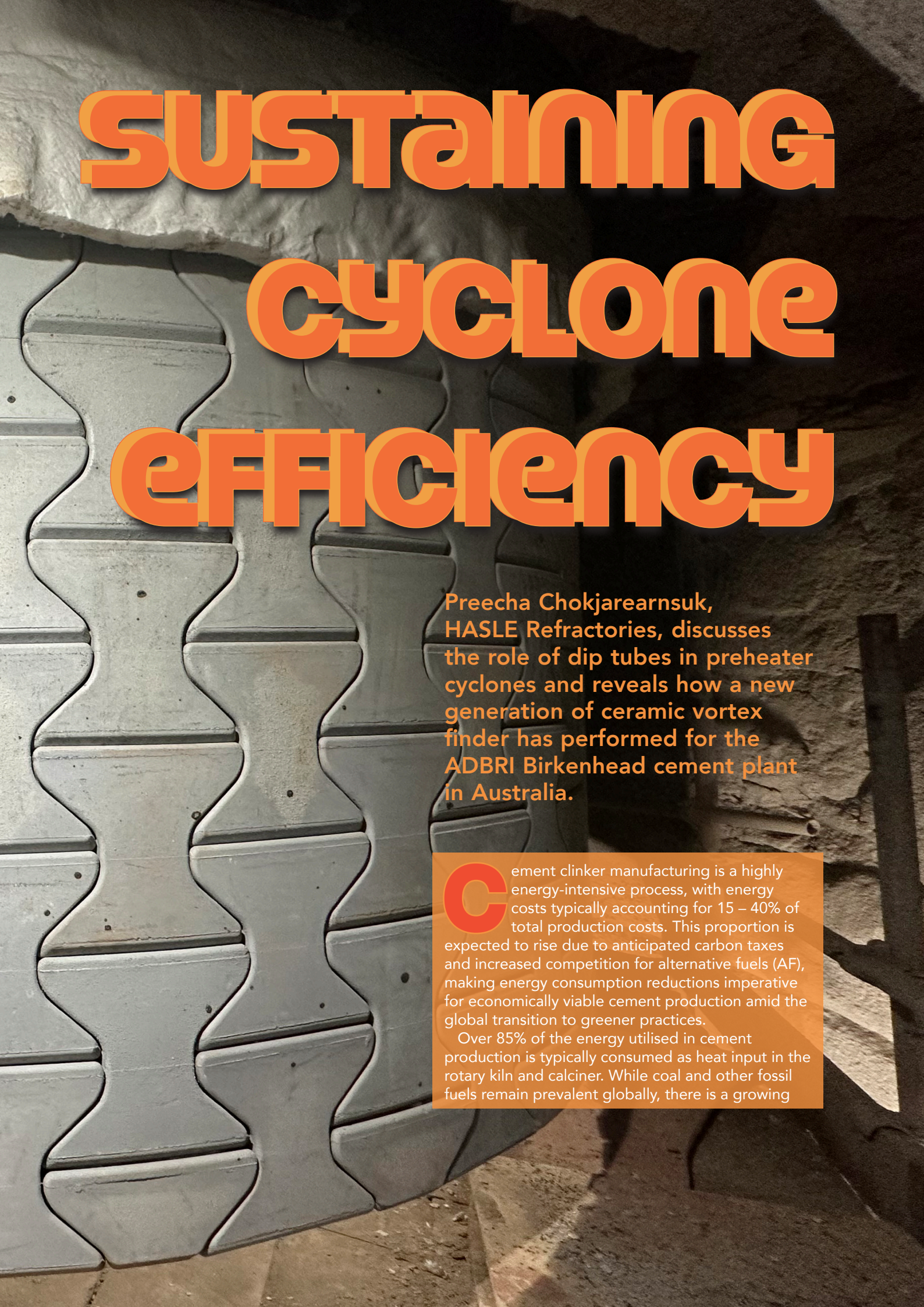
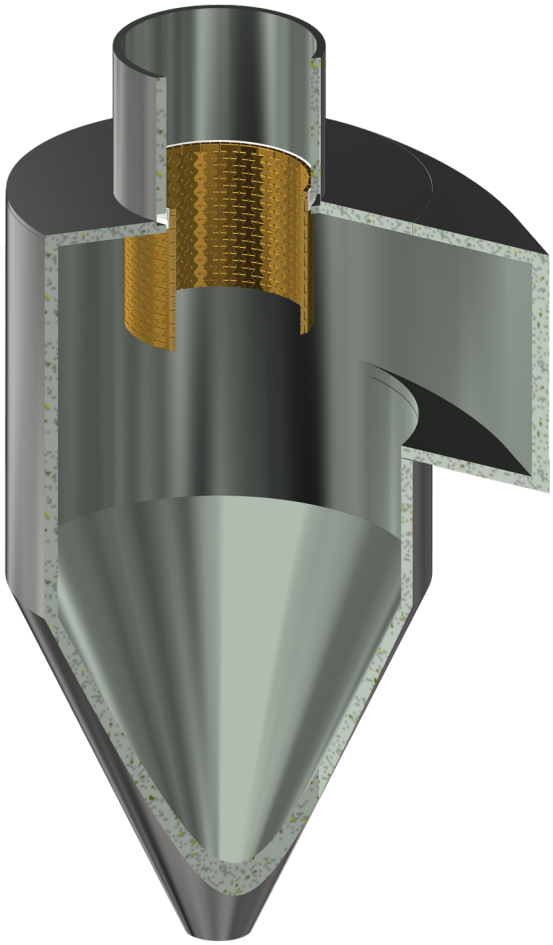
Sustaining cyclone efficiency



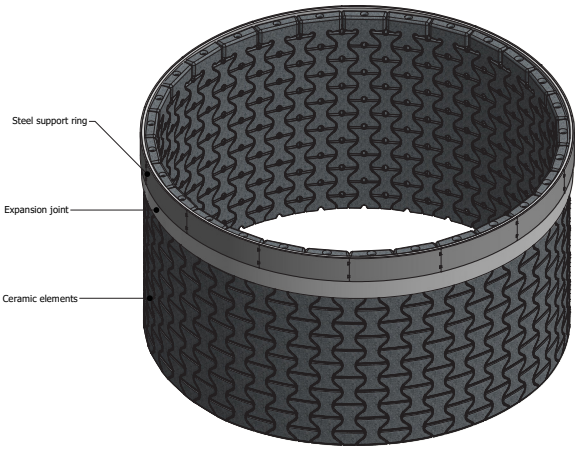
Preecha Chokjarearnsuk, HASLE Refractories, discusses the role of dip tubes in preheater cyclones and reveals how a new generation of ceramic vortex finder has performed for the ADBRI Birkenhead cement plant in Australia.

Cement clinker manufacturing is a highly energy-intensive process, with energy costs typically accounting for 15 – 40% of total production costs. This proportion is expected to rise due to anticipated carbon taxes and increased competition for alternative fuels (AF), making energy consumption reductions imperative for economically viable cement production amid the global transition to greener practices.

Over 85% of the energy utilised in cement production is typically consumed as heat input in the rotary kiln and calciner. While coal and other fossil fuels remain prevalent globally, there is a growing



Vortex finders are installed in preheater cyclones to improve the separation between the raw meal and the hot gas, thereby increasing the heat efficiency of the preheater process. But many plants run without it due to issues with short lifetimes.



The HASLE Ceramic Vortex Finder provides an alternative to steel dip tubes. It is assembled on-site by individual ceramic elements, which interlock to form a stable tube suspended from a steel support ring welded to the roof casing of the cyclone.

trend towards using AF such as waste materials, biomass, and other low-carbon fuels. However, increased usage of these fuels presents challenges in maintaining process stability, including temperature and pressure fluctuations due to unsteady combustion, as well as ensuring the longevity of refractory linings, imposing higher maintenance costs.

Efficiency gain with dip tube

One component especially impacted by the intensified usage of AF is the dip tube, also referred to as a thimble or vortex finder, in the lowest stage cyclone of the preheater tower. Its function is to define the flow field in the cyclone and prevent the entering particles from shortcutting the cyclone. A missing or damaged dip tube results in a significantly lower separation efficiency, which in turn lowers the heat recovery efficiency of the entire preheater tower, as a large portion of the preheated raw material particles is not entering the kiln but sent back to the upper cyclone stages. Consequently, the operating temperature in all cyclone stages increases, entailing a higher overall fuel demand. The additional fuel requirement may be in the range between 1 – 1.5% of the total fuel consumption when the dip tube is entirely absent in the lowest stage.

Troubled steel dip tubes at elevated temperatures

Today, most dip tubes are made of heat-resistant Cr-Ni-alloyed cast steel. In light of increased AF usage, steel however has some considerable disadvantages, which may limit the performance and lifetime of the dip tube. Firstly, steel is a ductile material and, hence, prone to deformation, especially at elevated temperatures. Higher mechanical and thermal loads from AF combustion can accelerate the deformation and creep of the commonly used steel dip tubes. Secondly, burning AF increases the concentration of various corrosive species in the gas phase, such as halides, acids, and alkali salts. In order to avoid intensified corrosion damage, higher alloyed steels have to be used, which results in both significantly higher investment costs and higher emissions of carcinogenic chromate (Cr(VI)), which are hazardous gasses posing health risks to maintenance personnel. In turn, many cement plants choose to run without any dip tube in the lowest stage cyclone.

A new vortex finder

To overcome the drawbacks of traditional steel dip tubes at elevated temperatures, a Ceramic Vortex Finder (CVF) was developed by HASLE Refractories during the 1980s. The CVF

consists of pre-cast and pre-fired refractory elements, which interlock to form a stable tube suspended from a steel ring welded to the roof casing of the cyclone.

Recently, a new generation of the CVF (GEN3-CVF) has been developed, which has been specially designed to cope with the harsh operating conditions in cement plants using AF. Following a thorough development phase involving laboratory as well as field tests, the GEN3-CVF is a general overhaul of the existing CVF product line with both new-shaped elements and a unique high-performance refractory material.

Australian plant looking for dip tube alternatives

Nestled on the LeFevre Peninsula in southern Australia, the ADBRI Birkenhead cement plant enjoys a picturesque setting, surrounded by the captivating panorama of the St. Vincent Gulf and the Adelaide cityscape. With a rich history spanning more than a century, this 4000 tpd plant operates predominantly on natural gas. But the plant also incorporates a substantial amount of refuse-derived fuel (RDF) – on average 40% – which is charged into the calciner.

The cement plant operates a dual-string preheater design merging into one calciner unit and subsequently the kiln. This design includes a single lowest-stage cyclone at the exit of the calciner where the operating temperature is maintained at 850 – 900°C. In the late 2000s, the plant initially trialled generation 1 of the HASLE CVF in the lowest stage cyclone. This, however, yielded mixed results with the GEN1-CVF experiencing operational lifespans down to six months. Notably, a contributing factor to the short lifetimes was the usage of AF in the calciner which was also increased during that period.

Faced with these challenges, the plant decided to run without any dip tubes in the lowest stage cyclone to minimise the risk of unscheduled shutdowns, as no dip tube solution could reliably operate for a full campaign at that point in time.

A new generation with high-performance castable

The ceramic elements for Generation 3 of the HASLE Ceramic Vortex Finder are made from a newly developed

The ADBRI Birkenhead plant, nestled by the St. Vincent Gulf and Adelaide's skyline, boasts a rich history spanning more than a century.

Developed in the 1980s by HASLE Refractories, the first generation of the Ceramic Vortex Finder was also installed at the ADBRI Birkenhead plant. Here an installation in 2009 is shown.

Due to the individual elements' low weight of 6 – 19 kg, no heavy lifting equipment is required for handling, and it is possible to use the existing manholes for the installation.

high-grade castable with pure synthetic and high-performance raw materials to ensure against impurities. Nanoparticles are included for high fracture toughness and optimal strength. In addition, the materials used provide high resistance to chemical attacks, making the CVF suitable for plants burning high levels of AF.

The alignment and level of the steel supporting are verified, prior to the installation of Ceramic Vortex Finder in the lowest stage cyclone at the ADBRI Birkenhead plant in Southern Australia.

Assembling the GEN3-CVF; the top row of ceramic elements is placed on the brackets of the steel support ring; the remaining elements are suspended from the elements in the top row.

The CVF (Gen3) fully assembled in the lowest stage cyclone at ADBRI's Birkenhead plant.

The GEN3-CVF elements are manufactured under strictly controlled conditions at HASLE's factory in Denmark. Firstly, the shapes are carefully cast and cured in specialised moulds to obtain a smooth surface and their unique profile. Subsequently, they are pre-fired to elevated temperatures to achieve maximum strength.

The result is a dip tube capable of withstanding temperatures up to 1200°C without deformation or creep and that exhibits high dimensional stability. This ensures that the CVF does not buckle, maintaining a high separation efficiency throughout its service life. Furthermore, the small-sized ceramic elements minimise the risk of cyclone blockage in case of falling elements as they can pass through the feed pipe, allowing operations to continue.

The CVF has a high level of corrosion resistance against all common corrosive substances in the gas phase as well as a high abrasion resistance. Additionally, only the precast refractory elements are in contact with the hot gas phase reducing the chromate emissions significantly.

A new trial

In light of the introduction of the GEN3-CVF in 2022, HASLE engaged in discussions with the management at the Birkenhead plant. Seeing potential for operational process benefits and equipped with a more robust dip tube solution, a trial in the lowest stage cyclone was initiated. Beyond the projected fuel savings, the primary goal is that the CVF will contribute to an enhanced RDF combustion. This, in turn, aims to reduce the amount of unburnt fuel carried down to the kiln inlet area, consequently minimising undesirable build up in that area.

Flexible installation

The HASLE Ceramic Vortex Finder was installed in the lowest stage cyclone, at the ADBRI Birkenhead plant in January 2023, featuring a diameter of approximately 3.7 m and a length of 2 m. The installation was assisted by an experienced supervisor from HASLE, supporting the work effort of the local installation team.

The installation sequence began with welding the steel support ring to the roof casing. Subsequently, ceramic fibre blankets were placed against the steel ring to allow adequate space for thermal expansion. Following this, the assembly itself took only a few hours. The assembly process was initiated by placing the top row of ceramic elements onto the brackets on the steel support ring. The remaining CVF elements were suspended

from the elements in the top row. Thanks to the low weight of each individual element (ranging from 6 – 19 kg), no heavy lifting equipment is required for handling, and it is possible to use the existing manholes for the installation. Lastly, the final row of CVF elements was securely locked in place with a heat-resistant sealant.

The CVF is structured as a modular system of precast, ceramic elements, providing adaptability to individual operating conditions and cyclone dimensions. Its standardised shapes with different angles interlock through advanced tongue-and-groove joints and offer variable diameter options up to 7.5 m and lengths up to 5 m.

Surpassing one year lifetime in lowest-stage cyclone

After a complete year of continuous operation, the CVF at the Birkenhead plant underwent a comprehensive inspection during the annual shutdown in January 2024. Initially, the plan was to replace the existing CVF with a new one. However, the inspection revealed that the current CVF was in excellent condition. The thorough examination indicated no signs of damage, leading to the decision to extend its operational life for another 12 months, bringing the lifespan up to two full campaigns.

Experiences from Europe

The GEN3-CVF has also been applied in cement plants with even higher proportions of AF usage. A 5000 tpd cement plant in Germany, operating on 82 – 95% RDF, was facing short lifetimes of its steel dip tubes in the lower stages of the preheater. In the lowest stage cyclone operating at around 950°C, the dip tube typically only had a 2 – 3 month lifespan, before it was necessary to switch it due to heavy corrosion from the burning of AF. Consequently, the plant decided to explore the GEN3-CVF, with the latest installation reaching a one year lifetime. It achieved a significantly longer lifespan compared to the steel dip tube previously used, and is now able to run a full campaign. Further up in the preheater, the plant also successfully deployed a CVF in the second-lowest stage cyclone operating at temperatures up to 850°C, which has now achieved a three year lifetime and continues to be in operation. ■

About the author

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Scaffolding is often required to access the installation area in the cyclone roof.

The CVF at the ADBRI Birkenhead plant after four months of operation.

After a year of operation, the CVF in the lowest stage cyclone at the ADBRI Birkenhead plant underwent a comprehensive inspection. It was found to be in excellent condition with no visible damage, leading to the decision to continue its operation.