In order to confirm the experimental results, thermodynamic data will be proposed.

Energy Savings Through Refractory Design I

Room: Sidney

Session Chairs: James Hemrick, Oak Ridge National Laboratory; Valeriy Martynenko, Ukrainian Research Institute of Refractories named after A.S. Berezhnoy

11:20 AM

(UNITECR-054-2013) Evaluation of thermal conductivity of refractory monolitihcs by various methods and the issues this raises

Z. Carden*, Vesuvius UK, United Kingdom; D. Bell, Foseco, United Kingdom; I. Whyman, A. J. Brewster, Vesuvius UK, United Kingdom

The continuous increase in energy costs and the need for improved thermal efficiency and carbon reduction has highlighted the requirement for accurate and meaningful thermal conductivity values for refractory products. The testing of thermal conductivity is a long and expensive process so actual values given on typical data sheets are often estimates by calculation or by reference to similar products. As these values may be used to predict heat loss and shell temperatures then it is essential that they are realistic. Considering the huge range of products available on the market it is very difficult for the end user to confidently compare values from one supplier to another. This paper attempts to explore the relationship between the various test methods and theoretical values and gives the results of extensive product comparisons. Methods utilised include hot wire, calorimetric (panel), split column and laser flash. Heat flow calculations based on the measured findings are then related to actual measurements in lining configurations. The findings are discussed and compared to previous studies.

11:40 AM

(UNITECR-055-2013) Delevopment of a new Calcium Silicate Board with super insulating Properties

V. Krasselt*, J. Rank, Promat GmbH, Germany; A. Opsommer, X. Wu, Promat International, Belgium

The main function of refractory insulation materials is to minimize the heat loss in high temperature applications. Besides microporous insulating boards Calcium Silicates have become an essential part of high energy-efficient furnace linings. The highly improve Calcium Silicates features a special assembly of micro-crystal round hollow shapes, a high temperature resistant crystal matrix and additives to eliminate heat transfer by radiation. The development was supported by analysis methods like MIP, SEM and XRD additionally to common tests. In technical scale the process is realised in slurry reactor autoclaves using pure raw materials to create mainly Xonothlite crystals and an effective opacifier. The related thermal conductivity at 800 °C measured with hot wire method is 0.10 W/mK, which is a level closed to super insulating microporous boards.

12:00 PM

(UNITECR-056-2013) Nanoporous Refractory Insulatings: Solution or Illusion?

D. O. Vivaldini*, A. Mourão, V. R. Salvini, V. C. Pandolfelli, Federal University of São Carlos, Brazil

The physical factors affecting the thermal efficiency of ceramic insulating refractories were evaluated in order to find out the effects of nanopores containing microstructures. Mathematical analysis and simulations were carried out to quantify the effects of the pore size distribution on the thermal conductivity, which is the main physical property associated to the microstructure's insulating capacity. Based on those analyses it was found out an ideal pore size range (between 1 and 5 μm) that optimize the reduction of thermal energy transmission through the material. Therefore, the presence of nanopores (<0,1μm) is not the best microstructural option for reducing the thermal conductivity at high temperatures (>1000°C). Such argument is supported by experimental data for aerogels, which contain nanopores and show significant thermal conductivity increase with the temperature. Additionally, such nanopores would hardly present dimensional stability during continuous use at high temperature.

12:20 PM

(UNITECR-057-2013) Improvement of Thermal Efficiency in Iron/Steel Ladles

Y. M. Lee*, ArcelorMittal Steel, USA; S. Kumar, ArcelorMittal Burns Harbor, USA; L. Rebouillat, Pyrotek Inc, Canada

Thermal insulation in ladles is important in saving thermal energy and optimizing operational cost. Other benefits are to maintain the steel shell temperatures of liquid metal holding vessels under threshold temperatures and reduce steel shell deformation by minimizing thermal mechanical stress. ArcelorMittal Burns Harbor has evaluated insulation materials in the area of iron/steel transfer ladles. The current paper will discuss the benefits of insulation materials during service. The wear mechanisms and failure behaviors will be also reviewed.

12:40 PM

(UNITECR-058-2013) Effects of Fe2O3 on properties of novel heat insulation materials synthesized by molten salt method

C. Deng*, J. Ding, W. Yuan, J. Li, H. Zhu, Wuhan University of Science and Technology, China

In this paper, novel heat insulation materials were synthesized by molten salt method by using natural forsterite and NaCl-Na2CO3 molten salt. Impurity Fe2O3 with different mass ratios (0-9 wt.%) was added into raw materials, and the samples were prepared at the calcined temperature from 1173 to 1373 K for 10 h, respectively. Effects of Fe2O3 on properties including bulk density, apparent porosity and strength of heat insulation materials were investigated. Mechanism of molten salt during synthesis processing was discussed. The results show that the contents of Fe2O3 have significant effects on properties of samples. The strength of samples increases with the increasing of mass ratio of Fe2O3, and moreover, larger content of Fe2O3 may decrease the strength. The sintering of forsterite was promoted in molen NaCl, and the pores in samples formed through the decomposition of Na2CO3 and the removing of NaCl by washing in boiling water.

Nonoxide Refractory Systems

Room: Colwood
Session Chairs: Dave Derwin, Superior Graphite; Matt Lambert, Allied Mineral Products

9:20 AM

(UNITECR-174-2013) Compatibility between graphite as well as micropore carbon and synthetic PGM matte

B. Thethwayo*, A. M. Garbers-Craig, University of Pretoria, South Africa

Graphite blocks are currently used in the concentrate - slag zone in primary platinum group metal (PGM) smelters, and can possibly be extended to the matte zone. This study describes comparative tests that were conducted to determine the most suitable carbon-based refractory material for the matte zone. Extruded graphite and micropore carbon were exposed to synthetic matte at 1350°C and 1450°C for 12 hours. Carbon dissolution into matte was measured by LECO Carbon analysis, while matte penetration was studied using scanning electron microscopy. Carbon dissolved in matte was 0.1% and up to 0.3% for graphite and micropore carbon respectively. Micropore carbon exhibited low resistance towards matte attack, and disintegrated due to reaction of matte with silicon in the matrix whereby a sulphur deficient matte formed. Graphite has low solubility in matte and high resistance towards matte attack, and is therefore the most suitable carbon-based material to use as lining material in the matte zone.

9:40 AM

(UNITECR-175-2013) Nitride bonded Silicon Carbide refractories: Structure variations and corrosion resistance

A. Yurkov*, O. Danilova, A. Dovgal, Voljsky Abrasive Works, Russian Federation

During the fabrication of N-SiC refractory the reaction between Silicon and gaseous Nitrogen, resulting bonding Silicon Nitride phase, starts beginning from 1100 degrees. Nitrogen may react with solid Silicon, molten Silicon and with vapors of Silicon. The reaction of Nitrogen and Silicon is strongly exothermic. On the final stages of N-SiC formation the temperature of the process is higher, than the melting point of Silicon. Some part of Silicon is in the gaseous phase. The difference between the temperature in the middle of the shapes and at near the edges might be critical for the gradients of porosity and density in refractory shapes. Volatile Silicon tends to move in the places with lower temperature. Usually the gradients of porosity in the center of shapes and at the edges are 1-2 %, but sometimes it may reach 5-7%. Usually the problems with side lining in Aluminium reduction cells are due to the design of the pots or due to the problems with reduction technology (overheating, etc.), however that may have connection with the structure of N-SiC refractories.

10:00 AM

(UNITECR-177-2013) Structure evolution and oxidation resistance of pyrolytic carbon derived from Fe doped phenol resin

B. Zhu, X. Li*, Wuhan University of Science and Technology, China

Structure evolution and oxidation resistance of pyrolytic carbon derived from Fe doped phenol resin in a coke bed from 600 centigrade to 1 100 centigrade were investigated by X-ray diffraction (XRD), scanning electron microscopy (SEM) and thermogravimetry-differential scanning calorimetric analysis (TG-DSC). The results show that the doping of Fe powders in the phenol resin significantly reduces the graphitizing temperature. The graphitization degree of the phenol resin increases with temperature rising, and Fe powder addition promotes the graphitization of phenol resin significantly. The SEM analysis shows that massive micro sphere carbon with about 150 nm in diameter is generated on the surface of Fe dopants below 800 centigrade. With rising of carbonization temperature, the micro sphere evolves into bamboo-shaped carbon chains and finally carbon whiskers could be formed at 1 000 centigrade and 1 100 centigrade. The corresponding diameter and length of formed carbon whiskers are about 150 nm and several tens of micrometers respectively. The oxidation resistance of the pyrolytic carbon derived from Fe doped phenol resin after carbonization at 1 000 centigrade is greatly improved in comparison with that of phenol resin without Fe doped. The oxidation peak temperature of the former reaches 574 centigrade, much higher than 506 centigrade for the latter.

Refractories for Chemical Processes

Room: Lecture Theatre
Session Chairs: James Bennett, National Energy Technology Laboratory; Mathias Rath, Rath AG

2:00 PM

(UNITECR-198-2013) Mechanisms of Wear Reduction in High Chrome Oxide Gasifier Refractories Containing Phosphate Additions Exposed to Coal Slag (Invited Speaker)

J. Bennett*, National Energy Technology Laboratory, USA; B. W. Riggs, Eastman Chemical Company, USA; K. Kwong, National Energy Technology Laboratory, USA

Gasifiers are reaction vessels used to process carbon feedstock such as coal and/or petcoke at elevated temperature, high pressure, and in a reducing atmosphere (low oxygen partial pressure); forming CO and H_2 – also called synthesis gas or syngas. Syngas is used as a feedstock raw material for chemical production or in power generation. By-products of the gasification process include: 1) unreacted carbon, 2) hot gases such as CO_2 and H_2S, and 3) slag formed from mineral impurities or organic metallic compounds in the carbon feedstock that liquefy during gasification. In the gasifier, slags interact with the high chrome oxide refractory liner, causing wear by two primary means - spalling (structural and chemical) and chemical dissolution. Phosphate additions to high chrome oxide refractories were recently developed and are known to reduce spalling and lower chemical dissolution of the refractory liner. A discussion of how phosphates influence the brick microstructure to reduce refractory wear caused by coal slag will be presented.

2:20 PM

(UNITECR-200-2013) Investigation of Y_2O_3-stabilized Zirconia Ramming Mix after Service in Carbon Black Reactor

V. V. Martynenko*, V. V. Primachenko, I. G. Shulik, E. B. Protsak, N. G. Pryvalova, Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine; V. I. Ivanovskiy, G. V. Babich, Omsk Carbon Black Plant, Russian Federation

Because of the service temperatures increasing need in the combustion chamber of carbon black reactor up to 2200°C the ramming mix from Y_2O_3-stabilized zirconia on the phosphate bond has been developed. Since 2003 year this ramming mix is successfully served in the carbon black reactors lining, ensuring the prolonged service period and high temperature service. After 18 months service in the lining at the temperature of ~ 2000°C and the high-speed gas streams (~ 400-450 m/sec) in the carbon black reactor the lining samples from ramming mix were selected for studies. The complete petrographical, X-ray and chemical researches made it possible to establish the wear mechanism of lining. It was established that in the service process as a result of the volumetric transformations, connected with the zirconia phase transitions, in the refractory lining an increase of cracks and pores quantity occurs, that lead to lining insignificant softening. At the same time, in spite of the changes, proceeding in the lining, the indicated processes do not cause to any significant wear, and with small intermediate repairs the rammed lining service period in the carbon black reactor is not less than ~ 2 years.

2:40 PM

(UNITECR-201-2013) Spinel-Based Refractories for Improved Performance in Coal Gasification Environments

J. G. Hemrick*, B. Armstrong, Oak Ridge National Laboratory, USA; A. Rodrigues-Schroer, D. Colavito, MinTeq International, Inc., USA; J. Smith, K. O'Hara, Missouri University of Science and Technololgy., USA

Oak Ridge National Laboratory, in collaboration with refractory manufacturer Minteq International, Inc., academic partner Missouri University of Science and Technology and refractory end users have developed novel refractory systems and techniques to reduce energy consumption of refractory lined vessels. The objective of this U.S. DOE funded project was to address the need for innovative refractory compositions by developing MgO-Al2O3 spinel gunnable refractory compositions utilizing new aggregate materials, bond systems, protective coatings, and phase formation techniques. Materials have been developed specifically for coal gasification environments and work has been performed to develop and apply low cost coatings using a colloidal approach for protection against attack of the refractory brick by the service environment and to develop a light-weight back-up refractory system to help offset the high thermal conductivity inherent in spinel materials. This paper discusses the systematic development of these materials, laboratory testing and evaluation of these materials, and relevant results achieved toward the reduction of chemical reactions and mechanical degradation by the service environment though compositional and processing modifications.

3:00 PM

(UNITECR-202-2013) Chemical wear mechanisms observed in basic bricks removed from two high-carbon ferrochrome furnaces

A. M. Garbers-Craig*, University of Pretoria, South Africa

South Africa is the world's largest producer of ferrochrome. The country also possesses nearly 70% of the estimated world chromite reserves, which are located in the Bushveld Igneous Complex (BIC). This paper describes a post mortem study on magnesia and chrome-magnesia bricks that were removed from two high carbon ferrochrome producing DC arc furnaces, which were in production for four years and four months. Bricks were removed from the hearth, upper sidewalls as well as from the alloy and slag taphole areas. The slags that were produced in these furnaces were SiO2 - Al2O3 - MgO - CaO based, but also contained some chromium and iron dissolved in the slag as oxides, but also in the form of partially altered chromites and entrained alloy. Microstructures and wear mechanisms are described, while special attention is given to the wear mechanisms associated with the alloy and slag tapholes.

3:20 PM

(UNITECR-203-2013) Effects of Zirconia on the Thermal Shock Resistance of High Chrome Refractories for Coal Slurry Gasifier

Y. Li*, Luoyang Lier Refractories Co., Ltd., China; C. Ke, Wuhan University of Science and Technology, China; G. Ye, Zhengzhou University, China; S. Gao, Wuhan University of Science and Technology, China; J. Zhao, Luoyang Lier Refractories Co., Ltd., China

The effects of particle size and amount of zirconia addition on the thermal shock resistance of high chrome refractories for coal slurry gasifier were investigated by using fused chrome oxide and alumina micro powders. Phase transformation, microstructure and phase composition of samples after sintering and thermal shock were analyzed by SEM and XRD. The results show that: (1) zirconia addition with appropriate particle size can improve the thermal shock resistance significantly; (2)zirconia addition with particle size of 2μm~7μm has significant effects on prevention of cracks propagation; (3)crack deflection and bending toughening mechanism play an important role in improving the thermal shock resistance of high chrome refractories.

Iron & Steel Making Refractories - General Session I

Room: Lecture Theatre

Session Chair: Gary Hallum, CCPI; Yuechu Ma, Allied Mineral Products

4:40 PM

(UNITECR-120-2013) Development of new basic working lining for Ternium Siderar tundishes

S. Camelli*, M. L. Dignani, Instituto Argentino de Siderurgia, Argentina; M. Labadie, J. Mirabelli, Ternium Siderar, Argentina

The increase demand of clean steel production has influenced on the quality, design and performance of tundish refractory lining. There are different types of wear refractory lining for tundish according to the application systems (wet spray gunning, dry vibratable mass) and the types of binder (resins, sodium silicate, hydrocarbon binder, etc). The aim of this paper is to present the main properties of cold setting material are used in Ternium Siderar steel shop as well as the plant trial results. Chemical analysis, X – ray diffraction phase identification, thermogravimetric analysis of the self setting material was carried out. Also, the evaluation of the slag-refractory interaction was studied through static corrosion test at 1490°C during 90 minutes. The wear profile of the material specimens was determined. Besides, a post mortem study was performed though by optical and electronic microscopy and EDS analysis. By using these techniques the refractory microstructural changes were evaluated.

5:00 PM

(UNITECR-121-2013) Andalusite applied in EAF roof castable

X. Xiong*, Z. Li, F. Hu, Z. Mu, DAMREC-IMERYS, France

The high temperature radiation of electric arc, especially high temperature radiation of the nearby area of electrode, can cause refractory of EAF roof the structure spalling, the chemical corrosion, the erosion of high speed airflow and the slag corroding to refractory. The EAF roof refractory needs good thermal stability, excellent thermo shock resistance, excellent slag resistance. EAF roof castables generally use corundum-mullite based castables with chromic oxide addition. The main problem of this type of castable is spalling and poor thermal shock resistance. Andalusite is a refractory raw material composed by bi-oxide of aluminium and silica (Al2O3SiO2). It's very known that andalusite has strong thermal stability (resistance to thermal choc and low creep). Andalusite will be transformed to mullite at 1000°C-1400°C. In this research work we introduced andalusite in corundum castable to improve the spalling resistance and slag erosion resistance. The properties as CMOR, HMOR, RUL and slag resistance are obviously improved. An industrial trial using an andalusite (52%) and corundum castable has been made in an EAF for special steel (steel-chrome-nickel-molybdenum alloy) production with a very serious working condition. The life time is improved by 50% regarding the original corundum castable

Iron & Steel Making Refractories - BOF

Room: Saanich

Session Chair: Vanessa Mazzetti-Succi, ArcelorMittal Dofasco; Peter Quirmbach, University of Koblenz-Landau

2:00 PM

(UNITECR-080-2013) Improvement of the refractory lining concept and of the installation method of a BOF at voestalpine Linz

T. Schemmel*, H. Jansen, L. Schade, Refratechnik Steel GmbH, Germany; R. Exenberger, voestalpine Stahl GmbH, Austria

The basic oxygen furnace (BOF) is the essential furnace in the oxygen steel making process. Therefore an intelligent choice of the refractory material is the key to provide a high life time and to minimize downtimes of the BOF. Additionally, the lining of a spherical bottom is a special task for the refractory material producer. By the example

voestalpine Stahl (Linz, Austria) the way to improve the BOF refractory lining is given. A particular focus of the paper is the introduction of an upgraded stainless steel fiber reinforced MgO-C brick for the scrap impact. Furthermore, a novel lining method for the spherical bottom is presented.

2:20 PM

(UNITECR-081-2013) *Post mortem* analysis of BOF tuyeres

S. K. Kubal*, Swansea University, United Kingdom

In a Basic Oxygen Furnace with bottom agitation, wear around bottom blowing elements is one of the main factors limiting lining service life. Refractories adjacent to bottom tuyeres are subjected to thermo-mechanical stresses associated with thermal cycling, localized cooling originated from stirring gas, and molten bath agitation caused by interactions between detaching gas bubbles and molten metal. Even though the number of possible modes for wear of bottom blowing elements and surrounding refractories is limited, the mechanisms are not fully understood. Therefore, worn tuyeres from a Basic Oxygen Steelmaking converter have been retrieved and characterized after a completed campaign. Chemical and microscopic analysis of tuyere refractory cores revealed a phase change in MgO monolithic material, which helped define the tuyere wear mechanism. Furthermore, detailed examination of stainless steel tuyere tubes enabled the erosion mechanism of the non-refractory part of the blowing element to be determined. During the campaign, tuyere operating temperatures had been measured using high-resolution thermal imaging camera, whilst wear rate was monitored using a laser scanning technique and the bath height indicator. To better understand the results of *post mortem* analysis, these examinations were complemented by a statistical study of the interactions between operating factors and their influence on bottom refractories performance.

2:40 PM

(UNITECR-082-2013) Improvement of BOF bottom stirring at Ruukki, Raahe Steel Works

H. Pärkkä*, Ruukki Metals, Finland; T. Meriläinen, Ruukki Metals, Finland; J. Vatanen, Ruukki Metals, Finland; J. Kärjä, Ruukki Metals, Finland; P. Tuominen, Ruukki Metals, Finland

Ruukki Metals operates three 125 t LD-KG converters at Raahe Steel Plant with annual capacity of 2,8 Mt. Ruukki Metals strategy is to increase the share of special steel products, e.g. high-strength and wear-resistant steels. In order to increase the production of special steels demand for BOF bath agitation has increased. With bottom stirring it is possible to achieve good steel quality, cost efficiency and process control. Earlier the lifetime of the converter lining campaign was the most determining factor. Bottom stirring was working only part of the campaign because of wearing and blockage. First step was to change this principle and achieve 100 % availability for the bottom stirring. With new principle converter is relined after bottom stirring has been lost. New method decreased the lifetime of the converter campaigns but total cost efficiency improved. After 100 % bottom stirring availability was reached second step was to improve the lifetime of the bottom stirring and optimize lining thickness and brick qualities on other areas in order to improve cost efficiency. During this improvement work gas volume flow rates have been optimized and gas controllers have been updated. Different bottom stirring elements have been tested and the effect of the stirring elements placing has been studied. This paper describes how these industrial scale trials were done and what results were achieved.

3:00 PM

(UNITECR-083-2013) Properties and performance of gunning and patching material of BOF converter at TATA STEEL

G. Ghosh*, A. Banerjee, B. Singh, S. Biswas, A. Pal, TATA STEEL, India

During the past few years, efforts were incessantly aimed at increasing the life of the converter refractory lining and thus making the production process more cost-effective (in terms of rupees per ton steel). The optimality criterion for targeting higher converter life was assumed to be the higher performance of gunning and patching refractory of the converter charge pad and trunnion zone. Selection of high performance gunning and patching refractory is the most important aspect of converter life. The present paper deals with the comparative analysis of properties, performance and techno economical viability of gunning and patching refractory used in converter. Thermal expansion behaviour, oxidation resistance, MOE, HMOR, spalling and slag corrosion resistance test was conducted. The detail micro structural evolution has been carried out. XRD and microscopic evaluation of the gunning and patching material to identify morphology of the coarse grains and formation of different phases in the matrix. The detail morphology of the materials was studied by SEM with EDAX.

3:20 PM

(UNITECR-084-2013) Improvement of durability and tapping time of Sleeve by composition and shape control

K. Kim*, I. Bae, J. Lee, K. Lee, Poscochemtech, Republic of Korea

Tap-hole Sleeve which is a passage transferring the molten steel from BOF to ladle is an important refractory because it affects the productivity and steel quality of BOF. During the past 10 years in Korea, sleeve brick has been changed from segment type (short sleeves) to monolithic type (1 piece long sleeve) to extend the service life. And now, following two concepts are considered as the best way for improvement. The first is to extend the service life by controlling the initial spalling and improving the abrasion resistance through the optimization of chemical composition. And the second is to increase the productivity of BOF by decreasing the initial tapping time through the optimization of sleeve shape. In this study, service life of sleeve increases by improving the drying condition and a content/kind of graphite in sleeve, and tapping time decrease by improving the entrance shape through the water-model test.

Iron & Steel Making Refractories - Blast Furnace and Troughs I

Room: Saanich

Session Chair: Mike Alexander, Riverside Refractories; Atsuya Kasai, Nippon Steel & Sumitomo Metal

4:20 PM

(UNITECR-071-2013) High performing Al2O3-SiC-C monolithic refractories releasing no hydrogen for blast furnace casthouse applications

N. Duvauchelle, J. Soudier*, CALDERYS, France

Blast furnace runners require A-S-C castable that can be dried out very fast, especially considering the high thermal conductivity of carbon and SiC. Common approach of producers was to develop castables releasing hydrogen during curing and setting to increase the permeability and consequently to facilitate the evacuation of water vapor during heating up. Elementary precautions have to be taken for reducing the risk of explosion when handling products that liberate hydrogen in the working area. With the view to eradicate the safety risk due to hydrogen formation, Calderys has developed a new range of Al2O3-SiC-C castable for casthouse applications containing no metallic component undergoing hydrolysis reaction with water. The new range is based on the Quick Dry technology for enhancing gas permeability. Formulations have been specially optimized to meet the BF casthouse needs. The SiC content has been adjusted from 10% to 35% to cover the main BF runner applications. Castable present a good rheology that ensure a correct placement without risk of voids and lamination on site. They can be dried out as fast as regular A-S-C cement bonded castable releasing hydrogen. Both corrosion and oxidation resistance have been improved to lower the refractory consumption. They also exhibit a lower sensitivity to thermal cycling and a considerably facilitated wrecking ability.

4:40 PM

(UNITECR-073-2013) Novel dry mix technology for tundish refractory lining

E. Y. Sako*, V. Ramos, S. C. Frasson, S. M. Justus, D. Galesi, L. M. Souza, A. Nascimento, C. F. Leão, M. T. Fadel, Saint-Gobain do Brasil Ltda, Brazil

In steelmaking plants, quick refractory maintenance steps are required in order to ensure a high productivity level in the continuous steel production flux. For the tundish working lining, for instance, the ideal conditions for a suitable repair includes an easy deskulling, a fast installation procedure, and a short curing time. Considering these aspects, the present work addresses a novel refractory dry mix, which, due to a flexible binding system, could harden after only 30 minutes at room temperature, with no heating system requirement. In addition, a fast and simple disposal after use was achieved by the correct selection of additives, which provided an efficient sintering process without sticking to the tundish back lining. The monolithic material composition is also entirely water-free with very low residual carbon content, reducing the risks of any sort of elements pick-up from the refractory lining, and, consequently, helping the clean steel production.

5:00 PM

(UNITECR-074-2013) Hot Strength in Relation with Bonding System of SiC and Al2O3 Based Castables Incorporated with Silicon Powders after Nitridation

R. Yu*, H. Wang, N. Zhou, Q. Meng, Henan University of Science and Technology, China

Previous research reveals that hot strength of ULC castables incorporated with silicon powders can be enhanced by nitridation. However, HMOR at 1400oC drops a lot compared to that at 1200oC. To understand the key influencing factor, the present work investigated the relationship between HMOR during 1200oC and 1400oC and bonding system of two types of castables, SiC based and alumina based respectively. The binding system was designed to vary from CA cement (CAC) containing to cement free by either using hydratable alumina to replace CAC or silica sol as the binder. Cement free binding system yields a CaO free bonding which is favorable to maintain HMOR at 1400oC of the both castables. In the alumina based castables, glassy phase and anorthite are formed in the CAC containing bonding system, which is beneficial to cold strengths but not to hot strength due to softening effect. Replacement of CAC by hydratable alumina leads to significantly enhanced HMOR at 1400oC, as evidenced by the fact of 21.1 MPa in the cement free system vs. 4.5MPa in the ULC system, both at 10% Si addition after the nitridation. By XRD and scanning electron microscope, phase composition and microstructure were characterized and interpreted.

Modelling and Simulation of Refractories II

Room: Oak Bay

Session Chairs: Bill Headrick, MORCO, USA; Harald Harmuth, Montanuniversitaet Leoben

2:20 PM

(UNITECR-140-2013) Simulation of the steel ladle preheating process

M. Drózd-Rys*, H. Harmuth, Montanuniversitaet Leoben, Austria; R. Rössler, voestalpine Stahl GmbH, Austria

CFD simulation of a steel ladle preheating process was performed with several goals. One was to estimate the impact of process parameters on preheating. Further, the final lining temperature and the temperature distribution in dependence on the heating rate are of interest due to the impact on thermal shock during filling of the ladle. Steel ladles are preheated up to temperature of 700-800°C by natural gas firing before they are transferred to the steel plant and finally heated to operation temperature. In the model, both hot gas and refractory should be simulated. The calculations were executed with ANSYS Fluent software. For the gas combustion non-premixed combustion model including laminar flamelet approach was applied. The radiation was calculated with discrete ordinates model, the turbulence with realizable k-ε model. As a result, velocity field, temperature and composition of the gas were calculated. The model includes also the heat transfer between flue gas and refractory, which is calculated depending on temperature and flow conditions. Further simulations including parameter studies and optimization of the process with the aim of shortening preheating time are intended. The achieved results can support the thermo-mechanical modeling of the refractory lining, especially under the conditions of the following thermal shock, as well as the investigation of carbon burnout in magnesia-carbon refractories during preheating.

2:40 PM

(UNITECR-141-2013) The Transient Drying and Heating of Refractory Concrete

G. Palmer*, T. Howes, Y. Ge, Palmer Technologies Pty Ltd, Australia

Abstract The heat and drying rates of concrete structures is a significant issue for both public infrastructure and industrial processes due to the amount of damage, e.g. spalling and thermal stress fracture, due to rapid heating or stream pore pressure. In industrial processes the heat up and dry-out procedures for refractory concrete are used to control steam spalling failure during dry-out are based on imprecise empirical exercise with limited physical insight. Considering that a catastrophic event where internal steam spalling occurs means extra time for repairs and the dry-out process must start again, within the refractory industry, the dry-out and heating schedules publish by manufacturers are often very conservative and typically take days if followed explicitly. A better approach is to base dry-out and heating schedules on predictive computer simulations where the variation in material properties or heating rates can be scientifically evaluated. While several numerical models and schemes have been developed in the past these have proven to very limited and unstable due to the strong coupling between the input parameters. Choice of parameter values and model validation has also been difficult and inconclusive. The presentation describes Palmer Technologies' approach to model formulation and the effect of different heating/cooling rates, transient spikes and hold periods on a concrete body stress distribution.

3:00 PM

(UNITECR-142-2013) Modeling of masonries using homogenization and submodeling methods

N. Gallienne*, Prisme Laboratory, France; M. Landreau, Centre de Pyrolyse de Marienau, France; E. Blond, A. Gasser, Prisme Laboratory, France; D. Isler, Centre de Pyrolyse de Marienau, France

To face coke and steel market requirement, the coking process has to be more flexible. But changing process parameters such as coking temperature, time and blend composition have consequences on coke oven battery lifetime. The main objective of this work is to determine the admissible pushing pressure for the coke oven heating walls to prevent crack formation. Thus a numerical tool of the coke oven battery based on the Finite Element Method was developed. It is a two-step model using homogenization [BORNERT 2001] and submodelling [LIU 2009] techniques in order to decrease the computational cost. Coke oven masonries are large structures composed of thousands of bricks and mortar joints. In the model, bricks and mortar are replaced by a Homogeneous Equivalent Material (HEM) whose behaviour depends on the joint state [NGUYEN 2009]. The used HEM properties depend on the brick-mortar interface state. The brick-mortar behaviour is experimentally characterised at high temperature [BRULIN 2011]. In order to control joint opening, a criterion changing the HEM is used [LANDREAU 2009]. The use of the HEM gives the stresses at the scale of the whole structure, that is why, a submodelling step has been developed to improve the accuracy concerning local joint opening. To by-pass the high cost of a systematic sub-

modeling, an algorithm has been developed in order to have recourse on submodelling only when it is necessary.

3:20 PM

(UNITECR-143-2013) Modeling Cracking in Refractory Materials Due to Thermal Cycling

A. A. Pandhari*, P. V. Barr, D. M. Maijer, The University of British Columbia, Canada; S. Chiartano, TRB Refractories, France

In pyrometallurgical reactors, thermally induced refractory cracking is often considered the primary cause of in-service refractory failure. The current work focuses on quantifying this phenomenon. A lab-scale experimental apparatus was constructed using stainless steel heat/chill blocks to impose controlled thermal cycling on castable specimen blocks. Using commercial ABAQUS software a "damage-based" thermo-mechanical model was developed to predict thermal stress and damage during temperature cycling. The model is used to predict the stress field generated within the test specimens under the imposed conditions and the predicted versus actual damage are compared. Ultrasonic testing of the refractory shows significant reduction of the sonic velocity confirming micro-cracking damage. Model predictions for damage are in reasonable agreement with that observed in the test specimens.

3:40 PM

(UNITECR-144-2013) Influence of different masonry designs of bottom linings

A. Gasser*, L. Chen, J. Daniel, E. Blond, University of Orléans, France; K. Andreev, S. Sinnema, Tata Steel R&D, Netherlands

Many bottom linings of refractory structures used in steel making industry are made of masonries with or without mortar. Several designs are possible: parallel, fish bone or radial. To compare the influence of these designs on the level of stress and displacements in the steel shell, the different masonries were modelled by an equivalent homogeneous material. The thermo-mechanical properties of this equivalent material were determined using a periodic homogenization method. They are temperature depending and depend of the joint states (open or closed in the two directions) for masonries with dry joints. This masonry model is used to simulate by the finite element method the behaviour of a simplified steel ladle. It demonstrates the influence of different parameters: presence or not of joints, dry joints/mortar joints, thickness of mortar joints, masonry design, refractory material. It brings a help for the design of refractory masonry linings.

Modelling and Simulation of Refractories III

Room: Oak Bay

Session Chairs: Bill Headrick, MORCO, USA; Harald Harmuth, Montanuniversitaet Leoben

4:20 PM

(UNITECR-145-2013) The load-displacement curve of steady crack propagation: An interesting source of information for predicting the thermal shock damage of refractories

D. Y. Miyaji, C. Z. Otofuji, J. A. Rodrigues*, Universidade Federal de São Carlos, Brazil

In the refractories field, fracture energy is an important parameter related to the thermomechanical behavior of materials. Basically, it is the amount of energy necessary to generate two surfaces per unit of projected area. It can be determined by calculating the integral of the load-displacement curve, which can be obtained from a steady crack propagation test. Besides the analysis of fracture energy, it was also verified that the curve of load-displacement itself provides interesting information to predict the thermal shock damage resistance of refractory castables. An example is the value of the tangent at the inflexion point of the crack propagation portion of the load-displacement curve. Good qualitative correlation was found between the prediction obtained from the load-displacement curves and the resistance to thermal shock damage, which was obtained experimentally through water quenching procedure. Actually, the need for just one test (fracture energy) to predict the thermomechanical behavior of castables was considered remarkable. This is so because figures of merit related to thermal shock damage resistance typically require three or more different types of characterization, usually the Young's modulus, modulus of rupture, fracture energy, etc.

4:40 PM

(UNITECR-146-2013) Adequacy check of refractory design by FE modeling

P. Saha*, P. Pal, B. Sarkar, P. P. Lahiri, Engineers India Limited, India

Refractory lining in a furnace undergoes thermal and mechanical stresses during operation. The amount of thermal expansion and stresses need to be ascertained for a successful design and material selection. Finite element analysis is an important tool which can be utilized to assess the effect of expansion and stresses in a lining system and necessary guideline can be framed during design stage. This paper presents a case study of finite element analysis undertaken by the authors for an absorption tower refractory dome of an sulphuric acid plant. Refractory dome of sulphuric acid tower is a self supporting low rise dome made of double tapered bricks arranged in concentric rings. For the purpose of analysis, the dome is assumed to be uniform and cyclic-symmetric about the centre and FE modeling is done accordingly. The stress distribution in the refractory lining dome has been ascertained considering the mechanical and thermal load. The deformation and displacement behavior of dome refractory assembly under stress is studied and adequacy of the design verified.

5:00 PM

(UNITECR-147-2013) Mathematical modeling on slag corrosion of lightweight corundum spinel castable for ladle

A. Huang*, H. Gu, Y. Zou, M. Zhang, State Key Lab Breeding Base of Refarctories & Ceramics, Wuhan University of Science & Technology, China

Based on the porous medium theory, the micro-structure parameters were considered, the Al2O3-CaO refining slag was selected, a mathematics model for slag corrosion of lightweight corundum spinel castables was established. The slag corrosion process of lightweight castable was studied by mathematical simulation method, the effect of micro-structure parameters including average pore-diameter and porosity of porous aggregates on slag resistance of castables was discussed, and the phase composition and distribution of corrosion products in castables were predicted by combining simulated results with phase equilibrium diagram. The results show that, the mathematics model based on porous medium is suitable for describing the slag corrosion process of lightweight castables and predicting the phase composition and distribution of corrosion products; when the dense matrix is contained, as long as the average pore-size of aggregates are small enough, the slag corrosion resistance of castables will not be deteriorated significantly with a relatively high porosity of aggregates. Keywords: lightweight castable, slag corrosion, mathematical simulation, ladle

Cement and Lime Refractories II

Room: Esquimalt

Session Chairs: Fielding Cloer, SPAR, Inc.; Christoph Woehrmeyer, Kerneos

2:20 PM

(UNITECR-036-2013) A new type of basic castable for the cement industry

V. Wagner*, P. Malkmus, Calderys, Germany

Hot and liquid clinker produced in a cement rotary kiln requires suitable refractories. Consequently the standard lining of the burning zone of such an aggregate consists of magnesia spinel bricks. Magnesia can withstand high temperatures; the incorporation of spinel

grains has been deeply investigated and is known to improve key properties as thermal shock and corrosion resistance. However, there are sections in a clinker production unit where such bricks cannot be installed easily; mainly due to geometrical reasons. And some of these sections are exposed to similar conditions as they can be observed in the burning respectively transition zones of a cement rotary kiln. Such examples are: nose ring, burner lance, kiln hood and cooler inlet. In many cases well-proven standard solutions like low cement castables do not give a satisfactory performance as liquid clinker is attacking the refractories under the influence of extremely high temperatures. To solve these problems we have developed a new type of basic castable. These dense materials are based on magnesia containing spinel and can be easily installed in the described problem areas.

2:40 PM

(UNITECR-037-2013) Magnesia-spinel refractories for rotary kiln burning 60% alternative fuels

M. Sulkowski*, L. Obszynska, C. Golawski, ArcelorMittal Refractories, Poland

Technology of production of the magnesia-spinel refractories resistant to extremely difficult working conditions was developed. Material is designed for the transition and burning zones in the cement clinkier rotary kiln with a diameter of 5.75 m. The micronized additives were used for sealing the structure of the material by "in situ" reaction products. Modeling tests of corrosion by alternative fuel were performed in the complex conditions of different chemical factors and reducing atmosphere. After full campaign in the cement plant samples of the bricks were used to determine the mechanisms of corrosion of magnesia-spinel materials with micronized additives.

3:00 PM

(UNITECR-038-2013) Development of Magnesia-Spinel Brick for the Transition Zone of Cement Rotary Kilns under the Vastly Increasing Use of Waste

M. Ohno*, H. Toda, K. Tokunaga, Y. Tsuchiya, Y. Mizuno, MINO CERAMIC CO.,LTD., Japan

In cement industry in Japan, the utilization of waste as fuels and raw materials has been increasing year after year, reaching to 469kg per one ton of clinker production in 2010. The vastly increasing use of waste makes the lining bricks of cement rotary kilns exposed to extremely severe conditions, and their increasing wear and shorter lifetime have been observed recently. To achieve the stable operation of cement rotary kilns and contribute to establishing a recycling society, high quality lining bricks are in highly demand. Based on the postmortem analysis of used bricks, we reconsidered the characteristics required for transition zone under the increasing use of waste, and developed the Magnesia-Spinel brick with redesigned microstructure. It features an enhanced bonding in the matrix and a higher strength than conventional ones while showing sufficient flexibility. The developed brick was applied to the hard transition zone, where the coating was unstable and the conventional bricks were worn significantly. The brick after the service demonstrated much less deterioration of its texture and the wearing rate was greatly reduced. The number of the application to actual kilns is now increasing and we anticipate the excellent performance.

3:20 PM

(UNITECR-039-2013) Dry and wet gunning: Technico-economic refractory concrete concepts for highly loaded cement plants

K. Beimdiek*, H. Klischat, Refratechnik Cement GmbH, Germany

The viability of a cement plant demands constantly increasing efficiency and shorter downtimes. Furthermore increasing plant capacities and changing process conditions cause complex loads and require high grade refractories in all kiln areas. Therefore, especially in case of repairs, the focus is put on the dry and wet gunning technology. Both are adjusted installation procedures, which are linked more closely than ever to technical and economic compromises. These compromises do not represent a conflict. A combination of the system requirements of the gunning equipment for low cement dry gunning, and a comparable product philosophy of wet and dry gunning concretes lead to an excellent gunning behavior and superior performance by an optimized densification factor. The improved dry and wet gunning technology offers a high potential of technical and economic flexibility. This includes also the refractory design. From extremely light weight products, e. g. as a substitution of calcium silicate, right through to highly compacted low cement gunning concrete can be installed in thermo-mechanically and thermo-chemically stressed areas. General application recommendations for the different kiln areas are shown by the recent positive experiences of the use of acid fireclay up to bauxite-based gunning concretes including the addition of SiC and zircon.

3:40 PM

(UNITECR-040-2013) Achieving Higher Thermochemical Resistance by Installation of Magnesia Forsterite Bricks

H. Klischat*, H. Wirsing, Refratechnik Cement GmbH, Germany

Magnesia refractories for cement kilns contain an elastifying component to provide the necessary mechanical elasticity. The majority of these elastifyers are spinel minerals (spinel, hercynite, chrome ore, pleonaste), containing considerable amounts of alumina. As a typical corrosion mechanism by overheated cement clinker, low-melting and low viscous calcium aluminates are formed causing premature wear. As response to this frequent wear, a novel brick generation was created by introducing alumina-free forsterite into the brick structure. This new generation of magnesia forsterite bricks is characterized by a superior resistance to cement clinker attack, as the deleterious formation of calcium aluminates from the elastifier is prevented. Furthermore, an increased alkali resistance is observed, so generally a superior thermochemical behaviour to the prevailing conditions in cement kilns is achieved. Additionally, due to the adjusted amount of iron oxides and silica, this brick facilitates desired coating build-up by mineral formation in the contact area of magnesium silicates from forsterite and calcium silicates from the kiln feed. All relevant brick properties, like strength, elasticity, porosity, refractoriness, thermal shock resistance, are carefully adjusted to meet the conditions in cement kilns. Numerous worldwide installations prove the advantage of this innovative concept.

4:00 PM

(UNITECR-041-2013) The effect of TiO2 on microstructure and properties of chrome-free basic brick

S. Ghanbarnezhad*, Azad University, Islamic Republic of Iran; A. Nemati, Sharif University of Technology, Islamic Republic of Iran; M. Bavand, Azad University, Islamic Republic of Iran; R. Naghizadeh, Iran University of Science and Technology, Islamic Republic of Iran

The considerable amount of water soluble, hexavalent chromium ion has been reported for used magnesia-chrome bricks from rotary cement kilns. Nowadays, chrome-free bricks of magnesia–spinel type for the burning zone it, ferrous and non-ferrous industries have been developed. In this research, the positive effect of TiO2 addition on the properties and microstructure of spinel-bonded chrome-free basic brick has been reported. Thus, 0, 2, 4, and 6 wt% TiO2 ratios were used in the blend. Properties such as density, prosity, cold crashing strength, modulus of rupture strength, hot modulus of rupture strength and refractorines under load are measured on the basis of JIS standard. Microstructural analysis and phase identification were done by (SEM/EDS) and X-ray diffraction So, According to results indicated that the TiO2 addition to 2wt.% has promoted the densification at lower sintering temperature, cold crashing strength, Modulus of rupture strength, hot modulus of rupture strength and refractorines under load, because of spinel phases particular magnesium-titanate is formed. Moreover, the addition TiO2 up to 6 wt.% reason for expansion problems and amount of spinel phases those properties has smaller decline.

Iron & Steel Making Refractories - RH Snorkels

Room: Esquimalt
Session Chair: Carlos Pagliosa, Magnesita Refractories; Nathan Leicht, Shinagawa

4:40 PM

(UNITECR-104-2013) Theoretical and practical the temperature gradient of the refractory lining of the RH snorkel

Z. Czapka*, Zaklady Magnezytowe "ROPCZYCE" S.A., Poland; J. Szczerba, AGH University of Science and Technology, Poland; W. Zelik, Zaklady Magnezytowe "ROPCZYCE" S.A., Poland

During the degassing process in an RH Degasser, the snorkels submerged in liquid steel are exposed to cyclic heating both from the inner and outer side of the refractory lining. Such working conditions can lead to excessive temperature rise of the snorkel steel shell that holds its refractory lining and provides stability and tightness of its construction. This paper presents the results of temperature distribution calculations in the vertical section of the RH snorkels obtained by using the finite element method (FEM) for different operating conditions. The comparison and verification of results has been presented with the results of temperature measurements by using the temperature sensors placed in the selected places of the snorkel refractory. The calculations and measurements showed that the temperature of the cross section area of the RH snorkel varies continuously during operation. The temperature of the steel shell grows together with the number of the hits in the sequence. The rate of temperature growth of the steel shell and inner zones of the snorkel depends on the operating conditions taken for the calculations, such as: duration of each degassing, duration of the breaks between heats, number of heats in one sequence and temperature of the steel.

5:00 PM

(UNITECR-105-2013) Development of degasser snorkel refractories and the effect of process parameters on wear rate

Y. Bi*, Tata Steel Europe, United Kingdom; I. A. Smith, Tata Steel Strip UK, United Kingdom; K. Andreev, Tata Steel Europe RD&T, Netherlands

Tata Steel UK Port Talbot has embarked on a programme to improve the RH and RD degasser snorkel life through material selection, design optimisation and process control. The critical wear around the tuyeres (argon flow) has been investigated using thermal mechanical modelling to assess the effect of snorkel construction, preheat temperature and refractory material selection on wear rate and wear mechanisms. The increased rigidity and thermal expansion of the fired magnesia chrome bricks has reduced the resistance to thermal cracking. The formation of micro-cracks in the early stage of the campaign would weaken the lining structure and accelerate the degree of hot erosion. This paper has examined various grades of magnesia-chrome, particularly the RuL and creep resistance properties, to optimise the thermal stresses and the hot face spalling resistance. The degasser operational parameters, maintenance practice and performance data have also been reviewed.

5:20 PM

(UNITECR-106-2013) Development of High durability Hot Repair Spray and New Installation Method for the RH Snorkel

J. Lee*, C. Kim, D. Lee, B. Kim, POSCOCHEMTECH, Republic of Korea

It is common that one of the ways improving the life time of RH vessel is Hot Repair Spray for RH snorkel. In the recent days, steel makers demand reduction of repair cycle & time of Hot Repair Spray increasing the productivity of steelmaking. For this reason, the needs of a new installation method and Hot Repair Spray with high durability are increasing. In this study Hot Repair Spray of high durability shows increased thermal adhesion by low sintered shrinkage and enhanced erosion resistance by high purity seawater magnesia with special binders. The developed Hot Repair Spray has improved adhesion strength and erosion resistance compared to conventional Hot Repair Spray, and shows 20~30% increasing of lifetime in the field test Finally we introduce a new installation and hot repair Materials of Dipping method which reduces installation time compared to conventional Hot Repair Spray

Energy Savings Through Refractory Design II

Room: Sidney
Session Chairs: James Hemrick, Oak Ridge National Laboratory; Valeriy Martynenko, Ukrainian Research Institute of Refractories named after A.S. Berezhnoy

2:20 PM

(UNITECR-059-2013) Achievement of the reducing erosion for investigation of trough bottom angle in the semi pooling type main trough

H. Fujiwara*, NIPPON CRUCIBLE CO.,LTD., Japan

Relation between the trough bottom angle and the erosion amount (speed) was found by the investigation of the trough bottom angle to reduce the erosion amount for the semi pooling type main trough. Number of molten pig iron tapping could be increased and the stable life could be achieved by controlling the slope trough bottom angle of the blast furnace.

2:40 PM

(UNITECR-060-2013) New Insulating Lining Concepts Based on Calcium Hexaluminate

D. Zacherl*, Almatis Inc., USA; D. Schmidtmeier, A. Buhr, R. Kockegey-Lorenz, M. Schnabel, Almatis GmbH, Germany; J. Dutton, N/A, United Kingdom

Synthetic raw materials based on calcium hexaluminate (CA6) are commercially available as dense and lightweight aggregates and are used successfully in various applications. The key properties of CA6 such as high chemical purity, high refractoriness, high thermal shock resistance and low thermal conductivity are well known in the industry. In recent years energy saving concepts and environmental friendly solutions became more and more the focus of attention as the industry has to cope with increasing energy costs and environmental regulations. Therefore innovative concepts and material solutions will be required to optimize the performance of the processes. The combination dense and lightweight CA6 enables the development of tailor-made solutions taking into account density, strength and thermal insulation. New insulation lining concepts will be presented and discussed in the current paper.

3:00 PM

(UNITECR-061-2013) Energy saving in steel reheating furnaces of voestalpine (Austria) and ArcelorMittal (Germany) by a new concept for skid pipe insulation

M. Springer*, FBB Engineering GmbH, Germany; M. Gumpenberger, voestalpine, Austria; J. Heinlein, ArcelorMittal, Germany; A. Buhr, Almatis GmbH, Germany

Increasing energy costs and targets for reduction of CO2 emissions provide a challenge to optimise high temperature processes. The costs for energy and environmental requirements play an important role. New technical solutions are required to improve the energy efficiency and reduce the energy consumption. The target is to optimise the hot rolling process from an energy point of view, and reduce the operational cost of the furnaces. The paper discusses how energy consumption and energy loss can be reduced in reheating furnaces of hot rolling mills by new lightweight refractory materials and a new modular lining concept for the skid pipe insulation using pre-fabricated shells. The new lightweight pre-fabricated shells based on the microporous castable and a thermotechnical optimised sandwich design, can significantly reduce the heat losses to the cooling system of the skid pipe system. Trials and CFD calculations show a potential of more than 50% reduction of heat losses compared to dense castable.

Industrial application of the new system in a 400 t/h walking beam and a 110 t/h pusher type furnace resulted in reduction of heat loss about 30% and more compared to the dense castable. The annualised energy saving gives a cost reduction higher than the costs for the new lining, resulting in a payback period of less than 1 year.

3:20 PM

(UNITECR-062-2013) Energy savings of slab reheating furnaces by the improvement of refractories

M. Sato*, T. Takeuchi, K. Kohno, S. Akihiro, Nippon Steel & Sumitomo Metal Corporation, Japan

Slab reheating furnaces consume a lot of thermal energy in the steel making process and some of which are lost through refractories lining to furnaces roof, wall, bottom and skid-beams. The energy loss extends to several tens percent of the energy input from fuel. Therefore, the improvement of refractories insulation is important for saving energy of slab reheating furnaces. On the other hand, refractories are also required improvement of durability to increase productivity due to high occupancy rate of furnaces. In this paper, we report the recent results of energy savings by improving refractories materials and structures for slab reheating furnaces at Oita-works in Japan. As for the skid-beams that lose large energy to cooling water, the energy loss was greatly reduced and the durability of refractories was improved by applying three-layered insulation structure.

3:40 PM

(UNITECR-063-2013) Energy savings and improvement of productivity in continuous reheating furnaces

P. Tassot*, J. Fernau, H. Lemaistre, CALDERYS, Germany

Energy consumption in the steel industry is important and contributes to more than 35% of the costs. Specific energy consumption decreased in all countries in last decade, while structural changes encouraged by the target of CO2 emission fixed are necessity for surviving for this industry in the developed countries. In emerging countries like India the rise of energy consumption necessitates optimizing the process and imagining innovative solutions. The reheat furnace is an important tool in this equation for the hot rolling mill operation whereas the efficiency is in the best case close to 50%. This study was carried out for developing the suitable way for transferring the energy in the stocks and avoiding thermal losses as possible. Calderys focused on 2 main points at 1st for optimizing this aspect and also minimizing the defects occurred during the reheating phase: - Optimizing the heat transfer using a revolutionary concept maximizing the radiation efficiency with the diamond roof, decreasing the consumption more than 2% in some cases. - Reducing the thermal losses in the water cooled skids and post These concepts have been reinforced by FEM studies and construction target for increasing the productivity during installation and saving time for the steel production.

4:00 PM

(UNITECR-064-2013) Novel generation of kiln furniture

U. Scheithauer*, K. Haderk, T. Moritz, M. Zins, A. Michaelis, Fraunhofer IKTS Dresden, Germany

The main requirement on kiln furniture is the save support or transport of the ceramic products during the thermal processing. Therefore a high compression and bending strength is needed especially at high temperatures. States of the art are thick plates of dense or porous ceramic. But these structures have a high thermal mass which has to be heated and quenched and a homogeneous temperature distribution could only be realized at low heating or cooling rates. Higher rates could result in thermal induced mechanical stresses which could damage or destroy the kiln furniture and the supported ceramic products. At the Fraunhofer IKTS the principle of manufacturing of a novel generation of kiln furniture with advanced properties is investigated. The combination of different shaping technologies (tape casting, winding, extrusion) allow the manufacturing of kiln furniture with a low density and low heat capacity but also with a high stiffness and a good thermal shock behaviour. Planar green tapes are laminated with a supporting structure, which has macroscopic cavities allowing passage of air or gas and which reduce the density of the structure. The presentation will show the manufacturing and the advantages of the new kiln furniture. The simulation of different geometries for the supporting structure allows the maximization of the ratio between strength and mass of the kiln furniture. Creeping and bending tests quantify these properties.

Iron & Steel Making Refractories - General Session II

Room: Sidney

Session Chair: Jacques Poirier, University of Orleans - CNRS; Dilip Jain, Kyanite Mining

4:40 PM

(UNITECR-123-2013) Application and Development of Top Combustion Style HBS in China

D. Hongqin*, S. Gengchen, L. Fuchao, L. Jiantao, zhenzhou Annec Industrial Co., Ltd, China

There are three kinds of hot blast stove (HBS) for blast furnace in the iron-making process, i.e., internal combustion style HBS, external combustion style HBS and top combustion style HBS. This paper gives the refractories arrangement for the different areas in the top combustion style HBS based on the hot simulation results of top combustion style HBS and analysis of practical performances and damage mechanism of the refractories for top combustion style HBS. The wide applications of top combustion style HBS in China demonstrated its advantages and make it become the development trend for HBS in the future.

5:00 PM

(UNITECR-124-2013) Development of active and reactive carbon-bonded filters for steel melt filtration

M. Emmel*, C. G. Aneziris, Technical University of Freiberg, Germany

In terms of this contribution, multifunctional carbon-bonded filters for steel melt filtration have been developed. By means of the application of these filters, an increasing filtration efficiency of up to 90 % is assumed. Therefore the first emphasis consists of the development of MgO-C based filter materials which are supposed to reduce the formation of ternary and quarternary inclsuions over the formation of secondary MgO. The second emphasis consists of the development of active filter systems – based on Al2O3-C – which are subdivided into an activation by the application of an oxide coating, and an activation by amorphous carbon. In case of the cold sprayed active oxide coatings, the chemism of the coating materials equates to the chemism of the nonmetallic oxidic primary and secondary inclusions. In contrast, the activation by amorphous carbon was investigated with regard to varying binder systems, as well as varying coking temperatures, to analyze the influence of amorphous and crystalline carbon, as a consequence of different surface energies. Concluding all developed filters have successfully been tested, using the impingementtest, whereat the cold filters (18 °C) are impinged with steel melt (1670 °C), in order to evaluate their thermal shock resistance, as well as their permeability.

5:20 PM

(UNITECR-125-2013) Influence of composition and processing on the microstructure of carbon bonded Al2O3-C filter materials and their behavior at high temperatures

Y. Klemm, H. Biermann, C. Aneziris*, TU Bergakademie Freiberg, Germany

Carbon-bonded Al2O3-C is the base material for ceramic foam filters for the filtration of liquid steel and hence the production of high quality components. At operational temperatures up to 1700 °C, the flowing molten metal, when it impinges on the filter, causes high mechanical stresses leading to elastic and visco-plastic processes. The mechanical and wetting behavior of the filter material during this

process is significantly influenced by the phases that form during fabrication. In order to study the influence of composition and processing, the grain size distribution of the Carbores® P binder and thus the porosities were varied. Shaping was performed by uniaxial and isostatic pressing giving deviations in microstructure over the cross section. Additionally, two coking temperatures were tested upon the evolution of amorphous and crystalline fractions and their influence on mechanical strength. Finally, mechanical high-temperature properties were studied.

Petrochemical

Room: Colwood

Session Chairs: Don McIntyre, ANH Refractories Co., USA; Ken Moody, Refractory System Solutions

2:20 PM

(UNITECR-179-2013) Engineered refractory castables with improved thermal shock resistance

A. Luz*, T. Santos Jr., Federal University of São Carlos, Brazil; J. Medeiros, Petrobras, Brazil; V. C. Pandolfelli, Federal University of São Carlos, Brazil

Refractory castables used in fluid catalytic converter (FCC) risers for petrochemical industries are subjected to intense temperature changes and high speed particle erosion. Thus, the objective of this work was to analyze the thermal shock damage cycling of alumina and mullite-based castables designed for such harsh environment. Hot elastic modulus measurements were carried out for the evaluation of samples after drying (110°C/24h) and 0, 2, 4, 6, 8 and 10 thermal cycles (ΔT = 800°C). Furthermore, hot modulus of rupture, erosion resistance, apparent porosity and fracture energy tests were also performed. According to the E changes, it was detected at which temperature range the stiffening or embrittlement took place in the mullite-based refractory (M-SA) microstructure. The alumina-based composition (TA-SA) presented improved mechanical strength and high thermal stability. Based on mechanical simulations, it was found out that refractories with high E values (~140 GPa, as the evaluated alumina-based castable) present low stored elastic strain energy even under severe thermal stresses, which seems to be a key aspect for the engineered design of advanced castables.

2:40 PM

(UNITECR-180-2013) Deterioration of Refractory Ceramic fibre lining in an Ethylene Cracking Furnace: A case study

M. K. Maity*, E. Al-Zahrani, Saudi Basic Industries Corporation, Saudi Arabia; M. Al-Thomali, M. Abdul Kareem, Eastern Petrochemical Company, Saudi Arabia

Refractory ceramic fibres (RCF) are extensively used for the lining of Ethylene cracking furnaces in the petrochemical industries. Ceramic Fibre materials do normally have a tendency of deterioration (de-vitrification, densification, shrinkage, reduced fibre resiliency, reduced thermal shock resistance, etc.) after a continuous exposure to high temperature for a long time. Premature deterioration of ceramic fibre module lining was noticed in one cracking furnace. The problem was unusual and was restricted to only one of the furnaces in the plant. The root-cause of the problem was investigated by evaluating the process condition of the furnace and analysing the damaged ceramic fibre samples. The results revealed that the presence of alkalis (Na2O & K2O) within furnace contributed faster deterioration of ceramic fibre lining. The detailed observations and results of ceramic fibre post-mortem analysis will be discussed.

3:00 PM

(UNITECR-181-2013) The coke effect on the fracture energy of a refractory castable for petrochemical industry

D. Y. Miyaji, C. Z. Otofuji, M. D. Cabrelon, Universidade Federal de São Carlos, Brazil; J. Medeiros, Petrobrás - Petróleo Brasileiro S/A, Brazil; J. A. Rodrigues*, Universidade Federal de São Carlos, Brazil

Cracking is a very common occurrence in the refractory linings of fluidized catalytic cracking units. Motivated by that problem, the present work evaluated the effect of coke on the fracture energy of aluminosilicate refractory castables for petrochemical industry. If one observes load-displacement curve of a fracture energy test, there are two elementary ways to enhance the fracture energy of any material: enhancing the material's flexibility (tolerance to crack propagation) or/and increasing the mechanical resistance. Results have indicated that coking the castable increased its fracture energy due to densification of the microstructure. Moreover, no significant additional flexibility seemed to be gained. As a consequence, the material became more brittle, despite the increase in fracture energy. These results were related to the themomechanical behaviour of the material when submitted to thermal cycling in the typical operational temperature range.

3:20 PM

(UNITECR-182-2013) Avoid Cosmetic Repair of Refractory Lining in Critical Equipments

E. S. Al-zahrani*, M. M. Maity, SABIC, Saudi Arabia

Repair or replacement of refractory lining is a continuous process. Dismantling and replacing large amounts of refractory during a turnaround is a challenging and time consuming task. There is a general tendency to squeeze the lining repair schedule to reduce the production losses. This often results in compromise on repair procedures and overlooking basic technical issues. Also, in many cases cosmetic patch repair is carried out instead of a proper repair. The non-performances of repaired refractory and recurring problems are common in the industry. The effects of patch falling out and causing additional operational problems and downtime should always be weighed against carrying the repair job properly. This paper, in general, discusses the importance of proper lining repair and highlights the experiences of detrimental effect of patch repair in a Process Gas Boiler in a petrochemical plant.

3:40 PM

(UNITECR-184-2013) Sintering additive role on the performance of advanced refractory castables

A. Luz*, T. Santos Jr., Federal University of São Carlos, Brazil; J. Medeiros, Petrobras, Brazil; V. C. Pandolfelli, Federal University of São Carlos, Brazil

High-alumina refractory castables are commonly used in risers for petrochemical fluid catalytic converters (FCC). Although such materials attain high erosion resistance levels, they do not usually present suitable densification and thermal shock performance at temperatures close to 800°C. Therefore, the addition of sintering additives is required to improve their performance. The aim of this work was to evaluate the thermo-mechanical behavior of alumina-based castables designed for petrochemical applications and containing a boron-based sintering additive able to speed up the system densification at lower temperatures. Hot elastic modulus (using the bar resonance technique), thermal shock, hot modulus of rupture and erosion resistance measurements were carried. According to the attained results, as the sintering additive induced liquid formation at high temperature, higher amounts of this compound resulted in refractoriness drawbacks. Furthermore, the E changes observed throughout the thermal cycles indicated that a continuous decrease of the elastic modulus values after each analyzed cycle might be due to thermal fatigue, affecting the overall castables performance, especially for the samples containing higher sintering additive content.

Friday, September 13, 2013

Plenary Session II

Room: Lecture Theatre
Session Chair: Dana Goski, Allied Mineral Products

8:00 AM

(UNITECR-003-2013) Trends for the World's Most Important, but least known Products

C. Semler*, Semler Materials Services, USA

not available

Iron & Steel Making Refractories - Spinel Castables

Room: Lecture Theatre
Session Chair: Arnaud Lafaurie, ALTEO; Carl Zetterstrom, Kerneos

9:20 AM

(UNITECR-107-2013) Thermal shock resistance of alumina and alumina-rich spinel refractories using the decomposition of aluminum titanate

K. Moritz*, S. Dudczig, C. G. Aneziris, Technische Universität Bergakademie Freiberg, Germany

Oxide refractory materials containing aluminum titanate (≦ 10 %) as second phase have been investigated. The basic idea is to improve the thermal shock resistance of the matrix material by the incorporation of a second phase whose decomposition on cooling down is accompanied by a change in volume. By thermal treatment after the thermal shock, the second phase is formed again (at least partially). Self-healing can be achieved in this way. A ceramic material with an alumina content that is greater than 90 % by weight and additions of titania and zirconia was developed whose high thermal shock resistance could be attributed to the in-situ formation of aluminum titanate during sintering and its decomposition on thermal shock. The residual strength after quenching from 1200 °C was higher than the original strength after sintering at 1650 °C. Aluminum titanate could be reformed by annealing at 1400 °C. Alumina-rich magnesium aluminate spinel is used as matrix material in ongoing investigations. Pre-synthesized aluminum titanate is added, or it is formed from alumina and titania during sintering.

9:40 AM

(UNITECR-109-2013) Development of Alumina Magnesia Non-Cement Castable for Steel Ladle

M. Nishimura*, S. Nishida, H. Sasaki, M. Namba, Shinagawa Refractories Co,.Ltd., Japan

Alumina-magnesia castables are widely used as working lining for steel ladle. In recent years, there is an increased tendency load on the materials, and there is a need for high life materials.In generally, Alumina cement is used to ladle castable as a binder, and so, there is a limit to improve the performance like a corrosion resistance for containing a CaO component. Therefore, in this study, we examined the application of non-cement binder, and developed a new castable which have excellent corrosion resistance and spalling resistance.

10:00 AM

(UNITECR-110-2013) Charateristics and Design of Spinel-containing Castables for Steel Ladle

R. Kim*, S. Lee, S. Jung, S. Lee, Korea Refractories Co. LTD, Republic of Korea

The characteristics of three types spinel-containing castables those are alumina-spinel, alumina-spinel-magnesia and alumina-magnesia were investigated. The finer spinel formed in alumina-magnesia castable would bring better corrosion and penetration resistance than alumina-spinel castable. On the laboratory test, magnesia-containing castable showed dramatic increase of permanent linear change by second spinel formation over 1200 degree C, and showed the best corrosion resistance among three types of castables. However, alumina-spinel castable was stably used without peeling caused by structural spalling in the field test. Magnesia-containing castable was not satisfied with the targeted life time by showing peeling caused by structural spalling. It is judged by the difference in second spinel formation speed which is caused by the reaction between alumina and magnesia. The difference in intensity and content of spinel could be confirmed through the XRD and XRF. Each type of spinel-containing castables should be selected properly depend on the operational condition and each installation part. Finally, we will suggest the control technique of spinel formation speed.

10:20 AM

(UNITECR-108-2013) Expansion under Constraint and its Effect on High-alumina Spinel-forming Refractory Castables

M. Braulio*, E. Sako, V. Pandolfelli, Federal University of Sao Carlos, Brazil

This work addresses practical aspects of the steel ladle environment and the performance of Al2O3-MgO refractory castables. This sort of refractory present an expansive behavior due to the in-situ spinel formation. In excess, the associated expansion can lead to crack formation, resulting in paths for slag penetration. Nevertheless, during its application in steel ladles, the castable is under constraint. To simulate this condition, a high-alumina CAC-bonded castable was used as a physical barrier. Corrosion tests were conducted in spinel-forming castables with different expansion levels and their results were compared with those attained after performing similar experiments without constraint. The penetration indexes were reduced when the corrosion was performed in an expansion controlled condition, as a result of lower castables' porosity. As a final remark, this work points out that the already outstanding high-corrosion performance attained in lab conditions of spinel-forming castables is most likely improved during its use in ladles.

Monolithics VI

Room: Saanich
Session Chair: Randy Mauzy, Aluchem; Ted Huang, Allied Mineral Products

9:20 AM

(UNITECR-170-2013) Development of Light Weight Al2O3-CaO-MgO Castables Using Micro-pored CA6-MA Aggregates

C. Li, Y. Bi*, N. Zhou, Henan University of Science and Technology, China

For certain severe applications, it is critical whether the insulating castables have high refractoriness and good resistances to reducing atmosphere and alkali attack. This work developed series lightweight castables in the Al2O3-CaO-MgO system, using our newly developed micro-pored CA6-MA aggregates with a mass ration 70: 30 of CA6 over MA to replace sintered alumina aggregates by 12%, 24%, 36% and 42% respectively in alumina based castables with CA cement as binder. The influence of the CA6-MA addition on water addition, flowability, apparent porosity, bulk density, permanent linear change, cold strength, hot modulus of rupture at 1400oC, thermal conductivity and microstructure of the castables were investigated. As the micro-pored CA6-MA addition increases, porosity of the castables increases, while their bulk density, cold and hot strengths and thermal conductivity decrease. The developed lightweight castables are featured by very low thermal conductivity and it slowly increases with temperature, thank to the micro-pore structure of the CA6-MA aggregates.

9:40 AM

(UNITECR-171-2013) Effect of process parameters on phase growth in high purity alumina cements

S. Sengupta, T. K. Roy, N. Ramasubramanian*, CUMI Super Refractories, India

High purity alumina cement (HPAC) made using hydrated lime & calcined alumina, results in the formation of two phases $CaAl_2O_4$ (CA) & $CaAl_4O_7$ (CA_2), depending on process conditions. The ratio of the two phases has a significant effect on the final cement properties. Chemical & physical characterization methods were employed to study the effect of various process parameters (particle size, forming process & temperature) on the formation of these two phases. Nucleation of transient phases such as CaO, $Ca_{12}Al_{14}O_{33}$ ($C_{12}A_7$) and CA_2 is seen to occur at different points of solid-solid interface, depending on particle size, mix ratio (of Al_2O_3 & CaO) and temperature. Ca^{2+} diffuses through $C_{12}A_7$ and CA_2 layers and results in the formation of homogeneous CA phase and residual CA_2 phases. Further increments in temperature cause the formation of CA_2 as the major phase in HPAC. Higher densification at raw mix forming stage leads to the formation of higher CA_2 phase at lower temperatures. Higher CA_2 phase leads to a more refractory but longer setting cement. The results reported here provide an efficient way of tailoring the $CaAl_2O_4$ vs $CaAl_4O_7$ phases in high alumina cements, by modifying the process conditions.

Refractories for Nonferrous Metallurgy II

Room: Oak Bay

Session Chairs: Rick Volk, United Refractories Co.; Angela Rodrigues-Schroer, Wahl Refractory Solutions

9:20 AM

(UNITECR-211-2013) Molten Aluminum Long-Distance Transportation: A Refractory Issue

M. Braulio*, D. Oliveira, Federal University of Sao Carlos, Brazil; J. Gallo, Alcoa, Brazil; V. Pandolfelli, Federal University of Sao Carlos, Brazil

This work adresses the molten aluminum process optimization by a deep evaluation of the refractory ladles working conditions and their effect on the molten aluminum delivering (~ 8 Mton/trip) after a long distance journey (200 km). Among various advantages of this procedure, the reduction in the customer's ingot inventory, in the losses with re-melting and in the energy costs are pointed out. Concerning energy savings, an increase in the delivering aluminum temperature is welcome as it reduces the homogenezation time in the customer's furnace, increasing its productivity. In order to optimize the refractory's performance, its thermal insulation design, the crucible's preheating profile and the material's maintenance procedure were explored. The typical molten aluminum delivering average temperature was increased by 20C, mainly by adjusting the crucibles' pre-heating step and also by improving the refractory maintenance procedure. Based on a systemic evaluation, comprising not only a suitable material's selection but also application and maintenance aspects, this delivering temperature increase was attained, resulting in energy savings and cost reduction, as a consequence of lower requirements for thermal homogenezation of the molten metal in the customer's furnace.

9:40 AM

(UNITECR-212-2013) Chromium-Free Spinel Bonded Castables versus Rebonded Fused Grain Basic Bricks

G. Oprea*, H. Zargar, C. Oprea, R. Lodha, T. Troczynski, University of British Columbia, Canada; D. Verhelst, Teck Metals Ltd., Canada

Chromium-free spinel bonded basic castables made using our novel chrome-free binding system and fired at as low as 1450°C have been scaled up to industrial size and their life in service was compared with rebonded fused grain (RFG) basic bricks, lined-up in a Bottom Blown Oxygen Convertor (BBOC) mainly used for Pb-Ag cupellation. The used brick samples were compared on the basis of their physical, chemical and mineralogical properties changes due to impregnation and reactions with the molten slag. The variations in properties from the hot to cold faces were correlated to their performance during use. The results showed that the cast bricks made with our newly developed chromium-free binder system had the physical properties, micro- and macrostructures less affected by the slag penetration and corrosion than the RFG magnesia-chrome bricks, usually fired above 1720°C.

10:00 AM

(UNITECR-213-2013) Development and Application of Improved Shotctrete Refractory for Aluminum Rotary Furnace Applications

J. G. Hemrick*, Oak Ridge National Laboratory, USA; A. Rodrigues-Schroer, D. Colavito, MinTeq International, Inc., USA; J. Smith, K. O'Hara, Missouri University of Science and Technololgy., USA

Oak Ridge National Laboratory, in collaboration with refractory manufacturer Minteq International, Inc., academic partner Missouri University of Science and Technology and refractory end users have developed novel refractory systems and techniques to reduce energy consumption of refractory lined vessels. The objective of this U.S. DOE funded project was to address the need for innovative refractory compositions by developing novel gunnable refractory compositions for use in high temperature and high alkali environments. Developed materials utilized new aggregate materials, bond systems, protective coatings, and phase formation techniques. Under this project, materials were developed specifically for aluminum rotary dross furnace applications and a light-weight back-up refractory system was also developed to improve the thermal efficiency of the installed lining system. This paper discusses the systematic development of these materials, laboratory testing and evaluation of these materials, and the performance of several industrial trials performed using these newly developed materials. The success of the industrial trials will be highlighted and future areas of application of these materials discussed.

10:20 AM

(UNITECR-214-2013) Phosphate bonded monolithic refractory materials with improved mechanical and chemical resistance for applications in the aluminum industry

J. Decker*, Stellar Materials, USA

Phosphate bonded bricks have long been used in the aluminium industry because of their high impact resistance, non-wetting properties, alkali resistance and relatively high tensile strengths.Phosphate bonded monolithic castables have been available for many years but such materials found acceptance mostly as veneer repair materials or in furnace areas with moderate operating conditions. The limitations of these phosphate bonded monolithic materials are mostly due to the alkali content which is required for ambient setting properties and good bonding characteristics towards existing materials. As a consequence higher impact resistance can only be achieved if the liquid content, resulting porosity and alkali content of the phosphate bonded monolithic materials is very low. This,however, often makes placement of the material more difficult. In order to overcome these problems a water based phosphate bonded monolithic material has been developed that shows placement characteristics similar to high performance conventional castables. The result is a dense phosphate bonded matrix with properties similar to phosphate bonded bricks. In this paper the development process will be explained based on thermo-mechanical testing and scanning electron microscope analysis. In addition first application results will be discussed.

10:40 AM

(UNITECR-215-2013) Advances in No Cement Colloidal Silica Bonded Monolithic Refractories for Aluminum and Magnesium Applications

M. W. Anderson*, L. A. Hrenak, D. A. Snyder, Magneco/Metrel, Inc., USA

Throughout the past 20 years, colloidal silica bonded monolithic refractories have been developed and utilized for their properties, ease of installation, and forgiving dry-out thereby reducing costly down time and production loss. This paper discusses how the many improvements that have been made in the technology of colloidal silica bonded monolithic refractories can be applied in the aluminum industry. Research suggests alumino-silicate refractories in contact with magnesium and Al-Mg alloys are particularly susceptible to corrosive attack due to the reduction of oxides. In industry qualification tests for aluminum contact applications, these new colloidal silica bonded products have shown improved performance in comparison with other monolithic refractories. The improved corrosion resistance, superior alkali resistance, and versatility in installation method make colloidal silica bonded refractories an excellent alternative to traditional cement based refractory in both contact and non-contact applications.

11:00 AM

(UNITECR-216-2013) Functional Coatings on Reticulated Porous Foam Ceramics made of Alumina for Aluminum Filtration

C. Voigt*, C. G. Aneziris, TU Bergakademie Freiberg, Germany

Collaborative Research Center 920 – "Multi-Functional Filters for Metal Melt Filtration", granted by the German Research Foundation (DFG), aims the investigation and optimization of the filtration process of metal casting. A key issue for the filtration efficiency is the influence of the filter surface. Therefore the preparation of alumina filters with two different coating materials (spinel and TiO2) were tested and optimized. Two different coating methods, spraying and dipping of the filter into the slurry combined with a centrifugation, were compared in terms of the cold compression strength and homogeneity of the coating on the example of the spinel surface. Furthermore, the influence of the application of one or two sintering steps for the spinel filter was investigated. In the second step the filters with spinel, TiO2 and without coating are prepared with a focus on obtaining the same porosity for all three surfaces. The thermal shock behavior of the filters was tested with a "Small Impingement Test" with aluminum. Furthermore, the interfaces between aluminum and the filter coatings were examined.

Raw Materials Developments and Global Raw Materials Issues III

Room: Esquimalt

Session Chairs: Shane Bower, Christy Minerals LLC; Bill Peschler, Minerals Technologies

9:20 AM

(UNITECR-194-2013) Development and Application of Bauxite-based Homogenized Grogs

T. Ge*, X. Zhong, Zhengzhou University, China; L. Wang, J. An, Yangquan JInyu Tongda High-temperature Materials Co., Ltd., China

Bauxite-based homogenized grogs(Al2O3: 60wt.%, 70wt.% and 80wt.%) are prepared by "three step homogenization, plastic forming and high temperature sintering" innovative technology, mainly using medium and low grade bauxites as starting materials. These homogenized grogs are characterized by quality consistency; Al2O3 content fluctuates in the range of ±2%. Their microstructure is mainly continuous interlocking network structure of well-developed prisimatic mullite crystals. Their apparent porosity is less than 4%. They have been used in manufacturing high alumina bricks and castables for blast furnaces and cement rotary kilns.

9:40 AM

(UNITECR-196-2013) Influence of additives on phase transformation and morphology

L. Zhu*, G. Ye, A. Fu, S. Li, C. Yao, X. Song, Zhengzhou University, China

Phase transformation and microstructure development of α-Al2O3 in the presence of various additives, such as NH4F, NH4Cl and H3BO3, have been studied by TG/DSC, XRD and SEM. This work is focused on the influences of type, amount and composition of additives on the phase transformation and morphology of alumina, and the mechanism of the effect of additives on the crystallization habit of α-Al2O3 was also discussed.

10:00 AM

(UNITECR-197-2013) Synthesis of High Purity Forsterite and Its Use in Magnesia Based Castable

N. Zhou*, L. Guo, Henan University of Science and Technology, China; H. Bai, Yanshi Zhongyue Refractories Co., Ltd, China

Taking into the consideration of that forsterite has high melting point, good crystalline stability, no hydration and good compatibility with magnesia, while for natural occurred olive ore, the impurity level is high, this work synthesized high purity forsterite with a mass ratio at 60: 40 of MgO over SiO2, using magnesite, caustic magnesia and quartz as starting materials. The synthesized forsterite as aggregates was added in a magnesia based castable, using dead burned magnesia as aggregates and MgO-SiO2-H2O binding, to replace magnesia aggregates up to 60% at an interval of 15%. The effect of the forsterite addition on properties of the MgO based castables was investigated. Microstructure analysis of related samples was carried out by means of SEM and EDAX. Hot strength at 1400oC and thermal shock resistance can be improved by adding the forsterite. Bulk density of the castable is reduced with increased addition of the forsterite. High alumina bauxite was also incorporated to make use of its reaction with magnesia to form spinel, accompanying volumetric expansion, to compensate the shrinkage at high temperature.

Global Education in Refractories I

Room: Sidney

Session Chairs: George Oprea, University of British Columbia; Yawei Li, Wuhan University of Science & Technology

9:20 AM

(UNITECR-065-2013) Enhancing Technology Transfer Capabilities: A German Perspective

A. Geigenmüller*, Ilmenau University of Technology, Germany

Particularly in turbulent times the refractory industry benefits from knowledge provided from universities and academic research centers. Transforming this knowledge into industrial applications, however, requires an effective technology transfer between universities and the industry. Technology transfer can be characterized as social interactions between technology transfer partners. High-quality interactions between transfer partners are vital to an effective exchange of knowledge and the performance of a technology transfer relationship. Consequently, refractory education programs should include forms and structures that support students in developing "technology transfer capabilities." This paper presents individual and organizational capabilities that have been recognized as critical to successful transfer relationships between universities and the industry. The study is based on a survey among academicians and practitioners in materials science and engineering in Germany and provides empirical support for strong and positive relationships between these capabilities, perceived interaction quality and individual evaluations of transfer success. The paper discusses how education in refractories can be enriched by introducing courses, workshops, and seminars for graduate and Ph.D. students, thus enhancing effective transfer relationships between universities and the refractory industry.

9:40 AM

(UNITECR-066-2013) Koblenz University of Applied Science, Department of Materials Engineering, Glass and Ceramics playing a key role in the science and education network for the refractory industry

O. Krause*, Koblenz University of Applied Sciences, Germany; P. Quirmbach, University of Koblenz-Landau, Germany

Amongst the international well-recognized institutes at TU Freiberg and RWTH Aachen, the Department of Materials Engineering of Koblenz University of Applied Science in Hoehr-Grenzhausen represents the third party who intensively deals with education and research for the ceramic industry. The Department is closely related to the cooperative education network, BFZK (educational and research centre ceramics), which allows best utilisation of the existing public education structure. Since 2010 the conversion from diploma degree programme to bachelor of material science has been successfully carried out and was followed by the implementation of a master degree in cooperation with the University of Koblenz-Landau. The Department follows two major tasks: Best possible and targeted education in order to provide graduates with tailor-made abilities for the ceramic industry. For this reason the industry and the State ministry of economics of Rhineland Palatia funded three endowed professorships, out of which two have already been converted into regular positions. The second task is to promote science projects that are closely related to the demands of the key industry refractories. The presentation will introduce the state-of-art master and bachelor curriculum and will briefly present recent research works.

10:00 AM

(UNITECR-067-2013) Integrating education concepts: The Koblenz region offers a one-of-a-kind infrastructure to identify and qualify future specialists in order to ensure reliable and continuous provision of best-skilled employees to the Refractory Industry

P. Quirmbach*, University of Koblenz-Landau, Germany; O. Krause, University of Applied Science, Germany

The refractory industry suffers a lack of young people in Germany. Within the past five years an integrating education concept has been developed to ensure a sustainable provision of young and best-skilled craftsmen, technicians and engineers to the refractory industry. The aim of this presentation is to demonstrate how the sophisticated network between education, science and refractory industry leads to efficient fulfilment of the industry's demands. Because of a vertically open vocational education structure as provided by public legislation it is possible to promote young people even with initial limited educational achievements to finish with an academic degree. The cooperative education network, BFZK (educational and research centre ceramics), which closely cooperates with the University Koblenz-Landau, allows best possible utilisation of this public education structure. Key of success is that industry as well as schools and universities cooperate permanently in defining contents and optimizing organisational demands in view of best practise for applicants and the refractory companies. It will be demonstrated that levels of qualification are adapted to each other so that a consistent system is available to lower mentioned suffering.

10:20 AM

(UNITECR-068-2013) Graduate Programs in Refractory Engineering: What is duly needed?

M. Rigaud*, École Polytechnique, Canada

Taking for granted that a Master and a Ph.D programs are duly needed, the goal of this paper is to describe what is needed. Based upon the seven years of experience FIRE has accumulated already, it appears more and more realistic to conceptualize what an ideal program would look like, mixing all the ingredients to be found in the FIRE academics networks. The suggestions made should be transposable in any one institution devoted to the matter. As it has been stipulated several times before, to maintain competition and avoid technical stagnation, relinguishing refractory education as a segment of the continuing education for adults is not an option.

Iron & Steel Making Refractories- General Session III

Room: Colwood

Session Chair: Brian Kenyon, Vesuvius; Yong Lee, ArcelorMittal Research

9:20 AM

(UNITECR-126-2013) Refractory response for pig iron refining with KR-process

P. Tassot*, CALDERYS, Germany; J. Wang, CALDERYS TAIWAN, Taiwan; H. Lemaistre, CALDERYS, France

Kanbara refining (KR) is an alternative technology to conventional deep injection for hot metal pre-treatment to achieve high productivity of hot metal desulphurisation with mechanical stirring . Main advantages of the process: - Extremely low sulphur contents in short treatment times - Controlled reduction of the sulphur content - Low cost desulphurising agents can be used. - slag skimming is carried out after desulphurisation operation Desulfurizing hot metal depends on the kind and amount of desulfurizer, the treatment temperature and stirring efficiency. For such a purpose, the use of an impeller to stir the molten pig iron is effective, and in connection therewith, the durability of the refractories to protect the impeller is an important issue from the technical for avoiding the eccentricity) and economical points of view. Optimization by FEM and or CFD has now allow to reach a very stable and reliable design and performance in Asia, compensating the higher investment cost by using a low cost burnt lime. This paper is describing the optimization of the impeller in Taiwan.

9:40 AM

(UNITECR-127-2013) Improvement of Refractory Castables for KR Desulphurization Impeller

S. Yeh*, C. Chen, W. Lin, H. Chen, Good Furnace Refractory Industrial Co., Ltd, Taiwan

KR desulphurization impeller was developed by Nippon Steel Corporation in 1963. It is a kind of sulfur removal technique applied on the outside container of refining furnace. In 2005, KR impeller refractory castable developed by the R&D team of Good Furnace Refractory Industrial Co., Ltd. passed the test requirement of China Steel Corporation and proceeded to the field test. In the field test, many cracks appear on the surface of KR impeller after 400°C drying and led the failure of test in the desulphurization process. In order to fix this trouble, two kinds of refractory castables, Al2O3-SiC based and high alumina based, for KR impeller are prepared to examine the explosion resistance, thermal shock resistance, and compare with the performance in the field test. The results show that Al2O3-SiC based castable pass the anti-explosion test and its loss of rupture of modulus and field test performance is 58% and 107 cycle times of sulfur removal process. However, the high alumina based castable also have the anti-explosion property and its loss of rapture of modulus, comparing to Al2O3-SiC based castable, reduces from 58 to 33%. And the field performance of high alumina based castable for KR impeller is 200 cycle times of desulphurization process. It means that high alumina based castable for KR impeller has a better thermal shock resistance and performance in the field test then Al2O3-SiC based castable.

10:00 AM

(UNITECR-128-2013) Study on Ladle Purging Plug with Gradient Composite Structure and Material

H. Zhang*, T. Yu, W. Yang, L. Chen, Luoyang Institute of Refractories Research, China; W. Yang, State Key Laboratory of Advanced Refractories, China

Ladle purging plug always fail to blow argon during ladle refining process due to plug thermal fracture when using at large temperature

different environment. We try to develop purging plug with gradient composite structure and material in order to improve thermal shock resistance of plug. With respect to slit structure, the thermal stress of plugs with gradient circular slit structure and radial straight slit structure were comparatively studied by means of ANSYS simulation. In the same sectional area of permeable slits, the internal thermal stress of plug with gradient circular slit structure distributed more evenly than that of plug with radial straight slit structure which is widely used in China. The maximum thermal tensile stress of plug with gradient circular slit structure is 45.3MPa, decrease 100% relative to 91.0MPa of plug with radial straight slit structure. And the maximum thermal tensile stress of plug with 24slits reduce 26.3% comparing with 57.2 MPa of 12slits plug. We also study to combine Al2O3-spinel material which is widely applied in ladle with high thermal conductivity Al2O3-SiC material into gradient composite plug. The thermal shock resistance of gradient composite plug will improve because the maximum thermal tensile stress of gradient composite plug decrease 32%.compraring with uniform material based plug.

10:20 AM

(UNITECR-129-2013) Benchmarking of CAS-OB Refractory Bells

K. Subramaniam*, A. Kremer, GSB Group GmbH, Germany

The CAS-OB (Composition Adjustment Sealed Argon Bubbling with Oxygen Blowing) process is otherwise known as CHS (Chemical Heating Station) or IRUT (Injection Refining and Up Temperature) was developed for composition and temperature adjustments of steel. With the capability of having better control in achieving good chemical composition, ladle homogeneity and reheating, these installations have become an ideal buffer station in the area of secondary metallurgy. The main advantage of such equipment is that it gives high alloy yields at low cost and has the ability to make wider range of alloys. However one of the biggest challenges faced is the operating costs of CAS-OB, a lion's share of which is attributed to refractory bells. This paper provides brief information about CAS-OB process and highlights the design concept of the REFRACTORY BELL and the factors affecting its performance. Besides this, the paper also underpins the importance of steel construction involved in refractory bell manufacturing, highlighting the benchmarking performance of selected steel mills in Europe and recent developments with regard to the bells.

10:40 AM

(UNITECR-130-2013) Effects of B4C Addition on High Temperature Properties of Al/Si Incorporated Low Carbon Al2O3-C Slide Plate Materials

X. Liu*, High Temperature Ceramics Institute, China; Y. Wang, Puyang Refractories Group Co.,Ltd., China; X. Zhong, High Temperature Ceramics Institute, China

The effects of 0.5-1.5% B4C addition on thermo-mechanical properties and oxidation resistance of Al/Si incorporated low carbon Al2O3-C slide plate materials have been investigated and their correlation with microstructure has been discussed. The results show: (1) Oxidation resistance at 1500C noticeably improved; thickness of oxidized layer is decreased from 4.3mm to 2mm with 1.5% B4C addition. This may be attributed to the formation of low melting borosilicate which would inhibit O2 infiltration. (2) With addition of B4C, (a) thermal shock resistance is well retained at high level, residual strength ratio is 76-80%; (b) hot modulus of rupture at 1400C is increased noticeably from 22.7MPa to 42MPa; this may be due to increase of in-situ formed well developed nonoxide (AlN and SiC) crystals.

11:00 AM

(UNITECR-131-2013) Improvement of the durability on SG Plate for steel ladle

Z. Ohmaru*, K. Akamine, K. Morikawa, J. Yoshitomi, Krosaki Harima Corporation, Japan

The slide gate (SG) plate is used for controlling the flow of the molten steel in the continuous casting. As a typical wear damages of SG plate, there are surface abrasion and edge damages and radial cracks, etc. It was tried to solve the improvement of the edge damages and surface abrasion. As a result of investigating an after-service slide gates, it was estimated that edge damages were caused by the thermal expansion of an inner bore part in services. Surface damages of SG plate are peeling by reaction between SG plate and CaO-Al2O3 slag. Results of the selection of appropriate evaluation methodologies and improvements of the ZrO2 amounts and low thermal expansion ZrO2-SiO2 raw materials, durability was improved.

Iron & Steel Making Refractories - Blast Furnace and Troughs II

Room: Lecture Theatre

Session Chair: Mike Alexander, Riverside Refractories; Andus Buhr, Almatis

11:20 AM

(UNITECR-075-2013) Innovative Graphitic Castable Utilized as a Repair Material for Carbonaceous Refractory Systems

F. Van Laar*, Y. Ma, Allied Mineral Products, Inc., USA; A. Petruccelli, Allied Mineral Technical Services, Inc., USA

This paper is a review of a new step in technology which has not been seen in the industry anywhere else to date. This high conductive carbon based shotcrete and castable refractory can be utilized as a repair material to a carbonaceous brick lining in the bosh and lower stack of a blast furnace. The material has properties which can cope with the process conditions and thermal fluctuations which make typical alumina silicon carbide type materials fail in these areas of the furnace. The high conductive castable is comprised of a blend of raw materials that creates properties superior in performance to monolithics composed of alumina, silicon carbide or a combination of alumina and silicon carbide. The material offers installation benefits over traditional bricks as well. Performance data of actual installations in operation and the product properties as compared to traditional materials will also be reported.

11:40 AM

(UNITECR-076-2013) Challenges to Improving the Environmental and Health Safety Characteristics of Tap Hole Clay

J. Stendera*, R. Hershey, G. Biever, Vesuvius, USA

The hazards of chemicals used in industrial products are largely defined by local governmental agencies and the standards that are written by such organizations as the Environmental Protection Agency, and Occupational Health Safety Agency in the USA and The REACH standards in Europe. Due to this fact there are regional differences in what chemicals in a product are considered to be hazardous, how the hazard is determined and what the permitted exposure limits are for the various substances. This is particularly true of materials such as Phenolic Resin and Coal and Petroleum Tars and pitches that are used in anhydrous tap hole clays to provide installation consistency and serve as a precursor to form high temperature carbon bonding. This paper will discuss the compounds that exist with the various carbon precursor materials commonly used in taphole clay. In particular, the various PAH (Polycyclic Aromatic Hydrocarbons) compounds will be discussed. The measured levels of the various PAH's will be compared for various raw materials and finished products. How this impacts the required disclosure and defined hazard for these materials based on local standards will be discussed. Recent efforts to produce a taphole clay with no measurable PAH content will be de-

scribed. The properties of this material will be discussed along with field trials to date.

12:00 PM

(UNITECR-078-2013) Invention Reaction Bonded Alumina bricks for BF Ceramic Cup

Y. Hong*, Chosun Refractories.,Co.Ltd, Republic of Korea

This invented product is the refractory for protection of carbon bricks which are installed at ceramic cup. Its original material was mullite, but this product is using special binder and burning atmosphere, which can product β-type silicon carbide, sialon, and etc. The main characteristics of this product are excellence resistance against pig iron and alkalies, high resistant against thermal shock, high resistant against oxidation and against the sequential corrosion oxidation, and etc. Also, it maximise the protecting function for carbon bricks by decreases of heat loss due to increases of thermal conductivity compared with mullite materials.

12:20 PM

(UNITECR-079-2013) Development and Application of Taphole Mud for 5800 m3 Large Scale Blast Furnace

P. Chen*, N. Lin, T. Lin, Sunward Refractories Co., Ltd., Taiwan

Large scale blast furnace possesses high production quantity of molten iron, high blast quantity and pressure, specific taphole mud is needed for tapping operation in large scale blast furnace. Taphole mud for 5800 m3 large scale blast furnace of Sha Gang Steel was investigated in this study. Two formulas were made using brown fused alumina (BFA) and calcined bauxite (CBX) as basic aggregate, respectively. A series of physical and chemical properties were compared, and these two formulas both showing good performance on field-testing results, the average tapping time were 160-165 min.

Iron & Steel Making Refractories - General Session IV

Room: Saanich
Session Chair: Vanessa Mazzetti-Succi, ArcelorMittal Dofasco; Rakesh Dhaka, US Steel

11:20 AM

(UNITECR-132-2013) Development of the monolithic refractory using spent refractories

N. Koji*, KOBE STEEL,LTD., Japan

By expanding the recycling of spent refractories, the durability of the refractories is reduced in general.In order to prevent a reduction of durability,We developed a monolithic refractory which selected the appropriate particle size distribution and selected a spent refractory with high corrosion resistance against steel making slag. In addition, by cooling the refractory, it was possible to improve the durability than conventional products.The result of applying this monolithic refractories to the snokel, campaign life of snokel was improved.

11:40 AM

(UNITECR-133-2013) Strengthening mechanism of graphene oxide nanosheets for Al2O3-C refractories

Y. Li*, S. Sang, M. Luo, T. Zhu, Q. Wang, Wuhan University of Science and Technology, China

Al2O3-C refractories containing graphene oxide nanosheets (GONs) with Al, Si and SiO2 additives were prepared in this work. The GONs/α-Al2O3 composite mixtures were firstly prepared by ball milling expanded graphite (EG) and α-Al2O3, then incorporated into Al2O3-C refractories. The results revealed that GONs with different size and thickness were well distributed in α-Al2O3 powder depending on addition amount of expanded graphite. The GONs produced positive influence on in-situ formed ceramic whiskers in specimens at lower temperature owing to its higher reactivity than that of graphite flake. The mechanical properties such as cold modulus of rupture (CMOR) and flexural modulus (E) of specimens with GONs were improved compared with those without GONs. This improvement was attributed to strengthening of GONs at 800°C and synergetic strengthening effects with graphite flake and in-situ formed whiskers at 1000-1400°C.

Safety, Environmental Issues and Recycling Solutions for Refractories

Room: Oak Bay
Session Chairs: Jason Canon, The Christy Refractories Co. LLC; Leonardo Curimbaba, US Electrofused Minerals/Electroabrasives LLC

11:20 AM

(UNITECR-222-2013) Analysis of Chemical Valence of Chromium in Magnesia-Chrome Bricks Used in Different High-temperature Furnaces

C. Yao, G. Ye*, X. Yang, Y. Mu, L. Chen, Zhengzhou University, China

Magnesia-chrome bricks are widely used in high-temperature furnaces for their excellent performances. As Cr^{6+} is classified among a highly hazardous and toxic substance, and used magnesia-chrome bricks which are believed to cause environmental pollution, need to be substituted by more environmental friendly refractories. But the chemical valences of Cr in magnesia-chrome bricks used in different high-temperature vessels have not been identified. Therefore, it is imperative to determine the chemical valence of Cr in magnesia-chrome brick used under different working environments. In this work, X-ray photoelectron spectroscopy (XPS) was used to determine the chemical valence of chromium in magnesia-chrome bricks used in RH furnaces, copper production furnaces and cement kilns. The phase compositions and microstructure observation of used magnesia-chrome bricks was investigated by XRD and SEM.

11:40 AM

(UNITECR-223-2013) The issue of usage of refractory materials scrap

A. Kielski, ArcelorMittal Refractories, Poland; P. Wyszomirski, AGH University of Science and Technology, Poland; P. Blumenfeld, ArcelorMittal Fos-sur-Mer, France; L. Obszynska*, M. Sulkowski, ArcelorMittal Refractories, Poland

The prices of raw materials for the production of the basic refractories are high and continue to grow steadily. One of the ways of limiting the rising manufacturing costs is to increase the usage of used refractory materials. Methods of processing of the used MgO-C refractories in order to obtain high quality of raw materials on the basis of experience of ArcelorMittal Refractories Company, Kraków, Poland are described herein. The methods make it possible to both reduce the manufacturing costs and to improve the quality of selected basic refractory materials.

12:00 PM

(UNITECR-224-2013) Is there a viable alternative fiber to RCF?

S. Chernack*, Morgan Thermal Ceramics, USA

In last years, regulations on the restriction of use of RCF have been seen only in the European Union. The EU classifies RCF as a CLP 1B carcinogen, presumed to have carcinogenic potential for humans. This classification is largely based on animal evidence. It strictly regulates the use of RCF in the workplace. On August 3 2010, came the first signs of change for RCF in the US market by limiting the exposure limit of RCF in the workplace from the federally recommended 0.5 f/ml - 0.2 f/ml. Use of low bio-persistent linings for HRSGs offer In each section of the unit -showing improved heat flow with equal of lower density material, Getting rid of shrouds in firing ducts which have been problematic over the years and lining with modules, Fixing hot spots on line.

12:20 PM

(UNITECR-225-2013) An Attempt Towards the Development and Successful use of Eco Friendly Basic Refractory Product

P. Sengupta*, N. Gupta, S. Mondal, S. Mondal, SKG Refractories Ltd, India

One of the major process requirements in manufacturing of basic Refractory shaped product, is high temperature firing, which provides the desired properties and microstructure to the Refractory. Firing itself emits considerable amount of CO2 to the environment. An attempt was made to develop Chemically bonded Magnesia- Chrome Refractories to replace the burnt Magnesia-Chrome Refractory, for the application in the roof of Twin hearth furnace, producing steel. The factors, responsible for the damage of the Refractories, in that particular application, are identified and the design parameters were set to achieve the desired properties of the Refractory. The effect of different binders and the quality of Magnesia, on the different properties of the developed Refractory, were studied. The developed product with the best obtained properties, were put in actual use in the form of a panel of 1.5 square meter area, in the roof of a 250MT capacity Twin Hearth Furnace and the performance obtained is same, as that of fired product, being used regularly. Now the planning is on, to construct the complete roof, with the newly developed chemically bonded Magnesia Chrome Refractory bricks.

Global Education in Refractories II and Facilitated Discussion on Global Education in Refractories

Room: Sidney

Session Chairs: George Oprea, University of British Columbia; Yawei Li, Wuhan University of Science & Technology

11:20 AM

(UNITECR-069-2013) Promoting Natural Science and Engineering at Freiberg University: Some outstanding tools and results

K. Haeussler*, TU Bergakademie Freiberg, Germany

Companies as well as universities observe a serious lack of well-educated graduates. There are different reasons for this unfavourable development. Interest in natural science and engineering education and the reputation for the associated profession is decreasing. Opposing this development, concerted actions are requested to attract more young people to the field of natural science and engineering. Student's labs and student's colleges, and so called KinderUni offer rich opportunities to arouse children's interest in natural and engineering sciences and to influence their images of a further profession in these fields. Events such as "open days" or "science nights" regularly invite interested visitors to learn more about research and education at Freiberg University. Schoolchildren's University is a good opportunity to combine personal communication and experience with an emotional atmosphere. Providing interactive formats such as public lectures, experiments, visitations of companies, visitors turn to actors. A new project "Night in the Lab" is another way for promoting engineering. Some projects will be presented and the first results, i.e. increasing numbers of freshmen in the study course ceramics, glass and construction materials, will be shown.

11:40 AM

(UNITECR-070-2013) Visualizing the Invisible: How to Attract Students to Refractory Engineering

A. Geigenmüller*, S. Lohmann, Ilmenau University of Technology, Germany

Attracting students and young researchers to the field of refractory engineering poses a constant challenge to universities and the industry. A lack of students does not only result in a lack of refractory engineers, it also threatens the existence and development of refractory engineering as a distinctive academic subject. It is repeatedly argued that the field of refractory engineering suffers from biased associations and an unfavorable image. Consequently, strategies are sought to correct that image and to improve the discipline's attractiveness to students and young researchers. However, suggestions of effective communication strategies and appropriate combinations of communication instruments are scant. Moreover, recent advances in employing social media have been widely neglected. This paper presents an empirical study which finds the image of the discipline to be rather blurred than explicitly negative. Referring to brand theory, this paper concludes on suitable strategies to sharpen the discipline's image and to enhance the visibility of refractory engineering as a field of education and research. The authors present communication measurements and instruments capable to raise students' interest in the subject. Examples of best practice illustrate communication activities for relevant target groups which include students and young researchers but also the wider public.

MEETING REGULATIONS

The American Ceramic Society is a nonprofit scientific organization that facilitates the exchange of knowledge meetings and publication of papers for future reference. The Society owns and retains full right to control its publications and its meetings. The Society has an obligation to protect its members and meetings from intrusion by others who may wish to use the meetings for their own private promotion purpose. Literature found not to be in agreement with the Society's goals, in competition with Society services or of an offensive nature will not be displayed anywhere in the vicinity of the meeting. Promotional literature of any kind may not be displayed without the Society's permission and unless the Society provides tables for this purpose. Literature not conforming to this policy or displayed in other than designated areas will be disposed. The Society will not permit unauthorized scheduling of activities during its meeting by any person or group when those activities are conducted at its meeting place in interference with its programs and scheduled activities. The Society does not object to appropriate activities by others during its meetings if it is consulted with regard to time, place, and suitability. Any person or group wishing to conduct any activity at the time and location of the Society meeting must obtain permission from the Executive Director or Director of Meetings, giving full details regarding desired time, place and nature of activity.

During oral sessions conducted during Society meetings, **unauthorized photography, videotaping and audio recording is prohibited.** Failure to comply may result in the removal of the offender from the session or from the remainder of the meeting.

The American Ceramic Society plans to take photographs and video at the conference and reproduce them in educational, news or promotional materials, whether in print, electronic or other media, including The American Ceramic Society's website. By participating in the conference, you grant The American Ceramic Society the right to use your name and photograph for such purposes. All postings become the property of The American Ceramic Society.

Registration Requirements: Attendance at any meeting of the Society shall be limited to duly registered persons.

Disclaimer: Statements of fact and opinion are the responsibility of the authors alone and do not imply an opinion on the part of the officers, staff or members of The American Ceramic Society. The American Ceramic Society assumes no responsibility for the statements and opinions advanced by the contributors to its publications or by the speakers at its programs; nor does The American Ceramic Society assume any liability for losses or injuries suffered by attendees at its meetings. Registered names and trademarks, etc. used in its publications, even without specific indications thereof, are not to be considered unprotected by the law. Mention of trade names of commercial products does not constitute endorsement or recommendations for use by the publishers, editors or authors.

Final determination of the suitability of any information, procedure or products for use contemplated by any user, and the manner of that use, is the sole responsibility of the user. Expert advice should be obtained at all times when implementation is being considered, particularly where hazardous materials or processes are encountered.

Author Index

*** Denotes Presenter**

Author Index

Author Index

Together

WE ARE IMERYS

There is more than one reason we are the global benchmark for Alumino-Silicate Minerals

Over many years, Imerys have invested in multiple companies, mines and assets to assemble a broad portfolio of products for the refractory market. Traditionally, these companies have maintained their regional identity and been given access to the broader IMERYS group to assist with research and development, geology and engineering.

In **2013**, in a challenging world environment, we began the transition to a global organisation, combining our refractory assets and presention ourselves to the market as **IMERYS Refractory Minerals**. Our local identities have always provided a strong ling to our customers, but it is clear that to match our ambition of providing the highest levels of quality and service while maintaining our competiveness, a new way forward was required.

Now, bringing together the combined teams of CE-Minerals, Damrec, AGS and VKV as well as our global sales network, we are able to offer the broadest portfolio of alumino-silicate materials for Refractory producers and build upon our foundations to re-invest in meeting the new demands of our changing world.

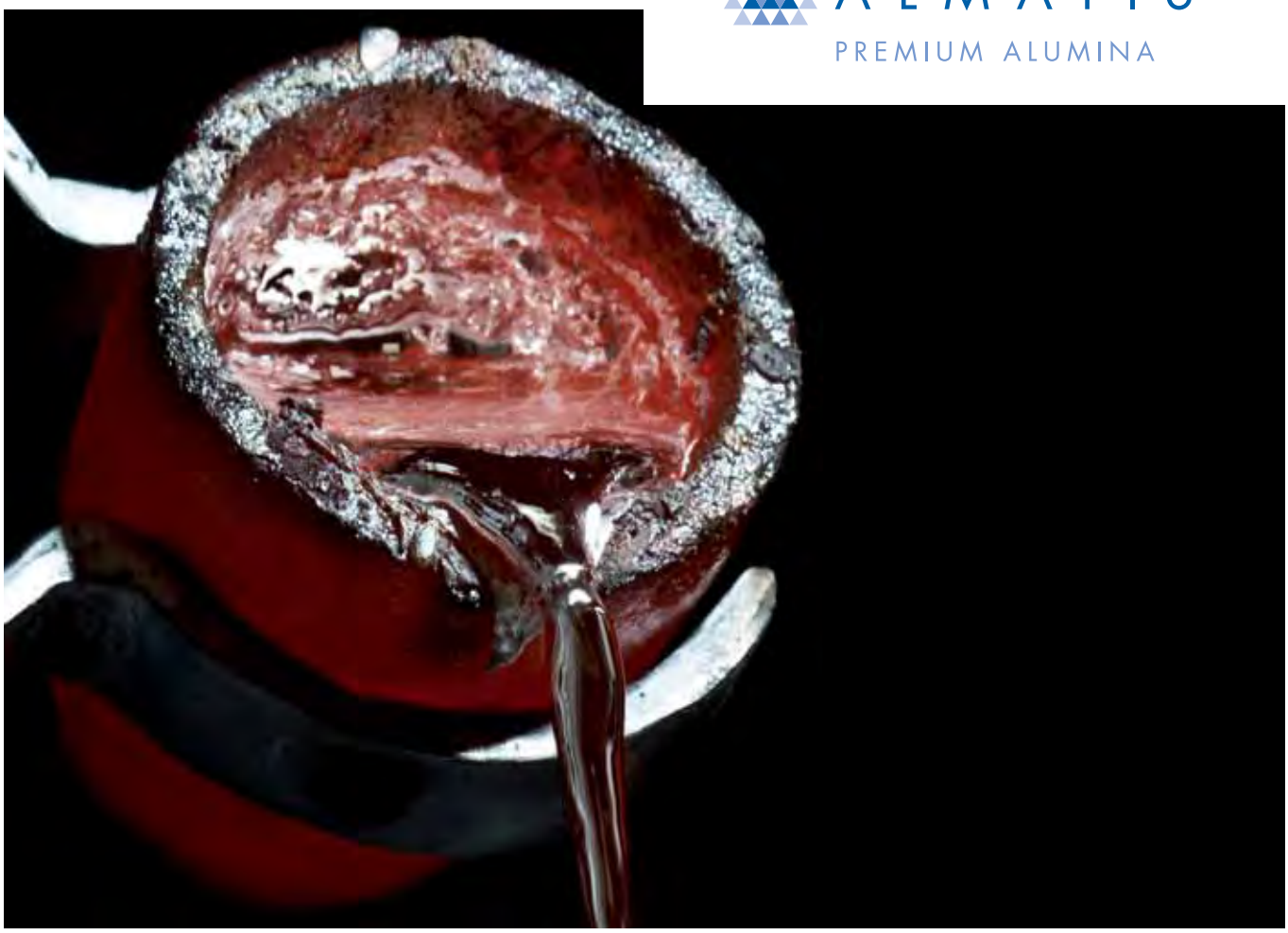
CE-MINERALS
DAMREC
AGS
MOLOCHITE
SAMREC
VKV
ECCA
GSM

Remco de Jong
Vice President & General Manager
IMERY Refractory Minerals

IMERYS
Refractory Minerals

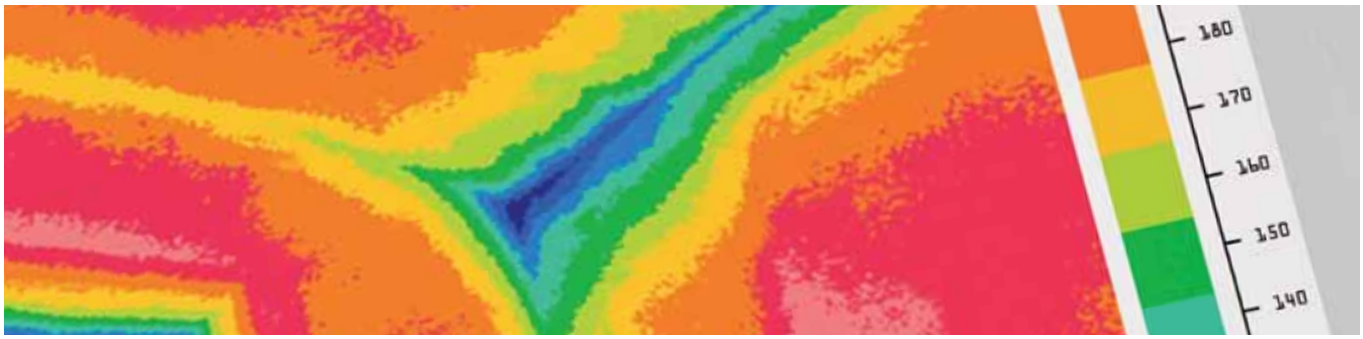
Unique combination of properties.

ALMATIS
PREMIUM ALUMINA



Bonite LD

CALCIUM HEXA-ALUMINATE (CA_6)



Bonite LD is the latest addition to the unique calcium hexa-aluminate product range from Almatis. CA_6-based refractories have already shown their high potential in applications in the aluminum, steel, cement and petrochemical industries. Bonite LD offers reduced bulk density resulting in lower thermal conductivity, making it the ideal choice for refractory linings where energy reduction is desired while keeping high strength and corrosion resistance.

www.almatis.com