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The Official Journal of the Institute of Refractories Engineers

Real world problems – **PRACTICAL SOLUTIONS** IRE Annual Conference and Training Day 2023

SAVE THE DATE: 15 -16 November 2023 The Mowbray, Kelham Island, Sheffield, UK

....see page 21 for more details

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Refractories Engineer



From the editor

I vnn Postle FICMF

Perhaps the greatest benefit of IRE membership is that of camaraderie and the opportunity to connect with like-minded professionals to exchange ideas and knowledge for the benefit of the whole. A collective force provides the strength to affect change and to inspire ongoing developments and improvements for long-term success. Working together as a team is the only way we can develop enduring momentum and drive to improve the industry and the skillsets and competence of those individuals employed in it.

This was particularly evident at the highly successful IRE AUS Conference in Sydney (Australia) in March, where delegates from the whole of Australia and from Asia and the UK came together to share not just professional experiences and technical insights, but also thoughts, ideas and conundrums that need to be faced if we are to continue to grow as a sector which provides expert solutions for a wide range of industries that are dependent upon the capabilities of refractories engineers. It seems incomprehensible that anyone wanting to highlight a commitment to this industry wouldn't already be a member, so if that is the case it's time to get involved. There are plenty of options, just contact the IRE to discuss what best suits you as an individual and your company.

In the meantime, the message was clear at the IRE AUS Conference, and it is clear in this issue of The Refractories Engineer - we need to find a sustainable way of manufacturing in our industry and all those sectors that we serve. There is much work being undertaken to achieve this and IRE members are at the centre of this drive. The topic will no doubt be an important part of the IRE UK Conference and Training Day, taking place on 15-16 November where practical solutions to several current predicaments will be considered. I urge you to come along to the event in Sheffield and become an active participant at the Institute to fully appreciate the inspiration and guidance taking part offers.

Don't risk suffering from FOMO - book your place today.

Front cover image: Shutterstock

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Message from the Acting President

Dear Members

It is with regret that, due to work commitments, Phil Walls has had to step down as President of the IRE. Given some of the work levels involved on both sides, the situation was not workable for him, so we wish him all the very best and thank him for his contributions, particularly his tenacity to help make change which was instrumental in helping the IRE to move forward. As such, and for a very short period, I have taken the mantel of Acting President until the next planned AGM later in July (after this issue has gone to print), where council has proposed that Mike Lamkin becomes our new President.

Mike will bring to the table a balanced approach and having been Treasurer for the last two years he has a solid grasp of the Institute finances. I and the rest of council are looking forward to supporting him in his role.

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Engineers

Refractories

In the meantime, we are busy preparing for our *Conference and Training Day*, this is scheduled for 15 and 16 November in Sheffield. Go online now to secure your places and we will look forward to networking with you!

I would also like to welcome onboard to our council Mario Taddeo and Greg Connor from the Australasia branch, it is great to get some extra support and help on council and their additions will be really useful in helping us to make the progress we want.

Lastly, I would like to thank Peter Rooney who has handed over the mantel of Secretary on IRE council and has stepped down. Peter has been a past President and he has served the IRE on council for so many years, he has been an unwavering support, has brought balance to every aspect of his work with the IRE and as such became our constitution guru, he spent countless hours pouring over rules and contracts. It's fair to say the evolution would not have happened without his input. I thank Peter on behalf of myself and all the members for his commitment to the IRE.

So, lots of change again for the first half of the year, I hope to see as many of you as possible at our AGM and hopefully this will be my very last President's column.

Katy Moss

Acting President Institute of Refractories Engineers

Membership Renewals

Membership of the Institute of Refractories Engineers offers a wealth of benefits and highlights a commitment to YOUR industry.

Remaining loyal to the Institute of Refractories Engineers shows to the wider industry that you and your company are proud of the heritage and professionalism of your leading sector organisation.

Members benefits include:

- A copy of the journal *The Refractories Engineer*, mailed direct to your door.
- Access to meetings and social media groups enabling networking opportunities with our refractories' community.
- The opportunity to submit papers for publication by the Institute.
- An IRE Membership Certificate to display in your premises.
- Discounted rates for meetings and other functions.

Make sure you don't miss out on all the latest refractory news and exciting improvements from the Institute of Refractories Engineers. Renew your membership today, or sign up by sending an email to secretary@ireng.org



A corporate partner package is a reflection of an organisation's commitment to the refractories industry and the professional institute that represents the industry. The IRE is appreciative of the support of our corporate partners and is delighted to be working with them for the benefit of the whole sector.

For more information on corporate partner packages refer to page 37.



Update from Australia

Dear Readers

At the recent IRE Australasia Annual General Meeting, I was honoured to be selected for President, serving a three-year term expiring in mid 2026. I join a long list of outstanding past Presidents whose legacy with the respective management teams is the robust organisation we have today.

So, I would like to dedicate my first column as President to our team members, our history and some strategies for future growth.

A bit about me. Regular readers will be somewhat familiar from previous editorial columns and published papers focussed on optimised refractory design through insulation. My background is technical sales with a specialty in the steel industry throughout the Asia-Pacific. In my travels, I have been promoting the IRE to much receptive positive interest.

The AGM also affirmed the following members on our executive committee including:

Mike Walton (Victoria) - Treasurer

Greg Connor (New South Wales) - Public Officer

Both Mike and Greg have been previous Presidents and have been great stalwarts and supporters of the IRE. Their efforts have maintained a greater than ten per cent year-onyear growth in our budget offering IRE Australasia a very strong financial foundation.

Dean Tredinnick (New South Wales) - Secretary

Dean has worked tirelessly supporting the IRE and garnering valuable sponsorships and attendees for our recent conference.

Michael Broadbent (Victoria) - Training Officer

One of the core purposes of the IRE is to facilitate training and encourage interest in refractories. I would thus also like to give a special mention to Don Merritt of 4D Delta and Mike Walton who facilitated the much needed training day in Western Australasia.

Mark Prince (Queensland) – the retiring President of IRE Australasia has agreed to maintain his role and authority in representing our executive committee at IRE UK meetings. His experience and knowledge results in an efficient conduit in co-ordinating both our organisations' activities.

Alan Blanch (New South Wales) – One of the founders of the IRE Australasia branch, though retired Alan offers insightful input and enthusiasm to our committee meetings.



Don Merritt (Western Australia) has recently accepted to fill the vacant position of Vice President for a three-year term. Originally from Canada, Don has a wealth of industrial experience, plus marketing, HR and internet media.

We have State committee members in New South Wales, Victoria, Queensland, South Australia, Western Australia and New Zealand and throughout the year we will have online Zoom meetings giving advice to the executive team on how we can do things better and increase our relevance. The aim is to host the meeting on location with the companies that are sponsors of the IRE to further gain their input.

So, the next three years promises to be exciting where we build upon what we have achieved and take it to the next level.

Look out for the next issue of *The Refractories Engineer*, where I will consider the success and outcomes of the *IRE Australasia 2023 Conference* and the trajectory of our branch.

Mario Taddeo MI Ref Eng President, IRE Australasia



Events Diary

Upcoming events to be added as dates in your diary

9 August 2023 International Conference on Refractory Materials and Alloys (ICRMA) 2023 Venue: New York (USA)

Contact: www.waset.org

26-29 September 2023 **Unified International Technical Conference on Refractories (UNITECR)** Venue: Kap Europa, Frankfurt (Germany) *Contact: www.unitecr2023.org*

26-28 October 2023

57th Australian Foundry Institute National Conference Venue: Marriott Hotel, CBD Melbourne, Melbourne (Australia) Contact: www.australianfoundryinstitute.com.au

8-10 November 2023 World Steel Dynamics (WSD) European Steel Conference 2023 Venue: Melia Milano, Milan (Italy)

Contact: www.worldsteeldynamics.com

15-16 November 2023 **IRE Annual Conference and Training Day** *'Real world problems – practical solutions'* Venue: The Mowbray, Kelham Island, Sheffield (UK) *Contact: secretary@ireng.org*

23-24 April 2024

Ceramitec 2024 Venue: Messe Munchen Exhibition Center, Munchen (Germany) Contact: www.ceramitec.com

14-19 July 2024 International Congress on Ceramics Hotel Bonaventure, Montreal (Canada)

Hotel Bonaventure, Montreal (Canada) Contact: www.ceramics.org/event

8-10 October 2024 Aluminium 2024 Venue: Exhibition Centre, Dusseldorf

Venue: Exhibition Centre, Dusseldorf (Germany) Contact: www.aluminium-exhibition.com

25-30 October 2024 **75th World Foundry Congress** Venue: Deyang (China) *Contact: www.75wfc.com*

Latest IRE News

We are delighted to announce that StudWeldoPro-UK Group has signed up to IRE as a Gold Corporate Partner.

Corporate Partner packages reflect an organisation's commitment to the refractories industry and to the professional institute that represents the industry. We welcome StudWeldPro-UK Group to the IRE family and thank them for their support. Read more about the company in the next issue.

Trent Refractories recognised at The Manufacturer Top 100 2023 Awards

Trent Refractories managing director and IRE Acting President Katy Moss has been named as one of the Top 100 in manufacturing by The Manufacturer.

The Manufacturer Top 100 awards showcase leaders and innovators who make a difference in their companies and their industrial sectors. The awards recognise the contributions dynamic individuals make to Net Zero, digital transformation, innovation and leadership. Nominated by their peers and judged by an expert panel, these individuals represent the very best of the UK manufacturing industry.

Speaking about her role at Trent and in the refractories sector, Katy Moss said: "I am passionate about our industry. I see refractories as the key to enabling our foundation industries to become more sustainable. Continuing manufacturing in the UK with local people and suppliers motivates me as it's important we add true value to product and pay forward our knowledge and expertise to our next generation."

When asked what advice she would give to her younger self, she said: "Have confidence in your beliefs and stand your ground more."

The Manufacturer is unique as it looks for a sign of the deepening commitment to the sector that being a member of *The Manufacturer Top 100* implies. They therefore ask candidates to make some, if not all, of these contributions.

- Pay it forward Nominate two individuals for The Manufacturer Top 100 2024.
- Share your story Record a video for the Top 100 website about your career and what it means to be part of the community.
- Be an active member of the community Also join in at one of *The Manufacturer's* events, or even better, take a speaking slot.
- Close the skills gap Become a STEM ambassador or help a colleague to do so.
- Showcase brilliant UK manufacturing Open your factory doors to schools, universities and the local community.
- Shape industry coverage Join *The Manufacturer's* editorial advisory board.
- Future-proof your business Employ an apprentice.
- Recruit the right talent from school age Build relationships through active outreach with local schools to promote STEM at a grassroots level.

These are all activities that Moss is passionate about and she said she felt "privileged" to have been named as one of the *Top 100* for 2023. "It was a great evening with some truly inspiring people," she said.



Long-term strategic co-operation to decarbonise refractories

RHI Magnesita has signed a long-term strategic co-operation agreement with the Australian organisation cleantech MCi Carbon. The global market leader is investing several millions into research and development for innovative technologies abating carbon emissions to achieve its goal of becoming a CO₂ neutral business. This will underline the company's role as sustainability frontrunner of the refractory industry.

"This partnership could become a breakthrough towards decarbonising the industry. It fits seamlessly with RHI Magnesita's ambitious sustainability strategy," says CEO Stefan Borgas. "We still have a long way to go but our early-stage investment and the clear intention of a long-term collaboration make this day so memorable. Together with the like-minded team from MCi we will pave the way for a greener industry."

RHI Magnesita is the world's leading manufacturer of refractory materials, which are used in all high-temperature industrial processes. As market leader, RHI Magnesita has a responsibility to drive sustainability. Striving to reduce CO₂ emissions is therefore one of the company's top priorities. A significant share of the company's carbon emissions is released during mineral processing. Decarbonising the company therefore requires unprecedented innovation and new technologies.

MCi's technology presents a safe and profitable means of storing CO₂ permanently. The chemical process, called mineral carbonation, creates a range of low-carbon embodied materials, including calcium and magnesium carbonate by carbonating minerals in by-products of industrial processes. For this innovative climate solution, MCi has recently been awarded #1 Global Cleantech Pitch at COP26 in Glasgow.

RHI Magnesita is convinced of the potential of mineralisation to achieve a significant CO₂ reduction within its Scope 1 emissions. To date, both companies have worked together on CO₂ mitigation studies, mineral carbonisation feedstock assessments and technoeconomic analyses at RHI Magnesita's worldwide sites. The investment now results from the cleantech's high industrial research maturity as well as its technology's exceptional suitability for use in the refractories industry and within the group itself.

"MCi and RHI Magnesita have formed a value-driven collaboration to accelerate the scaling of MCi's 'Circular Carbon Platform'," says MCi co-founder and CEO Marcus Dawe. "After a year of successful pilot studies, RHI Magnesita will be MCi's first commercial customer and a shareholder, helping advance the technology and decarbonise the global refractories industry. This is a positive step towards hard-to-abate emission reductions and a circular economy."

The next step will see the companies' joint efforts focus on industrial scale-up, expected to kick-off in 2024 with the setup of a demonstration plant by MCi in Newcastle, Australia, supported by the Australian government and in alignment with the goals of Mission Innovation's Net Zero Industries initiative, co-led by Austria and Australia.

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RHI Magnesita and Seven Refractories join forces

RHI Magnesita has announced the acquisition of the Europe, India and US operations of Seven Refractories; saying the acquisition will complement RHI Magnesita's existing non-basic refractories portfolio and open new opportunities in the development of low CO₂ emitting manufacturing technologies.

Seven Refractories is a specialist supplier of non-basic monolithic refractory mixes with broad applications across all the company's customer segments, including iron and steel, cement, aluminium and non-ferrous metals. Non-basic refractory mixes are expected to become increasingly important with the development of new low CO_2 emitting manufacturing technologies within RHI Magnesita's key customer industries. Products offered by Seven Refractories range from low temperature fireclay to ultra-high temperature zircon mixes, high-grade alumina mixes and sustainable taphole clay with a low CO_2 footprint. Seven Refractories employs around 240 staff at its production sites in Slovenia, India and the US and at its sales offices and service centres in Cyprus, Germany, Italy and the UK. The businesses to be purchased in the acquisition recorded revenues of €105 million and profit before tax of €11.4 million in 2022.

The acquisition will enable RHI Magnesita to offer a broader range of non-basic refractory mixes and is expected to be highly complementary to the group's existing non-basic portfolio. Attractive potential synergies are targeted through cross selling opportunities, logistics improvements, increased recycling usage, procurement efficiencies and low capital intensity brownfield expansion projects. The senior management of Seven Refractories, including chief executive officer Erik Zobec, will join the RHI Magnesita Group to drive initiatives focused on non-basic monolithics following completion of the acquisition.

Commenting on the acquisition, Stefan Borgas, chief executive officer of RHI Magnesita, said: "This transaction represents a significant step forward for RHI Magnesita in non-basic refractory mixes which is additive to our existing presence in this market and highly complementary to our overall customer offering. We see compelling opportunities to realise synergies through the integration of Seven Refractories into our existing network and there is a strong alignment in seeking to offer our customers more sustainable products with a low carbon footprint. I am pleased to welcome this entrepreneurial team to our group. RHI Magnesita's network will enable them to continue to build the business even more successfully on a truly global basis. Together we will continue to execute our strategy to grow through consolidation."

Erik Zobec, chief executive officer of Seven Refractories, said: "The Seven Refractories team is delighted to be joining the RHI Magnesita Group at this exciting stage in its development as the global leader in refractories. Our specialist presence in the non-basic monolithics market will be supported and driven forwards through this combination. We will continue to serve our customers with the innovative products, technology leadership and proven flexibility they have come to expect from us, whilst the additional capabilities and global presence of RHI Magnesita will deliver a step change in the breadth of products and services that we can offer to them."

The acquisition is subject to standard closing conditions including competition authority clearance and is expected to complete in the second half of 2023.

Strategic partnership to expand sustainable industrial heating technology offerings

Kanthal and Rath, both global leaders in their respective field – Kanthal in industrial electric heating technology, and Rath in high temperature refractory products – have formed a strategic partnership to expand their combined offering in industrial heating technology.

The companies say the partnership brings together the complementary strengths of both companies, creating the broadest range of sustainable industrial heating solutions on the market. Kanthal's expertise in heating elements and systems combined with Rath's premium insulation and refractory products will provide customers with a unique combined offering for their industrial heating needs.

"We are thrilled to partner with Rath to further expand our offerings in industrial heating technology, enabling societies and industries to make the green shift. In this era of electrification, this partnership will provide our customers with a broader range of innovative solutions that will enable them to optimise their operations and achieve their sustainability goals," said Robert Stål, president of Kanthal. "Together, we can leverage our collective expertise to deliver greater value to our customers and help them thrive in a rapidly evolving market."

Andreas Pfneiszl, CFO/CSO of Rath said: "For quite some time, we have been focusing on sustainability in all our activities – be it when it comes to developing energy-saving refractory products or, more specifically, refractory materials that can be used to line electrically heated furnaces. With the latter, we will – together with our strategic partner Kanthal – enable customers' shift towards fossil-fuel free production."

Through closer collaboration in developing new technologies

HWI unveils new brand identity

HarbisonWalker International (HWI), which announced in February 2023 that it would combine with Calderys, has unveiled a new brand identity. The new look reflects HWI as a member of Calderys, the global refractories company's brand in the Americas.



"The new visual identity of HWI, as a member of Calderys, is a significant step on our journey to form a unified business that incorporates the best of both brands to create a global high-growth leader. We have undertaken this exercise with thoughtful intention to preserve the legacy of the HWI brand in the Americas while reflecting the global stature of the Calderys brand," said Michel Cornelissen, president and CEO of Calderys Group.

For more than 150 years, HWI has built a legacy of refractories leadership in North America. The brand emerged as HarbisonWalker International in 2014 when three leading US-based companies joined forces, becoming known as HWI. During these years, the Calderys brand was built as Imerys SA's High Temperature Solutions global business across Europe, Asia, and Africa.

Both businesses were purchased by Platinum Equity, which announced in February 2023 that it would combine Calderys and HWI to create one of the world's largest and most comprehensive refractories producers with more product and service options and further investments in technology and customer care.

Elements of the HWI brand combine the visual identities of both companies, with HWI maintaining its well-known acronym and font while adopting the symbolism of the Calderys brand: hands joining together, flames, the caldera of a volcano, and the containing of heat.

Adopting the vibrant orange and black for both logos references the high temperatures in which refractories operate. The company says that assuming the same colour scheme strengthens the unity of HWI and Calderys and avoids diluting the brands.

"The new HWI brand reinforces how we unite in many ways beyond products and customers. Our cultures put safety and customers first. We value people while providing quality and innovative products and solutions to our broad customer base, and we embed sustainability in everything we do. We are all aligned on these common priorities as one company," added Cornelissen.



Andreas Pfneiszl, CFO/CSO of Rath, and Robert Stål, president of Kanthal

and solutions, the partnership will leverage both companies' existing and future co-developed products and services to enable the technology shift that industries such as steel and petrochemical are facing. The companies' joint go-to-market model will offer their customers a comprehensive portfolio of products and services, providing greater value and convenience to their clients.

Kanthal is an Alleima company and a world-leading brand for products and services in the areas of industrial heating technology and resistance material. *www.kanthal.com*

The renowned refractory expert Rath has specialised in refractory technology for more than 130 years and manufactures a wide range of innovative, premium refractory products for application temperatures up to 1800°C. *www.rath-group.com*

Quicker refractory solutions in the Nordic region

Following the growing demand for outsourced refractory services in Sweden and as part of its customer-centric approach, Calderys has inaugurated a Foundry Service Centre in Mariestad in the presence of major Swedish foundry customers, elected officials and local stakeholders.

Mariestad is a strategic area for Calderys because of its proximity to many of the group's clients. This foundry service centre will enable the company to provide "one stop shop" services to its Swedish and Scandinavian customers. It includes all the installation and equipment needed to improve flexibility and lead time. Calderys will be able to offer special solutions for customers' equipment such as prefabrication (or precast) for ladles, runners and coreless induction furnaces (CIF). Outsourcing these services will free up the availability of end-users' own equipment in production, and the centre's solutions will allow them to reduce their CO₂ emissions and improve the work ergonomics for installation. On-site installation of press pour furnaces and dryout operations will also be offered at the centre. www.calderys.com

Supplier adds split bedding cart to refractory maintenance lineup

Bricking Solutions, a full solution provider of refractory installation equipment, introduces a bedding cart with a split deck for increased access to brick during refractory brick installation. The split bedding cart features dual decks rather than a single deck to provide clearance for a forklift or skid steer. Along with allowing equipment to travel through the kiln to other work areas, the clearance also allows personnel to easily pass, improving efficiency and safety.

"Customers asked for a bedding cart with a split deck for easy access while bricking the bottom of the kiln, and we listened," said Jeff Mirisola, global sales and service manager at Bricking Solutions. "By giving our customers options between the single deck and the split deck, they can find the right product for the way they work."

The original bedding cart design greatly increased kiln lining efficiency by giving refractory brick installation crews a flat surface on which to place bricking materials. The use of a bedding cart is much safer than the traditional method of using stacked pallets or springboards for brick storage. The single-deck design gave workers a way to brick the bottom of the kiln in a more stable way. However, the single-deck platform made it impossible to move equipment throughout the kiln. The dual decks of the new split bedding cart provide clearance for equipment and allow room for workers, tools and brick throughout the refractory installation process.

The standard split unit has a minimum width of 1.3m and fits



The new split bedding cart builds on the original design by giving another installation option with clearance for skid steers and other machinery



The split bedding cart features a split deck, a design that allows a forklift or skid steer to supply bricks to side of the cart throughout the bricking process

kilns between 4-7m with sizing customisation options. The typical deck features a load capacity of 793kg per side. Curved bottom braces allow forklifts and skid steers to easily drive over and move to the front or back of the cart while inside the kiln. Rubber feet on the sides of the cart protect newly bedded brick.

The split bedding cart makes rebricking the bottom of the kiln to the spring line safer and easier. Workers are able to pass safely between the decks rather than climbing over to gain access to different parts of the kiln. Bricking Solutions recommends using the split bedding cart with a bricking machine, especially in larger kilns where masons cannot reach the spring level while bricking.

Like all Bricking Solutions equipment, the split bedding cart is made with high-quality materials that are rigorously tested for safety. The machine is manufactured with high-strength 6061-T6 aircraft-grade aluminium, which is as strong as steel but only two-thirds the weight. The design is simple to assemble and disassemble with pin connections between parts. Removable fall guards are a standard feature and steps make placing pallets of refractory safer and easier for brick masons. The design included polyurethane double wheels with brakes and an ergonomic step design up to the spring line for increased safety.

Bricking Solutions manufactured the industry's first bricking machine in 1966 to give refractory installers a safer, more efficient alternative to manual installation methods. From that time the company has believed that machines should do the heavy work rather than the people and customer feedback should drive product development. www.brickingsolutions.com

Sustainability strategy and goals to reduce environmental impacts

ASK Chemicals Group, a global supplier of high-performance industrial resins and materials, has announced its sustainability strategy and targets. On the way to climate neutrality in 2050, ASK Chemicals will steadily reduce its greenhouse gas emissions, such as by decreasing its Scope 2 emissions by 30 per cent until 2030. As part of its sustainability strategy, the company is continuously working to improve its environmental footprint, for example by implementing closed water cycles. The company's sustainability strategy covers all three pillars of sustainability: environmental, social and corporate governance.

In a true bottom-up approach, various departments appointed internal experts to spearhead the initiative and establish a sustainable strategy based on a thorough materiality analysis. This assessment identified the most significant positive and negative impacts ASK Chemicals Group could address to create an effective and achievable ESG roadmap. The strategy is receiving the full support of the ASK Chemicals Group's management, "We are happy and motivated to have achieved this important milestone – an important step forward to further strengthen ESG within our company," says Jens Müller, CTO at ASK Chemicals and responsible for ESG. "We will now transfer our strategy into the different regions as a holistic global approach, of course with adjustments to local challenges and consonant with cultural diversity."

The company's primary focus on sustainability is closely linked to efficiency, as efficient chemicals and materials make a significant contribution to reducing raw material inputs and emissions. This applies not only to ASK Chemical Group's internal manufacturing processes, but also to R&D and product development.

Elkem acquires VUM to further expand customer offering in carbon solutions

Elkem ASA has acquired VUM, a Slovak producer of carbon materials. The transaction will further increase Elkem's capacity and competence in attractive specialty markets and increase its flexibility in the supply chain. Elkem expects the acquisition to contribute with an additional turnover of around NOK 360 million per year.

VUM was founded in 1954 and currently has around 65 employees at a plant located near the town of Žiar nad Hronom, in the centre of Slovakia. The company is an independent producer of carbon-based materials for industrial smelters, including anode paste, electrode paste and ramming paste as well as recarburisers. These are important materials to support the production of metals that the world needs.

"With the acquisition of VUM, Elkem continues to deliver on its strategy of growth and specialisation. This transaction gives Elkem improved access to central and eastern European markets. We look forward to working with our new colleagues in Slovakia and to further improve our joint value offering to our customers. Elkem also aims to realise synergies from optimising our value chain and utilising existing production capacity to serve other attractive export markets," says Luiz Simao, Elkem's senior vice president for carbon solutions.

VUM has a calcining technology based on rotary kiln furnaces

which adds flexibility to handle different raw materials. Research and development work by VUM will also add competence and knowledge to Elkem's competence centre for carbon in Norway. Slovakia's electricity generation is mainly emissions-free, with nuclear and hydropower as the country's two largest power sources.

Elkem will provide VUM with resources and best-in-class industry expertise to improve efficiency, value offering and economies of scale. The combination of being both a producer and consumer of carbon solutions gives Elkem a strong position with high quality products and superior technical support for improving electrode management and processes at customer operations.

"Elkem has had a leading role as technology provider and supplier of specialty carbon products to the pyro-metallurgical industry since the invention of the Søderberg electrode in 1919. We aim to be an industry leader and we are constantly developing our offering to be best suited for our partners and customers, as demonstrated by this transaction. We are committed to growing and expanding our business in a sustainable and environmentally friendly way," says Simao.

With the transaction complete, VUM will rebrand and operate under Elkem Carbon AS, a wholly-owned subsidiary of Elkem ASA. VUM will continue the operations under its current management. www.elkem.com

Funding success for two-year hydrogen research project for UK ceramic sector

The British Ceramic Confederation (BCC) has secured around £6million of UK government funding to support further research into the use of hydrogen as an alternative fuel for the UK ceramics sector.

The Department for Energy Security & Net Zero has awarded the funding through Phase 2 of the Industrial Fuel Switching Phase 2 Competition, as part of the £1bn Net Zero Innovation Portfolio (NZIP), which supports innovation in the development of pre-commercial fuel switch technologies to help industry switch from high to lower carbon fuels.

The Industrial Fuel Switching funding will allow Phase 2 of the 'Hydrogen for the Ceramics Sector' project to be taken forward.

The two-year project will deliver the first-ever demonstrations of one hundred per cent hydrogen-firing technologies for the two main types of kilns (batch and continuous) used predominantly across the more than 150 manufacturing sites of the BCC's ninety member companies; thus providing a key route to help decarbonise the UK ceramic sector (pending availability of sufficient volumes of hydrogen to each site).

The Phase 2 project follows a successful six-month study, conducted last year, which demonstrated the potential for firing a range of ceramic products using one hundred per cent hydrogen, without affecting product performance or properties.

Phase 2 will be supported by fifteen ceramic manufacturing companies, spanning all subsectors of the UK ceramics industry (bricks, roof tiles, drainage pipes, floor/wall tiles, sanitaryware, tableware, refractories, and technical ceramics). Following on from the work they carried out for BCC in Phase 1, further support will be provided by the not-for-profit research and technology organisation, Glass Futures.

BCC deputy chief executive Andrew McDermott said: "Phase 1 answered a lot of questions about the feasibility of hydrogen as a fuel for the ceramics sector and the next phase will build upon these outputs. It will evaluate a far greater range of ceramic products, gaseous blends and firing atmospheres in a bespoke pilot kiln, as well as conducting demonstrations on production kilns, to build understanding in using hydrogen within an industrial environment.

"As for achieving Net Zero by 2050, the UK ceramic industry's pathway to meet that target remains uncertain, with many of the technologies that will enable deep decarbonisation, such as hydrogen, electrification, carbon capture and bioenergy, either commercially unviable or simply unavailable.

"Therefore, we expect Phase 2 to demonstrate a key route to help decarbonise the UK ceramic sector."

BCC chief executive Rob Flello said: "UK ceramics play a pivotal role within the Net Zero journey and are key to decarbonising society.

"Without ceramics, the production of renewable energy is hampered as, without refractories, there is no steel for wind turbines and no glass for photovoltaic panels. Ceramics are needed for electric vehicle batteries. Without high temperature industrial processes, there are no durable homes or commercial properties. There is no heat from waste without advanced ceramics.

"This is a vitally important project, and it is reassuring that the government is supporting it and believes in the UK ceramic industry's commitment to decarbonisation."

Lord Callanan, Minister for Energy Efficiency and Green Finance, said: "Britain has a long and proud history of pushing the boundaries in science – and our backing with over £80 million for these cutting-edge projects today will help make way for the next era of innovation.

"The transition away from fossil fuels presents a huge opportunity for our growing green energy sector and we will continue to make sure UK business can benefit from its full potential." www.ceramfed.co.uk

Excellent performance figures from new stainless steel plant in China

Recently, a joint venture of Chinese steel producers Taiyuan Iron and Steel Group Co (TISCO) and Shandong Xinhai Industry granted the final acceptance certificate (FAC) to Primetals Technologies for an extensive combination of meltshop and casting equipment at a stainless steel plant in Linyi, Shandong province, China and they have reported "excellent" results.

All equipment has been implemented successfully, with performance figures exceeding the customer's expectations. For example, charge-to-tap times of less than 89 minutes, including the intermediate deslagging process, are achieved on a regular basis, which is particularly remarkable as the mass build up of materials in the AOD converter is high.

The process optimisation systems are also showing great results. The contractual performance value for the hitting rate, i.e. 85 per cent for a temperature range from -10 to +15°C, was already reached during start-up. These systems are now exhibiting hitting rates of almost one hundred per cent for the given temperature and carbon windows. In addition, plant availability was already above 99 per cent during the performance test phase.

The key equipment for this large project supplied by Primetals Technologies comprises four converters in total, two continuous slab casters, the AOD Controller, which is a process control system, and the process optimisation system AOD Optimizer. Primetals Technologies has engineered, supplied, and implemented two AOD converters and two converters that can be used for



Primetals Technologies has received the FAC for a combination of stainless steelmaking equipment implemented at a plant operated by Chinese steel producers TISCO and Shandong Xinhai Industry. Image source: Shandong Xinhai/TISCO/Primetals Technologies

either AOD or DeSi processes – the latter process desiliconises the melt before it is sent to the AOD converters. The converter scope also encompasses Vaicon Quick vessel-suspension systems that ensure the fastest possible vessel exchange.

Primetals Technologies is a leading provider of AOD equipment, which was one of the main factors contributing to the customer's choice of supplier. The portfolio also includes special processes, like intermediate de-slagging, and process optimisation systems tailored to the AOD process. An additional important factor for the customer was Primetals Technologies' extensive reference base, which includes several major stainless steelmaking projects in China.

Since 1988, Primetals Technologies has supplied eight new slab casters to TISCO, and the Chinese steel producer has tasked Primetals Technologies with 24 casting projects in total to date. The two stainless slab casters at the site in Linyi have an annual capacity of 0.9 and 1.2 million tons and a maximum width of 1,600 and 2,100, respectively. The bow radius is at nine metres.

TISCO is a holding subsidiary of China Baowu Iron and Steel Group and was founded in 1934. TISCO is focusing on the development of special steels, for example ultra-wide, ultra-thick and ultrathin strip tubes and high-quality silicon steel for electric vehicles.

Based in Linyi, China, Shandong Xinhai Industry processes, manufactures, and distributes metal products. The company produces plating alloys, high nickel alloys, manganese alloys, and other products. www.primetals.com

Difficult times and weak expectation for EUROPEAN FOUNDRY INDUSTRY

It is alarming that the negative trend in the European foundry sector is intensifying, says the European Foundry Association, CAEF.

The picture emerged following the results of the latest *European Foundry Industry Sentiment Indicator (FISI)*, which faces its fourth decrease in a row. Rating of 2.1 index points lower than in May, the index reached a value of 98.6 points in June. Hence, the value is now below the initial value of 100.0 in 2015.

While order backlogs are still high but being worked off, new orders seem to have collapsed across several sectors. Meanwhile, a turnaround is not in sight particularly regarding the expectations for the coming six months.

While in recent months the development of steel and iron foundries on the one hand and non-ferrous metal foundries on the other hand was contrary due to statistical base effects, foundries of all materials groups are currently turning negative in their assessment of the business situation compared to the previous month.

The Business Climate Indicator (BCI) decreased by 0.13 points in June and brings the index to 0.06 points. The value is therefore now almost

back to late pandemic times at the end of the year 2020, when it turned negative. Overall, the selling price expectations for the month ahead (August) are decreasing together with the current production level and the order book levels.

The FISI – European Foundry Industry Sentiment Indicator – is the earliest available composite indicator providing information on the European foundry industry performance. It is published by CAEF every month and is based on survey responses of the European foundry industry.

The BCI – Business Climate Indicator – is an indicator published by the European Commission. The BCI evaluates development conditions of the manufacturing sector in the euro area every month and uses five balances of opinion from industry survey: production trends, order books, export order books, stocks and production expectations. www.caef.eu

Joining of forces for new green steel production plant in Spain

In June 2023, Hydnum Steel and Primetals Technologies signed a memorandum of understanding (MoU) with the intention to implement a greenfield plant for green steel production in Puertollano, Spain. The comprehensive project is a collaboration between Hydnum Steel, Russula, ABEI Energy, Siemens, and Primetals Technologies as the engineering and technology provider.

The plant is set to become one of the most prominent sites for green steel production in Europe. While it will initially produce 1.5 million tons of hot rolled coils, the annual capacity is projected to be at 2.6 million tons of hot and cold rolled coils by 2030.

"We are very glad to announce the plans for this massively important green steel project. Our minimill concept features highly efficient electric steelmaking technology and the Arvedi ESP line for unmatched energy efficiency. These solutions ensure that Hydnum Steel has the right technology to produce steel with significantly reduced carbon emissions compared with a conventional integrated steel plant," says Andreas Viehböck, head of upstream technologies at Primetals Technologies.

"The facility will be designed from the ground up to use nonfossil energy throughout the manufacturing process, thus, it will use green hydrogen into the production process with the aim of substantially reducing CO_2 emissions," says Eric Vitse, chief technical officer at Hydnum Steel.

The plant will supply high quality flat steel to different industries and applications including high strength grades for the automotive industry, as car manufacturers are moving into the electrical vehicle market. The automotive industry accounts for some ten per cent of Spain's gross domestic product (GDP). At the same time, Spain – and Europe as a whole – are currently and traditionally net importers of flat steel.

The partners' intention is to implement a direct reduced iron (DRI) production unit and a complete cold rolling complex in Phase 2 and 3. The DRI plant will be powered by green hydrogen generated using local renewable energy.

Global engineering company Russula is leading the project development, with support and contribution from independent power producer ABEI Energy, global industrial company Siemens, and Primetals Technologies.

The Hydnum steel project creates 1,200 direct jobs, as well as some 2,600 indirect jobs, in the Puertollano region, contributing massively to the development and recovery of the Spanish industry.



Representatives from Hydnum Steel and Primetals Technologies during the signing ceremony. (I-r): Eric Vitse, CTO at Hydnum Steel; Fernando Pessanha, CSO at Hydnum Steel; Andreas Viehböck, head of upstream technologies at Primetals Technologies; Eva Maneiro, CEO at Hydnum Steel; and Norbert Petermaier, executive vice president, sales at Primetals Technologies



Our Norwegian silicon and microsilica plants have a carbon

- Our Norwegian silicon and microsilica plants have a carbon footprint of only 1/3 compared to the global average
- The electricity consumption across our operations is >80% renewable
- Investing in energy recovery plants
- Ambitious biocarbon strategy

Delivering your potential

Under-threat: European stainless steel industry no longer cost-competitive!

Early 2023 had brought an improvement in market conditions for Europe's stainless steel sector following the low demand suffered in 2022, reported BIR Stainless Steel & Special Alloys Committee chairman Joost van Kleef of Netherlands-based Oryx Stainless BV in his opening comments to the body's latest meeting in Amsterdam on 22 May.

However, as revealed in a subsequent review of the world market by new board member Ritesh Maheshwari of India-based Shabro Metallic Pvt Ltd, the stainless sector in Europe was now suffering renewed price pressure and a sharp slowdown in production, with some mills reportedly operating at only 50 per cent of capacity utilisation. Stainless steel demand had also declined in the USA following a drop in consumer spending on durable goods, whereas US stainless scrap exports had surged 120 per cent year-on-year during the first two months of 2023 to more than 73,000 tonnes on improved demand from India, Taiwan, Mexico and Canada.

In listing some positives, Mr Maheshwari noted that: South Korea's major stainless mill run by Posco had restarted smelting operations at all furnaces following major flood-related stoppages; the Middle East was enjoying strong consumption growth prospects for stainless steel on the back of project announcements amounting to US\$2.3 trillion; and superalloy manufacturers were now booking orders as far out as 2025.

Guest speaker Prof Dr Frank Pothen, professor of economics at Ernst-Abbe-Hochschule Jena University of Applied Sciences and senior research associate at the Fraunhofer Center for International Management and Knowledge Economy IMW in Germany, reported on: "the substantial ecological benefits from using scrap" in stainless steel production. A Fraunhofer UMSICHT study earlier this year had found that CO₂ emissions were reduced by 6.7 tonnes for every tonne of stainless steel scrap used, he pointed out.

As to how the "scrap bonus" of environmental cost savings could be internalised into pricing mechanisms, policy options suggested by Fraunhofer included: integrating mining into the EU emission trading scheme; and integrating raw materials and intermediate products into the Carbon Border Adjustment Mechanism. Having argued that incentives to use scrap were better than mandatory utilisation quotas, he also insisted that EU export barriers not only would reduce scrap prices in Europe but also would cut scrap use outside of the EU, thereby undermining climate policy efforts.

Fellow guest speaker Markus Moll, managing director of Steel & Metals Market Research in Austria, warned that Europe's stainless steel industry is: "increasingly becoming the ping-pong ball of politics" as the emergence of stricter climate goals coincided with competition from major mills in Asia "who draw from a supply chain that gives them the lowest cost base in the world". And he added the warning: "Europe is no longer cost-competitive. Without protection, we are losing this industry."

Moll noted that the rapid growth of nickel pig iron-based stainless steel production had dragged down the overall 18/8 scrap ratio to an estimated 41 per cent in 2022 – "the lowest global total seen in a long time". He also confirmed his company's projection of a 2.4 per cent increase in global crude stainless steel production in 2023 to just short of 58 million tonnes. China was expected to see growth of 4.5 per cent whereas European production was thought likely to record a decline of 3 per cent following the almost 12 per cent drop in 2022. "The good news for Europe," said Moll, "is that there will be less import of stainless steel."

BIR is the international trade association of the recycling industries. Around 70 countries are represented through their national trade associations and individual companies, which are involved in recycling. BIR comprises four commodity divisions: iron and steel, non-ferrous metals, paper and textiles, and has four commodity committees dealing with stainless steel and special alloys, plastics, tyres and rubber and E-scrap. BIR's primary goal is to promote recycling and recyclability, thereby conserving natural resources, protecting the environment and facilitating free trade of secondary raw materials.

The above report is from the meeting of the stainless steel and special alloys committee at the *BIR World Recycling Convention & Exhibition*, held in Amsterdam from 21-24 May 2023.

New British Ceramic Confederation president

The trade association for the UK ceramics manufacturing industry, the British Ceramic Confederation (BCC), has confirmed that Alan McLelland will be its new president.

McLelland, who is vice president of technology at Morgan Advanced Materials, succeeds Edward Naylor, chief executive of Naylor Industries Plc, for a two-year term as president of the BCC board of directors.

Speaking about the position, McLelland said: "I am honoured to take up this role and look forward to working even more closely with the BCC team. It is a challenging time for UK ceramics, and the team will continue to support and represent this essential UK industry, providing a strong voice for the sector."

The BCC will also welcome its first female vice president onto the board, as Hannah Ault, managing director of Valentine Clays Ltd, has agreed to take up the role.

Ault, who grew up in the ceramics industry and is a third-generation leader in clay manufacturing, said: "I am delighted to represent an industry that I'm incredibly proud of. Ceramics impact on all our lives, and my mission is to continue to build awareness and increase nationwide support, especially through education and skills."

Rob Flello, BCC chief executive, said: "We are grateful for the expertise and knowledge that all our board members bring to the British Ceramic Confederation.

"As we welcome our new president and vice president, we continue to be supported by people who are passionate about the UK ceramics industry and who bring a wealth of experience to these roles. We look forward to what the future will bring as we continue to raise awareness of the UK ceramic industry's needs.

"I thank Edward for his leadership during challenging times, especially as the energy crisis bit, and for his commitment, understanding, and guidance.

"Having our first female vice president is also quite an accolade in this forward-thinking industry. It is a significant milestone for an organisation that has been supporting the UK ceramics industry for nearly one hundred years."

Naylor, who will remain on the board as deputy president, said: "The past two years have certainly been busy, especially as BCC welcomed a new chief executive. There is plenty of work ahead, and I look forward to continuing to support BCC."

The board rotation also means that Keith Barker, managing director of Wienerberger UK, will now step down as deputy president, having previously served as president and vice president.

Flello added: "Keith has dedicated six years to the BCC board and has helped to set the course for UK ceramics during that time. We cannot thank him enough for his dedication, counsel, and wisdom."

The bi-annual board rotation was confirmed at the BCC's AGM. *www.ceramfed.co.uk*



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Collecting data is one thing, but collecting it safely and having the knowledge and competence to offer expert remote asset inspection services and advice is why 4D Delta has become Australia's leading asset inspection solutions provider.

REFRACTORY INSPECTION – a complete inspection picture on a revolutionary scale

Founded in 2014 to provide innovative solutions to traditional industry problems, the company has developed a loyal customer base thanks to its commitment to preventative maintenance principles through incredibly accurate and safely obtained data collection.

Speaking about the company's rise to the top, commercial manager Don Merritt said: "We have revolutionised remote sensing data capture and analysis in Australia, propelling maintenance into a new age of reliability and optimisation."

This claim is backed by an excellent track record of working with customers to increase site production at their companies with safe and cost-effective preventative maintenance programs, thanks to advanced digital technology. 4D Delta employees are able to speak the same language as customers because the company comprises surveyors, engineers and industry professionals who are well equipped and experienced in understanding the very real, and often complex, needs of their customers.



Refractory Inspection

Using a combination of 3D laser scanning, photogrammetry and bespoke software, 4D Delta safely and accurately inspects refractory vessels for various industries, including lime, pulp and paper, cement and alumina.

Results can be delivered rapidly, along with the identification and solutions to problems to ensure immediate attention to refractory issues such as spalling, or anchor failure. This in turn results in preventative maintenance and the prevention of unplanned shutdowns. Also, the use of high-tech scanning technology inserted into the vessel means a safer environment for employees by eliminating hazards associated with the more traditional methods of inspection.

Purpose-built refractories management software

4D Delta has developed the industry's first purpose-built refractories inspection and maintenance planning tool – 4D Delta Cloud. Combining 3D laser scanning, high-definition imagery and smart analytics, this easy-to-use online platform provides the information needed to help engineers and planners identify the root causes of poor refractories condition to prevent failure, optimise maintenance and increase asset availability. The latest release of 4D Delta Cloud also allows users to create inspection reports, develop maintenance plans, and calculate volumes of refractories required to perform repairs or overhauls.

3D laser scans and hi-definition 360



images are captured throughout the vessel to inspect and measure every square-inch of the refractory hot-face. The scans and images can be viewed on any device at any time, meaning customers can place themselves inside their asset in a virtual manner to perform inspections from the comfort of an office chair, or indeed from anywhere. Comparisons can be directly made between a photograph and a heat-map of refractory thickness, or between two thickness maps taken at different dates to display change in refractory condition over time. 4D Delta Cloud also stores all of the user's data for every inspection to enable users to select any point in time to perform an unprecedented level of analysis of condition.

This groundbreaking suite of digital tools thus enables clients to take control of their preventative maintenance programme and access remotely at any time. The perfect solution to an ever-present safeguarding problem.

Standard process improvement

Merritt explains the concept behind the company's success: "With innovation at our core, 4D Delta integrates technology to develop new processes and software applications that elevate our remote sensing data capture solutions beyond the industry standard."

Professional-grade cameras, lenses and software turn simple photographs into realistic 3D models of specific parts and assets. 3D laser scanning measures millions of angles and distances to record visible surfaces, creating a virtual impression of their immediate environment in a matter of minutes. Utilising 3D laser scanning technology, 4D Delta Cloud can see beyond just the surface condition of a refractory lining. It can detect the smallest movements in the refractory from the slightest chip to significant loss of hot face, and to a whole section on the verge of collapse from anchor failure.

The laser scanning can also be performed after repairs to monitor into the future to ascertain the repair's performance and endurance. This is particularly useful for ongoing scrutiny and decision making.

In addition, thermography enables surface heat to be measured in high definition to pinpoint areas where asset performance is compromised. The game-changing 4D Delta Cloud is an innovative remote asset inspection solution.

A decision-making partner

The powerful insights 4D Delta equipment and software provides is just part of the answer to a company's asset inspection and maintenance dilemmas. 4D Delta can also translate the acquired data into reliable solutions, acting as a full preventative maintenance arm of the customer's business.

This total solution offers peace of mind and a comprehensive, asset inspection service resulting in improved and reliable performance and long-term cost savings.

For more information contact: 4D Delta, Tel: +61 8 6150 9998, email: sales@4ddelta.com web: www.4ddelta.com





In the latest episode of Tata Steel's 'SteelCast' podcast about decarbonising the steel industry, Professor Jon Gibbins, centre director of the UK CCS Research Community Network Plus at The University of Sheffield warns that the clock is ticking for global action by governments and industries such as steel to put in place technologies that will deliver a Net Zero economy by 2050.



Fewer than 10,000 days to NET ZERO

"What the steel industry needs to face up to is the timescale – we've got 27 years to get to Net Zero globally (2050) to avoid dangerous warming and that's a bit under 10,000 days," says Gibbins.

Tata Steel's host Tim Rutter welcomed Gibbins to the pod to talk about the opportunity for energy intensive industries, such as steel, to utilise carbon capture and storage (CCS) as an alternative –even if as part of a transition – to technologies such as electric arc, scrap-based steelmaking.

In the podcast, Gibbins argued that the principle of capturing carbon emissions from industry, and sequestering (burying) them deep in disused offshore oil and gas fields, is not only feasible but desirable, adding: "You want to keep CO_2 out of use for at least ten thousand years."

While the earliest the UK can expect to see an active carbon capture and storage facility is 2027, Gibbins sees existing ore-based steelmaking assets having an endof-life far beyond this date, in the UK and particularly globally.

Many industry experts say there is value in re-using carbon-rich emissions for commercial uses such as aviation fuel or acetic acid, but Gibbins is less convinced: "Turning carbon into a fuel only to be released later will not get us to Net Zero," he said. "It would be nice to be able to reuse (all the carbon) but the quantities are so huge and natural processes to permanently remove the CO_2 are about one hundred times too slow to avoid dangerous climate change. All the CO_2 that we put in the atmosphere now will have to be taken out in the future by other people."

While some steelmaking sites are located close to existing oil fields and could benefit from a direct pipeline into the sea, others such as Tata Steel's Port Talbot works would have to ship the CO₂. This, said Gibbins, is not such a bad thing: "Single pipelines could be down for maintenance whereas with shipping you can go to multiple destinations.

"The question is not 'is Port Talbot expensive because you have to ship CO₂?' but 'is it more expensive than anywhere else that has to ship CO₂?' and the answer is no."

He added: "How many steel plants globally don't even have ship access or a $\rm CO_2$ pipeline – they're in real trouble."

The podcast discussion went on to talk about one of the alternative technologies

for steelmakers: scrap-based electric arc steelmaking. And while Gibbins appreciated the value of the technology in massively reducing carbon emissions, he made the point that leading industrial countries such as the UK have a far wider responsibility to global climate change than simply solving their own problems.

"If we hit our targets by doing things that are perfectly obvious but things that the whole world can't do, we've demonstrated nothing," he said.

"We have to have a noticeable effect through demonstration. We have to do it in a way that encourages and enables other people to do the same."

Host Tim Rutter added: "It was great to have Jon Gibbins on the pod for a very lively debate. With over twenty episodes under our belt, the series has hosted steel experts, academics, politicians and green groups. We're trying to open up the discussion around the challenges and opportunities of decarbonising the UK steel industry, with the people who know best."

LISTEN: to Tata Steel UK's podcast series on decarbonising the steel industry at https://tatasteeluk.podbean.com Contact: Tim Rutter, Tel: +44 (0) 7850 990755, email: tim.rutter@tatasteeleurope.com

Britons show overwhelming support for steel

Recent polling by YouGov found nearly two thirds of GB adults support the government investing in the steel industry to support decarbonisation. This reflects a growing consensus among the public that the country needs to transition towards greener technologies and industries to reduce its impact on the environment.

But the public doesn't just see investing in green steel as part of the move to Net Zero. It's also about ensuring their country, in an increasingly uncertain world, has a secure, resilient and strong manufacturing sector.

While politicians debate the future of the UK steel industry, the public's view is clear: More than seven in ten GB adults would prefer the UK government to invest in UK steel to support jobs and manufacturing in the UK rather than sourcing steel from abroad, and around two thirds (67 per cent) of GB adults think it is important to have a secure British supply of steel.

Tata Steel UK chairman Henrik Adam said: "The UK steel industry is at a crossroads – we must decide whether to give up on steel, and in doing so lose our steel self-sufficiency and resilience as well as thousands of well-paid jobs in steel communities, or we take an alternative path and transform the way we make steel to make it fit for the future.

'This is a hugely exciting opportunity,

which would secure steel supplies for the UK's future, supercharge levelling up, and create well-paid, high-skilled jobs. Critically, it would play an essential part in achieving the UK's Net Zero ambitions. This opportunity is Green Steel.

"The UK has a proud history of steelmaking, but we need to look forward. Britain could lead the next technological leap forward to produce Green Steel for the wind and solar farms to power us, the electric vehicles rolling off the production lines, the major infrastructure projects, and the efficient green buildings of the future.

"The public understands that having a secure supply of primary manufacturing material today is as important as it has ever been. Anyone who has witnessed supply chain shortages in recent years – from PPE and semi-conductors during the pandemic to the shortage of domestic energy production – knows the importance of building domestic resilience in essential industries.

"In a volatile and uncertain world, a strong domestic steel industry is a vital pillar of our economic independence, industrial resilience and national security. There is clear support from voters for a plan for the future where Britain leads the world in the Green Industrial Revolution, we can grasp it now or watch this great opportunity slip away."

Results of YouGov survey into perceptions of the UK steel industry

- □ Two thirds (67 per cent) of GB adults think it is important to have a secure British supply of steel, even when told it could be more expensive.
- Two thirds (66 per cent) of GB adults support the government investing in the steel industry to support with decarbonisation.
- □ Almost three quarters of GB adults (72 per cent) would prefer the UK government to invest in UK steel to support jobs and manufacturing in the UK, over sourcing the cheapest possible steel from abroad (7 per cent).
- Almost two thirds (65 per cent) of GB adults believe that the UK government should invest in UK steel, so that it can be made with fewer carbon emissions, even if it is more expensive, over sourcing the cheapest possible steel from abroad (8 per cent).
- Over half (55 per cent) of adults believe the government should put money into making steel in an environmentally friendly way, as opposed to putting money into alternative projects that also have potential to protect the environment (17 per cent).
- Nealy two thirds (64 per cent) of GB adults would prefer the government uses environmentally friendly steel over the option of using cheaper steel in UK public construction projects (11 per cent).

Technical Papers

The readership of The Refractories Engineer is keen to hear about the latest technological advances and research being undertaken to help drive the industry forward. Therefore, we are happy to receive technical papers from interested parties for publication in The Refractories Engineer.

All papers submitted must be original, written in English and have the approval of the author(s) prior to submission. They must either report original research work or be a detailed description of the latest technology or knowledge within a specific field related to the refractories industry.

Technical papers are required to be in a Microsoft Word format with any supporting imagery supplied as separate, high resolution jpeg files.

Submissions should be sent to the editor: editor@ireng.org



Heat treatment is an essential part of the manufacturing process as it enables a metal piece to be improved for the material to better withstand wear and tear. The process involves heating a metal or alloy to a specific temperature and then cooling it to harden the material.



Heat Treatment – an ESSENTIAL PROCESS

Metallic materials consist of a microstructure of small crystals called 'grains' or crystallites. The nature of the grains (i.e. grain size and composition) is one of the most effective factors that can determine the overall mechanical behaviour of the metal. Heat treatment provides an efficient way to manipulate the properties of the metal by controlling the rate of diffusion and the rate of cooling within the microstructure. Heat treating is often used to alter the mechanical properties of a metallic alloy.

Heat treatment can be used at different stages in the manufacturing process to change certain properties of that metal or alloy, such as improving strength, hardness, durability and ductility to ensure the good performance.

To achieve the desired effect, the metal or alloy is heated up to a specified temperature and is held at that temperature for a specified amount of time, and then cooled. While it's hot, the metal's physical structure – the microstructure – changes, ultimately resulting in its physical properties being altered.

The length of time the metal is heated for is called the 'soak time.' The length of soak time plays an important role in the characteristics of a metal, as metal soaked for a long amount of time will see different microstructure changes than metal soaked for a shorter time period.

The cooling process after the soak time also plays a part in the result of the metal. Metal may be cooled quickly, which is called quenching, or slowly in the furnace to ensure it achieves the desired result. The combination of the soak temperature, soak time, cooling temperature, and cooling duration all play a role in creating the desired properties in a metal or alloy. The point at which the metal is heattreated during the manufacturing process also determines what properties are changed, and some metals may even be treated multiple times.

Knowing what temperatures to heat and cool metals at, as well as how long each step of the process should take for a specific metal or alloy, is complex. Thus, metallurgists study the effects of heat on metal and alloys and provide precise information on how to perform these processes correctly. Manufacturers rely on this information to ensure their metal pieces will have the correct properties at the end of the process.

Some common forms of heat treatments include:

Hardening

When a metal is hardened, it's heated to a point where the elements in the material transform into a solution. Defects in the structure are then transformed by creating a reliable solution and strengthening the metal. This increases the hardness of the metal or alloy, making it less malleable.

Annealing

This process is used on metals like copper, aluminium, silver, steel, and brass. These materials are heated to a certain temperature, are held at that temperature until transformation occurs, and then are slowly air-dried. This process softens the metal, making it more workable and less likely to fracture or crack.

Tempering

Some materials, e.g. iron-based alloys, are very hard, making them brittle. Tempering can reduce brittleness and strengthen the metal. In the tempering process, the metal is heated to a temperature lower than the critical point to reduce brittleness and maintain hardness.

Case Hardening

The outside of the material is hardened while the inside remains soft. Since hardening can cause materials to become brittle, case hardening is used for materials that require flexibility while maintaining a durable wear layer.

Normalisation

Similar to annealing, this process makes the steel more tough and ductile by heating the material to critical temperatures and keeping it at this temperature until transformation occurs.

Without heat treating metal, especially steel, many metal parts wouldn't function properly, or might not even exist in the first place. Specifically, non-ferrous metal parts would be much weaker. Aluminium and titanium alloys, as well as bronze and brass, are all strengthened through heat treatment. Many of these metals are used in the automotive and aerospace sectors plus other industries that rely on strong metals for performance and for safety.

As heat-treated metals are often stronger than non heat treated metals, treating metal pieces upfront prevents corrosion, which won't result in the replacement of expensive metal parts later on or as frequently. This causes machines to run more cheaply and efficiently and prevents problems.

Types of furnaces

Furnaces used for heat treatment can be split into two broad categories – batch furnaces and continuous furnaces. Batch furnaces are usually manually loaded and unloaded, whereas continuous furnaces have an automatic conveying system to provide a constant load into the furnace chamber.

Science-based target initiative approval for emissions targets

Bodycote, the world's largest provider of heat treatment and specialist thermal processing services, has reported that its near-term science-based emissions target has been approved by the Science Based Targets initiative (SBTi).

SBTi is an independent global body enabling businesses to set and validate emissions reduction targets in line with the latest climate science and strict criteria. The initiative is a collaboration between CDP, the United Nations Global Compact, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF) and one of the *We Mean Business Coalition* commitments.

Science-based targets provide a clearly defined pathway for companies with ambitious climate goals to reduce greenhouse gas emissions, helping prevent the worst impacts of climate change and future-proofing business growth. Targets are considered 'sciencebased' if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement – limiting global warming to well-below 2°C above pre-industrial levels and pursuing efforts to limit warming to

1.5°C.

Bodycote, with over 165 facilities

in 22 countries, commits to reduce its absolute scopes 1 and 2 greenhouse gas emissions by 28 per cent by 2030 from a 2019 base. Scope 1 includes all emissions directly linked and emitted by Bodycote facilities and Scope 2 includes all emissions linked to the group's purchased inputs, those associated with the purchase of electricity, steam or cooling. Bodycote measures Scope 3 emissions, in line with the SBTi guidelines, but does not report them as SBTi deems the quantum to be immaterial

Avoiding emissions

Bodycote's services are vital to ensuring the performance and longevity of crucial components in almost every part of the modern world, enabling – amongst many other advantages – longer lifetimes, less machining, less waste and greater fuel efficiency. Both in the products the company processes and the way they are processed, Bodycote's services support industry to avoid emissions, commonly referred to as Scope 4. By avoiding emissions from the outset, Bodycote is a major contributor to helping industries to reduce their carbon footprint and help to minimise the adverse impact on the climate.

Commenting on the approval, Stephen Harris, Bodycote group chief executive, said: "We are very pleased to achieve approval of our near-term science-based emissions targets. Managing energy and reducing our environmental impact has long been part of our corporate culture. As a company, Bodycote is focused on ethical and sustainable growth, and proud of our commitment to setting an ambitious target. Leading by example, Bodycote demonstrates the positive impacts of carbon reduction for its stakeholders and encourages other businesses to commit to science-based targets."

With more than 165 accredited facilities in 22 countries, Bodycote is the world's largest provider of heat treatment and specialist thermal processing services. Through classical heat treatment and specialist technologies, including thermal spray coatings, Bodycote improves the properties of metals and alloys, extending the life of vital components for a wide range of industries, including aerospace, defence, automotive, power generation, oil & gas, construction, medical and transportation.

Global construction materials company Cemex has been trialling the use of existing pre-cast material in its concrete products, including solutions made of up to one hundred per cent recycled aggregates.



Cemex UK R&D trials use of up to 100 per cent recycled aggregates

These trials are the latest example of building materials supplier Cemex's creative and dynamic efforts to reach its 2050 goal of operating as a Net Zero company globally, in line with its *Future in Action* strategy.

The trials, conducted in partnership with UK based Manufacturing Technology Centre (MTC) and First Graphene at Cemex's National Technical Centre in the West Midlands have utilised various unique production processes which optimise the incorporation of recycled materials.

Following the success of initial testing, MTC and Cemex will now look to expand further into larger scale trials.

Cernex understands that contributing to a circular economy is vital if Net Zero is to be achieved, which is why it has made circularity one of the key pillars of its climate action strategy.

Mike Higgins, national technical manager for UK research & development, said: "Reusing recycled products in our materials where possible not only reduces waste, it helps to replenish our aggregates reserves and protects our business into the longterm.

"At our UK R&D facility we are focused on pursuing innovation to increase the sustainability of our operations and are always keen to work with partners such as MTC and First Graphene. We believe there is a significant opportunity to incorporate recycled

The Manufacturing Technology Centre (MTC) was established in 2010 as an independent research and technology organisation (RTO) with the objective of bridging the gap between academia and industry and is now formally recognised by UK Research and Innovation (UKRI) as an independent research organisation (IRO). The MTC develops innovative manufacturing processes and technologies in an agile, low risk environment, in partnership with industry, academia and other institutions. *www.the-mtc.org*

Cemex is a global construction materials company that is building a better future through sustainable products and solutions.

Cemex offers cement, ready-mix concrete, aggregates, and urbanisation solutions in growing markets around the world, powered by a multinational workforce focused on providing a superior customer experience, enabled by digital technologies.

CEMEX R&D, Innovation and Business Development projects are part of the global R&D collaboration network, headed by CEMEX Research Centers, based in Switzerland. www.cemex.com materials into our products and provide our customers with a solution for reducing the carbon footprint of their projects."

Cemex announced its climate action strategy; *Future in Action – Committed to Net Zero CO_2* in February 2020, along with updated targets in November 2022 and as part of this, by 2030 the company plans:

- To be below 430kg of CO₂ per ton of cementitious material, equivalent to a 47 per cent reduction*.
- □ To reduce the carbon content per cubic metre of concrete to 150kg, equivalent to a 41 per cent reduction.
- □ To reach 65 per cent in clean electricity consumption by 2030.
- □ To reduce Scope 3 transport emissions by 30 per cent by 2030.
- □ For Vertua lower-carbon to account for majority (50+ per cent) of cement and concrete sales by 2025.
- □ To manage up to 40m tons of waste per year by 2030.

* According to the company's 1990

baseline

- First Graphene Ltd is the leading
- supplier of high-performing graphene
- products with a robust manufacturing
- platform and an established 100 tonne/
- year graphene production capacity.
- PureGRAPH® graphene is easy to
- use and is enhancing the properties
- of customers' products and materials
 across industries and applications
- worldwide.



Real world problems – PRACTICAL SOLUTIONS

Institute of Refractories Engineers Annual Conference and Training Day 2023 15 -16 November 2023

The Mowbray, 118 Mowbray St, Neepsend, Sheffield S3 8EN, UK

Following the success of the IRE Annual Conference in 2022, we are pleased to announce that we will be holding the 2023 IRE Annual Conference at the same venue – The Mowbray in Kelham Island, Sheffield (UK) on 15 November 2023.

The conference offers the chance to come together to listen to industry experts impart their knowledge and is an ideal networking opportunity. We will seeking contributions for the event in the coming weeks and suggest you check out the website for updates.

Conference details: Online attendance is available. Please email secretary@ireng.org if you wish to attend online. Lunch will be included for those attending in person. Arrival: 9am for a 9.30am start, close of conference is at 4pm. **Dinner:** 7pm-11pm

Dress Code: Smart/Business Casual (no jeans or trainers). **Special Guest Speaker:** To be confirmed. **Entertainment:** To be confirmed.

Standard Pricing (members discount available)

- □ UK Conference Day £120.00 register at: https://www. ireng.org/register/2023-uk-conference-day/
- UK Training Day £100.00 register at: https://www.ireng. org/register/2023-uk-training-day/
- UK Dinner Event £99.00 register at: https://www.ireng. org/register/2023-uk-dinner-event/
- UK Conference & Dinner £160.00 register at: https:// www.ireng.org/register/2023-uk-conference-dinner/
- □ UK Training & Dinner £140.00 register at: https://www. ireng.org/register/2023-uk-training-dinner/
- UK Conference & Training £200.00 register at: https:// www.ireng.org/register/2023-uk-conference-training/
- UK Conference, Training & Dinner £250.00 register at: https://www.ireng.org/register/2023-uk-conference-trainingdinner/

Training Day – 16 November

The popular *IRE Training Day*, held the day after the *IRE Annual Conference*, offers an insight into relevant topics and gives attendees a broader understanding of the industry and specific aspects of it.

- Our 2023 *Training Day* will focus on:
- Raw materials and their properties
 Castables formulation and properties

Members Discount Code: IREmember2023

Students Pricing

- □ UK Conference Day £60.00 register at: https://www. ireng.org/register/2023-uk-conference-day-student/
- UK Training Day £50.00 register at: https://www.ireng. org/register/2023-uk-training-day-student/
- UK Dinner Event £50.00 register at: https://www.ireng. org/register/2023-uk-dinner-event-student/
- UK Conference, Training & Dinner £150.00 register at: https://www.ireng.org/register/2023-uk-conferencetraining-dinner-student/

IRE Corporate Package Discounts

IRE Corporate Package holders receive discounts on these as per the following (excluding the student rate).

- Bronze 10 per cent discount.
- Gilver 12.5 per cent discount.
- Gold 15 per cent discount.

For more information on IRE Corporate Packages see page 37.

For more information and to book visit: https:// www.ireng.org/2023-uk-conference/



Refractory innovations underpinning LOW CARBON EMISSION TECHNOLOGIES

IRE AUS brings delegates together to strengthen collective expertise to highlight 'green' inroads.

Opening the conference, held in Sydney on 27 March 2023, incoming Australasian President Mario Taddeo thanked all those involved in organising the event, before passing on words from President Mark Prince who was unable to attend. Prince was keen to remind attendees to take as much out of the conference as possible, thanks to the sharing of knowledge and detailed information on a wide range of topics. He said he was particularly delighted that several of the speakers were from end user plants.

Mario Taddeo then welcomed the speakers and delegates from around Australasia and the UK and thanked the sponsors: Calderys, ANTEC Refractory, SOTO Group Pty Ltd, Veolia, Vesuvius, Morgan Advanced Materials, Pyrosales, RHI Magnesita, Shinagawa Refractories Australasia.

Ironmaking decarbonisation: opportunities, challenges and research

Kicking off proceedings, Paul Zulli of the Steel Research Hub questioned how industry could engage with the energy sector to bring about necessary changes required to meet emissions targets in his presentation. He noted the three main production routes of: blast furnace; scrap-based electric arc furnace (EAF); and natural gas based, highlighting that there was a 70/30 ratio between blast furnace and EAF.

He spoke of how Australia was "gearing up" today but that the country needed to catch up with Europe and Japan – regions that were already engaged with the energy sector. "In Europe they say: 'I want carbon-free materials', in Australia we don't necessarily ask this and are not sure if it's the right statement," he said. "Since 2011, there are only two blast furnace ironmaking facilities left in Australia.

"In Japan they think deeply about the whole process and all considerations. Australia is in a transition period to the brave new world, whereas much work has already been undertaken in Europe. However, climate action initiatives are now being undertaken in Australia."

Looking at smart carbon usage (SCU) and direct carbon avoidance (DCA) – the two pathways for climate action – he said they were likely to be pursued simultaneously. He tabled an assessment sheet of the 17 current and emerging SCU and DCA technological areas, with more than one hundred different processes and materials. Thus, highlighting that the adoption of new, disruptive technology for decarbonisation of capital-intensive steel plants depends on various factors such as locality, available materials and energy sources, steel business conditions and market-driven requirements. "So, inevitably, and necessarily," he said, "bespoke technological solutions will be chosen for each steel plant, as they transition."

He also called for incentives to address the issues of infrastructure required for the energy switch.

"Refractory linings will be different," he confirmed. "Temperatures will be higher in furnaces that use electrodes; where they are will determine the heat loss. The key will be materials efficiency and energy efficiency."



Some of the presenters at the IRE AUS Conference 2023

Design of refractory linings in a virtual environment

Frank Soto, managing director of SOTO Group Pty Ltd, Australia spoke about the drawbacks of a traditional design approach for refractory linings and how the use of 3D modelling can improve the process, as complex geometries cannot be captured using 1D calculations. "Traditionally for refractory lined vessels, all the parties involved are disjointed," he claimed. "Integration between all involved is not as cohesive as it could be."

He said: "Not accounting for 3D effects leads to: anchor failures if inappropriate materials are used for the actual temperatures they are exposed to; and high localised shell surface temperatures. Also, too much expansion allowance leads to: process material ingress – refractory jacking; process gases ingress – chemical attack on anchors/insulation. In addition, not enough expansion allowance leads to: excessive refractory stresses – refractory failures; anchor failures."

He argued that the use of 3D modelling could avoid all of the above, by determining things such as the best suited anchor selection, temperature distribution and identifying what happens with the refractory itself.

A mammoth task

Problematic refractories and linings were considered by Roy Berryman of Glencore who gave an overview of refractory installations at Koniambo Nickel in New Caledonia. The project is jointly owned by SMSP (51 per cent) and Glencore (49 per cent) and has been in operation since 2013. The two main aspects being the metallurgical plant and the power station, with a number of global suppliers and partners involved.

There was an audible gasp when Berryman spoke of the 15,000t of installed refractory at the site. He said: "Of what is in the metallurgical plant, two thirds are in two furnaces!"

As one of just a few DC furnaces in the world, the one at Koniambo is used for smelting. He said: "There is a completely open bath in a DC furnace, 1650°C, two electrodes are on the Koniambo DC furnace, dissipating 50-60 per cent of power in arcing. With ferro nickel smelting (all for the stainless steel market) there is less than ten per cent yield of metal," he explained. "The other 90 per cent is slag – all that heat is radiated into the atmosphere."

The furnace has a brick dome in the

centre and uses three main kinds of refractory – magnesia, crucible and spinell alumina. He said: "The metal sits in contact with magnesia bricks which can last for decades. Part of the wall is copper. The part of the wall where alternating slag and metal (the wash zone) consists of two bricks, which tolerate exposure to magnesia slag. We completed a furnace rebuild in 2015 on furnace 1, which was back online in 2016, then we elected to do the same with furnace 2, two to three years later."

The large, fully integrated site is approaching its ten-year anniversary and he confirmed that the metallurgical plant and boilers are "refractory-intensive", explaining that a "major DCF repair is planned for 2024, along with a major boiler repair." The intention is to undertake an external repair, similar to the emergency side wall repair done in 2021, while keeping the hearth hot. "In 2024 the intention is to replace the bricks without cooling off the hearth."

Although the major fuel source on site is coal with diesel as a backup, Berryman said less carbon-intensive options were being investigated.

Recycling spent refractories – a circular economy for refractories users and manufacturers

Navin Singh of Veolia Australia and New Zealand spoke of how "the times are changing" as the refractories industry is "proactively reducing its carbon footprint." He said a key point to acknowledge is that "40-50 per cent of the cost is refractory raw materials."

He said: "There are seven to twelve million tonnes of spent refractories worldwide. This is going to become a competitive factor. For example, the steel industry will push for more environmentally friendly refractories production. In Europe everyone is already talking about carbon footprint reduction. We need to know the carbon footprint of our products. The value of material needs to be as high as possible – this must be achieved for a circular economy.

"The challenge is that it is very difficult to segregate and pre-sort, it requires a certain skill level. Demolishing different types of refractories and mixing them together is a real challenge."

He offered solutions as: spent refractory generation; design with recyclability in mind – refractory and lining; green dismantling.

He spoke of reducing manual handling, replacing some raw materials by sourcing alternatives, segregating products, and setting benchmarks for targets for certain amounts of products and materials to use.

He also considered spent refractory processing for the production of secondary raw materials.

He warned: "Today landfill is cheap, tomorrow it may not be, so big companies are looking at this. We need to work with industry to find solutions – there are so many possibilities. We can recycle castables coming out of ladles and there is a lot of work on this. However, recycling monolithics is a challenge."

Green transition of refractory use

Mats-Ove Eriksson, representing his former company Hoganas Borgestad, spoke on setting new standards on the green transition of refractory use. He said the industry was transitioning and that energy efficiency and preventative maintenance was fundamental.

"Can we who work in the industry work with manufacturers to reduce CO_2 ? Yes, we can. Choosing the correct refractory material, fit for purpose, is important and reducing the shell temperature to reduce mechanical problems in important kiln areas such as the inlet zone and pre-heating zone. If you use the right material, you get a stabilised temperature."

He detailed different examples, where making the right choice paid dividends. "Proper refractory design reduces costs," he said. "The right lining concept facilitates: avoidance of shell corrosion; avoidance of refractory failure; savings in energy; extention of equipment lifespan; reduction of carbon footprint; better production."

Controlling tundish liquid steel temperature with improved refractory lining design

With his Pyrotek hat on, Mario Taddeo gave a presentation highlighting the importance of selecting the right insulating material. He showed how the benefits of tundish insulation resulted in: better control of the overall thermal profile during casting sequence, minimisation of steel temperature drop, more uniform steel temperature flow, optimisation of casting speed and steel quality, more predictable temperature loss, and better control of superheat temperature." He reminded delegates that tundish insulation is designed to perform over very long refractory lining campaigns and "does not fail."

He said that the selected product must have the right combination of materials and even when it is a proven benefit as an insulation material, users should ask if it "goes the distance."

Ivan Gray of Vesuvius Australia Pty Ltd gave a detailed presentation on the American Petroleum Institute (API) Standard 936: refractory installation quality control, inspection and testing monolithic linings and materials, which was recertified in 2018.

Yogesh Tripathi spoke about the Mount Isa Mines copper smelter rebuild, explaining that "it is an asset that requires attention at every stage."

Don Merritt of 4D Delta gave a presentation on remote asset inspection, laser scanning and processing. Read more about this on page 14 of this issue of *The Refractories Engineer*.

Linda Apthorpe, lecturer, WHS Academic Program, Occupational Hygiene, School of Health and Society, University of Wollongong provided a stark warning by speaking about the risk of exposure to respirable crystalline silica, noting: "It's the most common mineral in the Earth's crust. It is everywhere and can be hazardous with long exposure, but it can be managed."

Phil Walls gave a presentation entitled, '*Recent developments in energy saving refractory materials and forming processes*', as previously presented at the IRE UK conference, refer to *The Refractories Engineer* Issue 1 2023, March, for more information.

Shankha Chatterjee of Almatis Alumina Priv Ltd gave a presentation entitled, 'Value addition of matrix aluminas in castable properties and performance,' where he considered brick technology versus castable technology. He considered best practice sampling and the importance of communication between all parties at all stages – before, during and after sampling.

Mark Herring of Shinagawa Refractories Australasia Pty Ltd also considered '*Preparation* and testing of site samples,' looking at the responsibilities of the customer, manufacturer and installer. Noting that several standards come into the equation, including official country, international and customer-specific standards. He urged: "Treat samples properly and take your time. They should be clearly identified for traceability."

The conference also included a table-top exhibition with plenty of networking breaks for delegates to chat with exhibiting companies and fellow conference attendees. In addition, there was a welcome reception on the eve of the conference and a dinner after the event. The relaxed and welcoming atmosphere highlighted all that the IRE Australasia branch has to offer and provided an opportunity to meet existing colleagues and friends and forge new friendships through common objectives.

For more information on the event and how to get involved in future IRE AUS events, contact: Dean Tredinnick on: deanbt1970@gmail.com

How to make a castable

Dr David Bell

ABSTRACT

Methods for optimising castable particle size distribution and water demand are described with examples, then approaches for dryout, thermal shock, slag attack, atmosphere attack and erosion are discussed. Several types of castable exist – high cement, LCC, ULCC and NCC are classifications based upon lime content but there are various other binder systems that can be used: silica sol, alumina sol, phosphate and carbon-bonding. Lightweight castables provide good insulation whereas dense castables are needed for resistance to molten metal ingress and chemical attack.

INTRODUCTION

Function

When designing a castable refractory, there are many points to consider. Most important is the intended function, for example:

- · Thermal insulation.
- Load-bearing.
- Abrasion resistance.
- · Molten metal containment (e.g. steel, aluminium).
- Slag resistance.
- Atmosphere other than air (e.g. CO, H₂ etc.).
- Maximum temperature of application.

Sometimes, of course, more than one of these functions may be required from the castable.

Aggregate type

The next consideration is the type of aggregate to be used. This will influence the raw material cost and it is always necessary to minimise these. To some extent, this will be decided by the intended function; for example, if good insulation properties are required then lightweight aggregates will be used but for containing molten steel it will be necessary to use high purity, dense aggregates. Many raw materials are available:

- Alumina in several forms (fused, tabular, bubble alumina, reactive, bauxite etc.).
- Alumino-silicates (kyanite, fireclay, mullite, sillimanite).
- Silica (fused, fumed/microsilica, fly-ash).
- Zirconia (baddeleyite, zircon, fused zirconia).
- Synthetic aggregates (spinel, CA₆).
- Carbon (graphite, amorphous).
- · Chrome (rarely used these days due to environmental considerations).
- Magnesia (dead-burned, seawater).
- · Super-lightweight (vermiculite, perlite, coconut husks, rice husks).
- · Reclaimed materials (all above types, reclaimed from used refractories).

Installation method

Several installation methods are available:

- Vibro-casting in-situ by poker.
- · Vibro-casting for pre-cast shapes (vibrating table).
- · Pumping into shutter-work.
- · Free-flow pouring (in-situ or pre-cast).

Binder

Only now should the binder system be selected. What has been decided in the sections above may determine the binder system, or there may be several possibilities:

- · Cement-bonded (traditional or high-cement castable).
- Low-cement castable (LCC, often defined as CaO <2.5%).
- Ultra-low cement castable (ULCC, sometimes defined as 0.2% < CaO < 1%).

- No-cement castables (NCC,
- sometimes defined as CaO < 0.2%).
- Sol-bonded (silica sol or alumina sol).
- Phosphate-bonded.
- Carbon-bonded.

Some of these types are not suitable for in-situ casting. LCC and ULCC types often include microsilica and reactive alumina. NCC types may have a sol binder, hydratable alumina or a chemical binder.

Although it is simple to use cement as the binder, there are some advantages in minimising or eliminating cement.

- The CaO Al₂O₃ SiO₂ system contains the possibility of liquid formation at several formulations, notably with the occurrence of gehlenite (2CaO.Al₂O₃.SiO₂ melts 1593°C) and anorthite (CaO. Al₂O₃.2SiO₂ melts 1553°C). If there are impurities of sodium or iron in the castable, melting point will be even lower.
- The use of cement leads to the requirement for a significant amount of water to form the hydrated bond. Water will have to be driven off before the castable can be used, a process that can lead to explosive spalling. Removal of water may take a long time, an inefficiency when equipment is required back in service as soon as possible. When the water has been removed, the castable will have high porosity, perhaps more than 20% by volume, which leaves the castable prone to gas or slag ingress and degradation by chemical attack.

Other additives

Still other additives are available for use in castables. Some of these will not be necessary in any particular case. Many of these are proprietary formulations offered by specialist suppliers.

- Deflocculants (dispersants) to increase flow and reduce water demand.
- · Steel fibres (to impart toughness).
- Polymer fibres (to improve dryout times).
- Accelerators/retardants (to control setting time).
- Surfactants (to aid mixing of non-oxide components).
- Non-wetting additives (to minimise corundum formation in aluminium contact applications).

Technical Paper •

FORMULATION

Once the type of castable has been decided and binder system selected, it is time to look at formulation. In general, the aims of castable formulation are:

- Minimisation of water addition.
- Good flow.
- · Controlled setting time.
- Adequate green strength and fired strength.
- Minimisation of risk of chemical attack, thermal shock, shrinkage cracking.

Minimisation of water addition by optimisation of particle size distribution

Water (or other liquid) is added to castables to enable flow and to provide an hydraulic bond. In order that the castable will flow, there must be a fluid between the grains of aggregate; if the grains are fully in contact with each other the system will not be mobile enough for casting. If enough water is added, any mixture will begin to flow but excessive water addition leads to segregation, low strength, high porosity and difficulty during dryout. Therefore, water addition should be minimised.

This is typically controlled in three ways, usually in concert. The first of these is determination of the correct particle size distribution.

Let us imagine a 2D example of particle packing, in which the square in fig.1 represents a region to be filled. Available materials are circular 'grains' of various sizes, and the aim is to fill as much as possible of the blue square with these grains. First, the largest grains available are used (orange), but that leaves a large gap between the four grains. Next, a grain is found that fits exactly in the gap (green). This leaves four spaces around the green grain, so grains are found that fit into these gaps (red). This process continues until the smallest available grains have been used. This process can easily be imagined in a 3D shape, such



Fig.1 Packing theory example



Fig.2 Flow behaviour related to proportion of coarse, medium and fine fractions. (Nakashima et al)

as the space to be filled by a castable installation. For this reason, it is necessary to have available the widest possible range of particle sizes when formulating a castable. The largest aggregate grains possible should be used, together with a range of particle sizes down to the smallest particles available. Of course, the range of sizes may be limited by the need for a smooth surface finish, the type of mixer, cost, pouring system etc.

If it is assumed that all grains are spherical then a mathematical theory can be derived describing the packing, and this can be used to optimise packing. In fact, several approaches are available but the simplest is that provided by Andreassen⁽¹⁾. The Andreassen model may be expressed as:

C = (d/D)^q Where

and

e	C is Cumulative % finer than particle size d
	d is a particle size
	D is the maximum particle size
	q is an exponent
	all quantities are expressed in volume terms

This equation is used by Myhre⁽²⁾ to explain the advantages of microsilica addition.

Myhre explained that low values of q (around 0.2) tend to give a free-flow castable but higher values (around 0.3) give a vibration castable. Free-flow castables formulated with microsilica tend to exhibit dilatant rheology (shear-thickening) but vibration castables tend to be thixotropic (shear-thinning).

In theory, optimum packing will be achieved with q = 0.37; however, there are so few fines at this q value that even under strong vibration, the fines do not move into the gaps between larger particles. Therefore, lower q values should be used, and the lower the q value, the more easily fines will move into the gaps. This is part of the explanation for lower q values giving free-flow castables.

An alternative approach is given by Nakashima, Sudo, Takahashi and Konishi⁽³⁾; they expressed the flow properties pictorially based upon the proportions of different size fractions (see fig.2).

Fig.2 shows the same reasoning as that of Myhre, that it is necessary to incorporate a wide range of particle sizes.

Minimisation of water addition by use of dispersants

The formation of a fluid layer between particles can also be assisted by dispersants. These are usually soluble chemicals containing an ionic group that attaches itself to smaller particles in the castable, especially cement particles, causing an effect of steric hindrance (forcing the small particles to spread out). There are many different types of dispersant ranging from the well-known sodium tripolyphosphate to more complex organic compounds such as gluconates. Dispersants may also affect pH, important in the stabilisation of e.g. silica or zirconia suspensions. Wetting agents are sometimes used, especially when non-ionic ingredients are included; wetting agents, typically surfactants, form a bridge between water and these materials. As a rule of thumb, it is a good idea to have only one dispersant and one surfactant in any recipe.

Minimisation of water addition by minimisation of hydraulic bond component

It is normal to use calcium aluminate cement as the main binder in a castable, but this entails water demand from the cement, as the binder function comes from the formation

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Ingredient	%
Fused alumina 3-5 mm	8.6
Fused alumina 1-3 mm	23.5
Fused alumina -1 mm	23.1
Fused alumina -0.5 mm	7.7
Fused alumina -100 mesh	15.95
Fused alumina -300 mesh	2
Reactive alumina A	2.7
Reactive alumina B	3.9
80% alumina cement	0.5
Hydratable alumina	4
Microsilica (high purity)	8
Sodium polyacrylate dispersant	0.05

(left) Table 1. Free-flow castable recipe

Property	Value
Water demand	4.9 %
Flow	85 %
Set time	3 hours
Crush strength (dried 110°C)	65 MPa

Table 2. Free-flow castable properties



Fig.3 Fused alumina castable ingredients PSD



Fig.4 Fused alumina castable, q = 0.23

of needle-like calcium aluminate hydrate crystals. The cement component can be reduced by use of alternate fine particles such as microsilica or reactive alumina, or eliminated completely by the use of a different type of binder. With ULCC or NCC castables, there can be difficulties due to low green strength, which must be considered during installation.

Fused alumina free-flow castable example

To optimise the particles size distribution it is useful to have well-defined fractions and for this purpose the most widely available, well-characterised aggregates are available in

alumina and silica. For this recipe, fused alumina was used. Two grades of reactive alumina and hydratable alumina were used, and cement with 80% alumina. Due to the low addition of cement, this mix is classified as NCC, even though it does contain 0.5% cement. Flow was measured using ASTM flow table without vibration.

The particle size distributions of the ingredients for the fused alumina castable (log-log plot) are shown in fig.3. By combining these ingredients in the optimum proportions, a PSD close to the theoretical ideal can be achieved, and this is shown in fig.4.

Fig. 4 shows the Andreassen distribution plot for this castable: when the axes are logarithmic, the plot should follow a straight line with slope equal to q. The fit is excellent except for particle sizes below 0.5 micron; theory indicated that more than 8% microsilica is required but it was found that when the microsilica content is above 8%, the mix becomes too sticky. The excellent fit to the idealised distribution was achieved by linear regression methods, using several alumina fractions. When the range of particle sizes was increased further by adding in particles up to 8mm, using g value of 0.26 and applying vibration, the castable was usable with water addition of 2.5%, an extremely low value.

Kriechbaum, Gnauck, Laurich and Stinnessen⁽⁴⁾ describe a vibration castable with water demand as low as 3.7%. The recipe is shown in Table 3. A comprehensive list of properties was also presented and is shown in Table 4. Hot MOR values were measured after one hour hold at test temperature but still are quite remarkable.

Controlled setting time

It is very useful to have a castable that stays fluid for a while so that there is time to take it from the mixer to the point of installation, without having to hurry unduly. The castable should also set in a fairly short time so that it can be de-moulded soon afterwards. In practice, a 'working time' (during which the mix is fluid) of 20 to 30 minutes is useful, but initial set should follow shortly afterwards. Final set, at which point setting is complete, will take much longer.

The addition of microsilica tends to increase the working time but setting can be slow. Therefore, an accelerant is often added. The most well-known accelerant is lithium carbonate, which induces very rapid setting in cement systems by precipitation of Ca ions. Li₂CO₃ is not the best accelerant, partly because it must be added in such small

Ingredient	% in recipe
Tabular alumina (various size gradings)	59
Spinel AR78, various size gradings)	19
Reactive alumina CTC55	17
Cement CA270	5
Dispersing alumina ADS1	1

Table 3. Vib 215 recipe (the dispersing alumina is not included in the total 100% composition, so percentages total 101%)

quantities that efficient mixing is difficult. A further consideration is that Li₂CO₃ is a psychological drug and should be handled with care. In high-cement mixes, or in hot weather, a retardant is often added, such as sodium citrate (or even sugar). Some commercial castables contain both an accelerant and a retardant.

Adequate green strength and fired strength

Green strength is necessary so that demoulding can take place, or to support further installations, and this can most easily be assured by including cement. If cement is not used, then another setting mechanism is necessary. Castables bonded by silica sol or alumina sol require some initiation of setting; this may be induced by pH modifiers, temperature change or some other additive.

Fired strength is usually sufficient, though cement-bonded systems are relatively weak after the hydraulic bond has been destroyed (above 400°C) but below sintering temperatures (from about 700°C upwards depending upon recipe). While at very high temperatures, hot strength may be low but after cooling, strength may be very high indeed and cold crush strength (CCS) values above 200MPa are quite possible. Hot MOR values at 1500°C are usually no higher than 2 or 3MPa, even for high alumina castables, but MacZura reported Hot MOR values of over 11MPa for a castable based upon tabular alumina and 15% of cement⁽⁵⁾.

Above 1500°C, hot strength is limited unless low-melting point compounds can be avoided. If lime, silica and alumina are all present in significant ratios, hot strength will be poor. Therefore hightemperature systems should be based upon CaO and Al₂O₃, or upon Al₂O₃ and SiO2.

A 100% alumina castable

It is guite possible to have a castable containing only alumina, by replacing cement with hydratable alumina; however, strength is significantly lower.

Property	Value	Property	Value
Water demand	3.7%	CCS cured 32°C	35 MPa
Bulk density dried 110°C	3120 kg/cu.m	CCS dried 110°C	95 MPa
Bulk density fired 1500°C	3110 kg/cu.m	CCS fired 800°C	122 MPa
Bulk density fired 1650°C	3140 kg/cu.m	CCS fired 1000°C	110 MPa
Apparent porosity dried 110°C	12.5 %	CCS fired 1500°C	334 MPa
Apparent porosity fired 1500°C	15.7%	CCS fired 1650°C	332 MPa
Apparent porosity fired 1650°C	14.3 %	PLC fired 800°C	-0.1 %
MOR after curing at 32°C	4.8 MPa	PLC fired 1000°C	0 %
MOR dried 110°C	15.8 MPa	PLC fired 1500°C	0 %
Cold MOR fired 800°C	9.1 MPa	PLC fired 1650°C	0.3 %
Cold MOR fired 1000°C	10.1 MPa		
Cold MOR fired 1500°C	62 MPa		
Cold MOR fired 1650°C	57 MPa		
Hot MOR @ 1500°C	32.7 MPa		
Table 4. Properties of vibration castable Vib 215 (Kriechbaum et al)			



Fig.5 Internal pressures at centre of large castable blocks heated at 25°F/hr to 1200°F (Bell and Winkelbauer)

MINIMISATION OF THERMAL SHOCK DAMAGE AND EXPLOSIVE SPALLING

It is essential to heat castables carefully on the first heating, as water must be driven off slowly. Although it might be expected that castables with low water content can be heated more rapidly than castables with high water content, in fact the opposite is true; LCC types with low water content show the biggest problems during dryout and cases of explosive spalling are common. The reason for this is that the fine particles (microsilica, reactive alumina etc.) included in LCC types cause the materials to have very low permeability and this is more important than the quantity of water present.

This is demonstrated by Bell and Winkelbauer⁽⁶⁾ who showed that internal pressure during drying is higher for a LCC type than for a high-cement castable (see fig.5).

Explosive spalling can be limited by using a suitable heating rate (linear ramps are better than the usual ramp-and-hold schedules), and by the use of polymer fibres in the castable. These should be of a type that breaks down below 100°C, or they will be ineffective.

Parr, Wöhrmeyer, Touzo and Bell⁽⁷⁾ demonstrate that the choice of calcium aluminate cement type, addition of polymer fibres and heating rate are all important factors determining the safe heating procedure. They note that water that forms part of the cement hydrate bond is not released until higher temperatures and therefore does not have a large effect on internal pressure development, which is caused mainly by free water, not the chemically-bound water. It is necessary to understand which calcium aluminate hydrate is formed to determine the temperature at which water is released from the hydraulic bond.

Meunier and Mindeguia⁽⁸⁾ instrumented castables with pressure gauges and also

Author →	MacZura (5)	Schnabel (12)	Schnabel (12)	Sako (11)	Sako (11)
Spinel Type →	Preformed	In-situ	Preformed	In-situ	Preformed
	Ingredient %	Ingredient %	Ingredient %	Ingredient %	Ingredient %
Tab alumina	60	75	50	80	72
Preformed spinel	15		25		21
Magnesia		5		6	
Reactive alumina	10	16.5	20	7	
Cement	15	3	5	6	6
Microsilica		0.5		1	1
Hydratable alumina					
Water demand	6.8	5.5	5	4.2	4.2
PLC 1650°C					
Hot MOR 1500°C (MPa)	21	1	23		
Slag resistance		moderate	good	poor	good

Table 5. Spinel castables

reported that: "The material which gave the highest pore pressure is a castable with a low water addition (high compacity). Drying fibres were present but did not prevent the pressure build up, probably because of hydrothermal conditions." Peak pressures measured were over 2MPa.

Luz, Moreira, Salomao, Braulio and Pandolfelli⁽⁹⁾ present a detailed analysis of the relative importance of drying agents, castable additives and heating rates in determination of the safe heating rate for castables.

SHRINKAGE CRACKING

Shrinkage cracking is a phenomenon particularly affecting castables installed in large panels or as large blocks. After firing at high temperature, some shrinkage is normal, and the temperature limit of a castable is usually determined by measuring permanent linear shrinkage (PLC). If part of a panel or block is heated to a higher temperature than other parts of the panel or block for instance, if the hot face temperature is higher than the cold face temperature, preferential shrinkage occurs at the hot face leading to cracking. There are several ways to overcome this problem:

- Inclusion of large aggregate grains in the castable.
- Inclusion of expansile material such as raw kyanite.
- Steel fibre reinforcement.
- Formulation such that the crack pattern is one of many microcracks, as opposed to a few large cracks.

Reference ten⁽¹⁰⁾ shows modelling of cracking in castable panels, where it is demonstrated that the work of fracture (WoF) test can be used to predict cracking behaviour. To avoid shrinkage cracking, therefore, the fracture mechanical properties of the castable should be optimised, or the formulation should be such that shrinkage at the hot face temperature is close to zero. Often, these two approaches amount to the same thing and the use of high purity, very coarse aggregate grains will achieve both aims.

The use of expansile materials in castables can be beneficial in resisting shrinkage cracking, but this must be judged very carefully to avoid other problems (such as liquid formation). Raw kyanite has traditionally been used but several authors^{(11) (12)} claim success from in-situ spinel formation.

RESISTANCE TO CHEMICAL ATTACK

Slag attack

Slag attack can be a serious problem for castables, an area in which fired refractories such as firebricks, are often superior. Nonetheless, castables with excellent slag resistance are possible. Resistance to steelmaking slags is difficult to achieve, especially since metal temperatures are very high. Recipes containing spinel give best results but some authors report that in-situ spinel formation gives best results while others prefer to include pre-formed spinel. Three recipes are shown in Table 5.

Schnabel reported that hot MOR was much higher for the castable with pre-formed spinel than for the in-situ spinel castable, and slag resistance was slightly superior in finger-dip tests. Sako, conversely, reported that the in-situ spinel castable showed much better slag resistance than the pre-formed spinel castable.

It is generally reported that addition of 0.5% to 1% microsilica is necessary in an in-situ spinel castable: this stabilises the magnesia and limits the effects of hydration. Microsilica also improves particle packing.

Table 6 shows properties of in-situ spinel castables prepared by the current author.

Tables 5 and 6 indicate that pre-formed spinel gives far greater hot strength, but in-situ spinel may offer improved slag resistance if the cement content is low. Including calcium aluminate cement together with magnesia and microsilica gives the possibility of low-melting complexes, certainly melting below steelmaking temperatures.

Corundum formation

The formulation of castables based upon fused silica is essentially similar to formulation of alumina castables, except that the density of silica is lower and therefore the percentage (by weight) of water required is greater. Free-flow silica castables typically require about 8% to 9.5% water. The use of reactive alumina, microsilica and dispersants is very similar. Fused silica has some limitations, in particular that it devitrifies above around 1100°C and so cannot easily be used at very high temperatures, except in short-term, one-shot applications. The most common use of fused silica castables is in aluminium applications at temperatures between 600°C and 1000°C (fused silica is used because it is a better thermal insulator than alumina), and here corundum formation is a problem. Since aluminium metal is very reactive, it displaces silicon from fused silica; this weakens the castable and forms hard, onion-like growths in and on the surface. These growths lead to cracking and

Spinel Type →	In-situ 1	In-situ 2	In-situ 3	Preformed
	Ingredient %	Ingredient %	Ingredient %	Ingredient %
Tab alumina	75	75	85	50
Preformed spinel				25
Magnesia	5	5	5	
Reactive alumina	14	14	4	10
Cement		5	5	14
Hydratable alumina	5			1
Microsilica	1	1	1	
Water demand	4.9	4.3	5.5	7.5
PLC 1650°C (%)	-0.17	+1.21	-0.30	
Hot MOR 1500oC (MPa)	1.7	1.4	0.8	18
Slag resistance (arc furnace slag 1650°C)	Almost no corrosion	Moderate corrosion	Moderate corrosion	Significant corrosion

Table 6. Spinel castables (Bell)

distortion of castable parts, especially in melting furnaces. The high fluidity of molten aluminium means that cracks are rapidly penetrated and molten metal can reach furnace casings.

The traditional approach to solving this problem is to add a 'non-wetting' agent to the castables, and barium sulphate has been used extensively, although not the best of these additives. Alumina is not attacked by aluminium, but if the aluminium alloy contains magnesium (as many alloys do), then even alumina may be attacked as reported by Nandy and Jogai⁽¹³⁾.

Since temperatures are relatively low in aluminium applications, there is no difficulty with cement forming lowmelting complexes, so larger proportions of cement can be used. In fact, calcium aluminate cement resists corundum growth very well.

Atmosphere attack

Several types of atmosphere attack are possible:

<u>CO attack</u>

This is a specific type of attack affecting mainly castables with some iron oxide content, and it occurs especially in the blast furnace bosh. The presence of iron causes dissociation of CO, forming C and CO₂. The deposited carbon causes swelling and disintegration of the castable. This reaction is especially strong around 450°C, though it takes place to some extent over a wide temperature range. See reports by Westerman⁽¹⁴⁾ and Bell⁽¹⁵⁾. The occurrence and severity of CO attack does vary with circumstances but the best way to avoid it is to eliminate iron from the castable recipe.

<u>Hydrogen</u>

Hydrogen has several effects upon castables; one effect is an increase in

thermal conductivity due to higher molecular velocity than air. Another effect is reaction with silica between 1200°C and 1400°C to form silicon monoxide (SiO) and water⁽¹⁶⁾. SiO is a gas at this temperature and leaves the system, so the effect is to remove silica from the refractory. Therefore, castables for use at high temperature in the presence of hydrogen gas should have a formulation avoiding silica. Clearly, the combination of higher thermal conductivity and avoidance of silica in the recipe is likely to result in the castable having poor insulation performance.

Acid fumes

Acidic fumes can be a problem in many applications from incinerators to chemical reaction vessels. On the whole, castables have good resistance to small concentrations of acid but problems occur when steel anchors and the steel shell are exposed to acid, especially in combination with water vapour. It is common practise to insulate the outside of a steel shell to keep it above sulphuric acid condensation temperature, around 166°C. Various coatings are available commercially which can be applied to shell and anchors to provide some protection.

TOUGHNESS

In applications such as fluidised beds, incinerators, cyclones etc., temperatures are usually below 1100°C and cracking and erosion are more significant problems than chemical attack. In such cases the toughness of a castable becomes important. Toughness is the ability to withstand damage; for example, wood is a very tough material and bone china is not. Toughness can be measured by several methods but the work of fracture (WoF) test is perhaps the most appropriate for castables⁽¹⁰⁾. This test measures the energy required to propagate a crack through a test bar. Palmer⁽¹⁷⁾ reported that addition of steel fibres improves fracture energy (toughness) significantly at 600°C but at 1000°C there is no improvement; this is because steel has low strength at higher temperatures.

Brochen⁽¹⁸⁾ measured fracture energy of various refractory materials at high temperature and reported that high-alumina castables had the highest values, over 1000J/m². Brochen attributed this excellent resistance to cracking to crack branching, also noticed by Bell⁽¹⁰⁾. Crack branching occurs when a crack meets an obstacle such as a steel fibre or a large aggregate grain and is forced to take an alternate route. Such obstacles are known as 'crack-stoppers'. If a crack branches or takes a convoluted route the energy required to propagate the crack increases and the resistance to cracking improves. It has already been mentioned that superior properties are achieved when the coarsest possible aggregate grains are incorporated, and crack resistance is another property that benefits from the inclusion of larger grains.

CARBON-BONDED CASTABLES

Many castables containing carbon are available and have been used in blast furnace troughs, for example. These generally employ a cement bond but include carbon in one or more forms (flake graphite, resins, pitch, carbonaceous clays etc.) and these have been successful. However, such castables are bound by conventional calcium aluminate cements and suffer from the typical restrictions associated with such a bond. When the

bond comprises only carbon then high-temperature properties are improved, especially resistance to chemical attack. Oxidation resistance of course may be poor.

Colle⁽¹⁹⁾ described the formulation and properties of such a material and added that environmental benefits are achieved by elimination of cement, a material whose manufacture generates high CO₂ emissions. Carbon-bonded castables comprise typical refractory grains, alumina possibly, but the bond is derived from resin additions (liquid or powder). Flake graphite or graphite powder may additionally be included. On heating, the resin breaks down to form glassy carbon, imparting strength that persists to very high temperature. Toughness is also very good due to the flexible nature of the carbon bond.

A big problem with carbon-bonded materials is the poor green strength, so these materials are usually not suited to on-site installation. The carbon materials impair rheology (compared to cement), so it is necessary to add surfactants so that the carbon materials are wetted. Heating through the resin breakdown must also be controlled carefully. As a result, carbon-bonded castables are suitable mainly for pre-cast shapes. Limited steel plant trials have shown good performance in applications such as nozzles and pouring tubes.

Chakraborty⁽²⁰⁾ reported development of a magnesia-carbon castable with nonaqueous liquid binder, giving good performance in a steel ladle bottom application. Wear rate for the castable was 1.53mm per heat, compared with conventional pressed MgO-C bricks which wore at 1.44mm per heat. Although the bricks did show a lower wear rate, the authors point out the advantages of a monolithic construction (fewer joints, ease or repair, lower cost).

CONCLUSIONS

Castables can be formulated for the majority of refractory applications and a wide range of raw materials is available to support recipe design. From lightweight insulation castables through to carbon-bonded castables suitable for aggressive steel plant applications, many possibilities exist and have been documented in work by hundreds of authors. In particular, particle size distribution and modern dispersants permit castables to be mixed with water addition down to less than 3% by weight.

Much work has been done on installation methods (free-flow castables, gun-pumping etc.) and dryout control. Even large ladle linings can now be brought into service within 48 hours of casting. More difficult materials may be precast in workshops and dried before use, so that they can also be brought quickly into service.

Work on fracture mechanics and chemistry has shown that thermal shock, shrinkage cracking, erosion and chemical attack can be overcome in most applications. The applications for which bricks are needed are now few.

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17 Jessops Riverside Brightside Lane, Sheffield S9 2RX England Website: www.elkem.com/contact/ Tel: +44 7810 428768

MIXERS



Gunform (Equipment Supplies) Ltd

33 Carsthorne Road, Carr Lane Industrial Estate, Hoylake, Wirral, Merseyside CH47 4FB Tel: (0151) 632 6333 Fax: (0151) 632 6444 Email: info@gunform.com Website: www.gunform.com

Markham (Sheffield) Ltd

Marspal House, Lawn Road Industrial Estate, Carlton-in-Lindrick, Worksop, Nottinghamshire S81 9LB Tel: (01909) 730861 Fax: (01909) 733584 Email: sales@markham-sheffield.co.uk Website: www.markham-sheffield.co.uk

🜙 Pemat

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Pemat U.K. Ltd

28 Culley Court, Orton Southgate, Peterborough, Cambridgeshire PE2 6WA Tel: +44 (0) 1733 390432 Mobile: +44 (0) 7553 374974 Fax: +44 (0) 1733 530002 Email: dan.spencer@pemat.uk Website: www.pemat.uk



Removable and tiltable drum, forced action mixers 3-500 litres **Pemat U.K. Ltd** 28 Culley Court, Orton Southgate,

Peterborough, Cambridgeshire PE2 6WA Tel: +44 (0) 1733 390432 Mobile: +44 (0) 7553 374974 Fax: +44 (0) 1733 530002 Email: dan.spencer@pemat.uk Website: www.pemat.uk

MONOLITHIC REFRACTORIES



Calderys NGJ Ltd Units H3 and H4 Gildersome Spur, Morley, Leeds, LS27 7JZ Tel: +44 (0) 113 263 6268



RHI MAGNESITA

RHI Magnesita Kranichberggasse 6, 1120 Vienna, Austria Tel: +43 50213 0 Email: office@rhimagnesita.com Website: www.rhimagnesita.com

MONOLITHIC REFRACTORIES -CASTABLE



Capital Refractories Ltd

Station Road, Clowne, Chesterfield S43 4AB, United Kingdom Tel: +44 (0) 1246 811163 Fax: +44 (0) 1246 819573 Email: info@capital-refractories.com Website: www.capital-refractories.com



Robert Lickley Refractories Ltd

Dormston Trading Estate, Burton Road, Dudley, West Midlands DY1 2UF Tel: (01902) 880123 Fax: (01902) 880019 Website: www.robertlickley.co.uk



Trent Refractories Ltd

Menasha Way, Queensway Industrial Estate, Brigg Road, Scunthorpe DN16 3RT Tel: (01724) 858684 Fax: (01724) 281577 Email: enquiries@trentrefractories.co.uk Website: www.trentrefractories.co.uk

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Trent Refractories Ltd

Menasha Way, Queensway Industrial Estate, Brigg Road, Scunthorpe DN16 3RT Tel: (01724) 858684 Fax: (01724) 281577 Email: enquiries@trentrefractories.co.uk Website: www.trentrefractories.co.uk

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PRE-CAST REFRACTORY SHAPES



Calderys NGJ Ltd Units 3 and 4, Olympic Park, Ellesmere Port, Cheshire, CH66 1ST Tel: +44 (0) 151 356 5888



Robert Lickley Refractories Ltd

Dormston Trading Estate, Burton Road, Dudley, West Midlands DY1 2UF Tel: (01902) 880123 Fax: (01902) 880019 Website: www.robertlickley.co.uk



Trent Refractories Ltd

Menasha Way, Queensway Industrial Estate, Brigg Road, Scunthorpe DN16 3RT Tel: (01724) 858684 Fax: (01724) 281577 Email: enquiries@trentrefractories.co.uk Website: www.trentrefractories.co.uk

REFRACTORIES ENGINEERING CONSULTANTS



Quartis Ltd PO Box 138, Cranbrook, Kent TN17 9AF Tel: (01580) 754747 Fax: (01580) 754949 Email: quartis@fccu.com Website: www.fccu.com

REFRACTORIES ENGINEERS



Quartis Ltd PO Box 138, Cranbrook, Kent TN17 9AF Tel: (01580) 754747 Fax: (01580) 754949 Email: quartis@fccu.com Website: www.fccu.com

REFRACTORIES FOR ALUMINIUM



Calderys NGJ Ltd Units 3 and 4, Olympic Park, Ellesmere Port, Cheshire, CH66 1ST Tel: +44 (0) 151 356 5888



Capital Refractories Ltd Station Road, Clowne, Chesterfield S43 4AB, United Kingdom Tel: +44 (0) 1246 811163 Fax: +44 (0) 1246 819573 Email: info@capital-refractories.com Website: www.capital-refractories.com

REFRACTORY ANCHORAGE SYSTEMS

MACH ONE

Mach One (International) Ltd Unit 8, Norfolk Business Park, Foley Street, Sheffield S4 7YW Tel: (0114) 270 0545 Fax: (0114) 276 7438 Email: anchors@mach-int.com Website: www.mach-int.com

REFRACTORY ANCHORS



Flouch Engineering Co. Ltd

Hazelhead, Stocksbridge, Sheffield S36 4HH Tel: +44 (0) 1226 763239 Mobile: +44 (0) 7377 212544 Email: contact@refractory-anchors.co.uk Website: www.refractory-anchors.co.uk

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REFRACTORY BRICKWORK INSTALLATIONS



S.H.L. Refractories (U.K.) Ltd Celcius House, Lawn Road Industrial Estate, Carlton in Lindrick, Worksop, Nottinghamshire S81 9LB Tel: (01909) 731959 Fax: (01909) 731579 Email: sales@shl-refractories.co.uk Website: www.shl-refractories.co.uk

REFRACTORY GUNNING EQUIPMENT



Gunform (Equipment Supplies) Ltd

33 Carsthorne Road, Carr Lane Industrial Estate, Hoylake, Wirral, Merseyside CH47 4FB Tel: (0151) 632 6333 Fax: (0151) 632 6444 Email: info@gunform.com Website: www.gunform.com



Markham (Sheffield) Ltd

Marspal House, Lawn Road Industrial Estate, Carlton-in-Lindrick, Worksop, Nottinghamshire S81 9LB Tel: (01909) 730861 Fax: (01909) 733584 Email: sales@markham-sheffield.co.uk Website: www.markham-sheffield.co.uk

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Email: sales@shl-refractories.co.uk Website: www.shl-refractories.co.uk

REFRACTORY GUNNING MACHINES



VELCO GmbH Haberstr. 40 42551 Velbert, Germany Tel. +49 (0) 2051 2087.13 Fax +49 (0) 2051 2087.20 E-mail: cwolf@velco.de Website: www.velco.de

REFRACTORY GUNNING ROBOTS/MANIPULATORS



VELCO GmbH Haberstr. 40 42551 Velbert, Germany Tel. +49 (0) 2051 2087.13 Fax +49 (0) 2051 2087.20 E-mail: cwolf@velco.de Website: www.velco.de

REFRACTORY INSPECTION SOFTWARE



4D Delta Pty Ltd – Australia 3D Laser scanning and photogrammetry 4D Delta Cloud service delivery platform for Refractory inspection International reseller enquiries welcome Website: www.4ddelta.com Email: sales@4ddelta.com Tel: +61 8 6150 9998

REFRACTORY RECLAMATION AND RECYCLING



Richmond Reclamation Ltd 325 Coleford Road, Sheffield S9 5NF Tel: +44 114 243 3141 Fax: +44 114 256 0088 Email: richmondreclaim@gmail.com

REFRACTORY SHOTCRETE EQUIPMENT



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Markham (Sheffield) Ltd Marspal House,

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SILICON METAL

Elkem

Elkem Silicon Products 17 Jessops Riverside Brightside Lane, Sheffield S9 2RX England Website: www.elkem.com/contact/ Tel: +44 7810 428768

SILICON METAL POWDER



S+A Blackwell Ltd 10 Market Square, Lytham, Lancashire , FY8 5LW Tel: +44 (0)1253 738121 Fax: +44 (0)1253 735831 Email: sb@sandablackwell.com Website: www.sandablackwell.com

SPECIALITIES FOR REFRACTORIES



Elkem Silicon Products

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STEEL FIBRES



Fibercon UK Ltd Unit 30 Loughborough Technology Centre, Epinal Way, Loughborough, Leicestershire LE11 3GE Tel: +44 (0)1509 211860 Fax: +44 (0)1509 211862 Website: www.fiberconfiber.com

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TESTING AND ANALYTICAL



Trent Refractories Ltd Menasha Way, Queensway Industrial Estate, Brigg Road, Scunthorpe DN16 3RT Tel: (01724) 858684 Fax: (01724) 281577 Email: enquiries@trentrefractories.co.uk Website: www.trentrefractories.co.uk

THERMAL INSULATION

BILTHERM EUROPE

Siltherm Europe Ltd

Paramount Court, Corrig Road, Sandyford Business Park, Sandyford, Dublin 18, D18 R9C7, Republic of Ireland Tel: +353 1 255 1800 Fax: +353 1 495 9201 Email: sales@siltherm.eu Website: www.siltherm.eu

TRAINING



CHB South Africa - Third Party Inspectorate 23 Delius Street, Vanderbijlpark, Gauteng, South Africa 1910 Tel: +27 (0) 82 557 2755 Mob: +27 83 275 8948 Email: dcbiggs@mweb.co.za

Website: www.chbinspection.com

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QUICKSHOT DIRECTORY





Institute of **Refractories Engineers Corporate Packages**

IRE Corporate Packages enable existing and new members to access an increasing number of benefits and they encourage greater input from individuals in the company. Each package enables a company to nominate several individuals for membership, plus giving the company an opportunity for added value at a highly competitive rate, including complimentary and discounted advertising in The Refractories Engineer and complimentary and discounted attendance at IRE conferences and courses.

> □ 10 per cent discount on conference and training day

10 per cent discount membership fees

A *Gold Corporate Package* entitles a company to:

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5 online training fees

Additional benefits

15 per cent discount on

15 per cent discount on

15 per cent discount

on additional individual membership fees.

£2,682.00 worth of benefits for just £1,500.00

Gold

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- Engineer
- □ 4 x Business Directory entries
- 2 IRE individual memberships 2 online conference fees
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Additional benefits

- □ 12.5 per cent discount on additional advertising. □ 12.5 per cent discount on
- conference and training day attendance.
- 12.5 per cent discount on additional individual membership fees

For more information and to take advantage of all the benefits an IRE Corporate Package has to offer, contact Georgina Nicol at IRE on: secretary@ireng.org or visit www.irengineers.co.uk



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Refractories Engineer

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The Refractories Engineer Editorial Programme 2023 Already Published

Issue 1 - March 2023

- Energy Supply and Efficiency
- Mineral Processing
- □ Waste to Energy (WtE)/Energy from Waste (EfW)

Editorial Deadline: 19th December 2022

Advertising Deadline: 12th January 2023

Issue 2 - June 2023

- GIFA/THERMPROCESS Preview
- Iron and Steel Production
- □ Non-Ferrous Metal Production
- Material Developments

Editorial Deadline: 17th March 2023 Advertising Deadline: 11th April 2023

Issue 3 - September 2023

- □ Ferrous and Non-Ferrous Foundries
- Cement Production
- UNITECR 2023 Preview
- Heat Treatment Industries

Editorial Deadline: 21st June 2023 Advertising Deadline: 12th July 2023

To be Published

Issue 4 - November 2023

- Glass Industry (shaped and flat)
- GIFA/THERMPROCESS Review
- Intelligent Systems and Digital Connectivity

Editorial Deadline: 21st September 2023 Advertising Deadline: 12th October 2023

The Refractories Engineer also includes regular *Technical Insights* throughout the year from industry experts covering a range of technical matters relating to refractories.









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age	265mm x 185mm
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