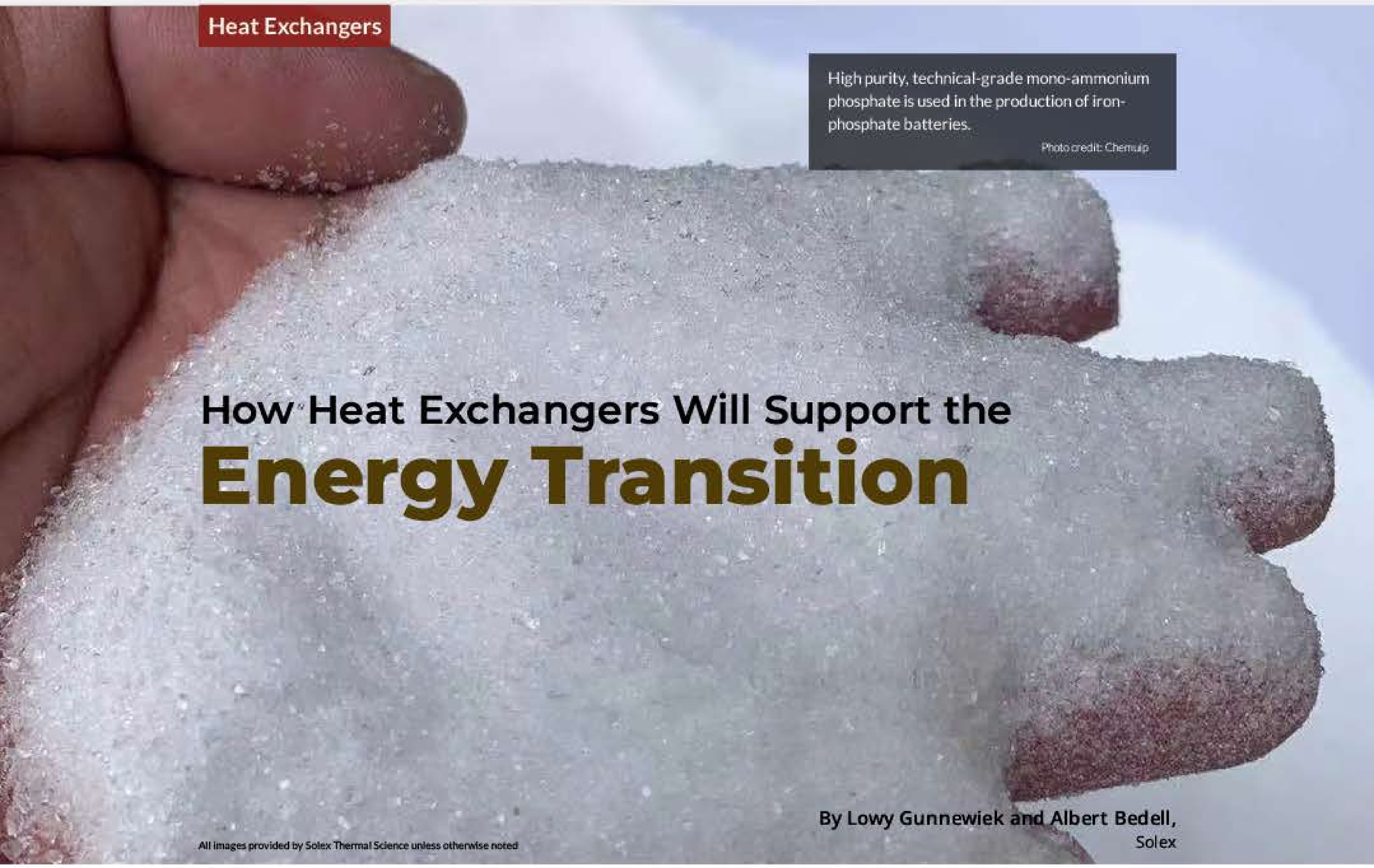

High purity, technical-grade mono-ammonium phosphate is used in the production of iron-phosphate batteries.
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How Heat Exchangers Will Support the Energy Transition

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Indirect technology is supporting the pursuit of a better, fairer and cleaner future.

The ongoing pursuit of a better, fairer and cleaner energy future is commonly captured in conversations about the energy transition and a circular economy. At their heart, these conversations are about finding a better way of capturing and converting energy from the sun for our use, and about reducing the amount of waste and pollution as we go about living our lives.

The breadth and diversity of work already underway en route to a better, fairer and cleaner energy future is remarkable. Some examples include renewable energy generation and storage, electric vehicles (EVs), energy efficiency, sustainable materials, carbon capture, decarbonized grids and alternative fuels such as hydrogen and nuclear power.

The cost to progress toward the goals we have set for ourselves is also remarkable. UN Climate Envoy Mark Carney has estimated that $100 trillion will need to be invested over the next three decades if we are to achieve the goals we have set for ourselves.

Technology will be at the core of our transition to a sustainable, net-zero future. While it is obvious that new processes and technologies will need to be developed as we move forward, we should also expect to see existing technologies evolve and be applied in new ways.

One example that we believe has a role in the future is moving-bed heat exchangers (MBHEs).

Large amounts of solid granular materials are produced every year. For example, there are more than five billion tons in the metallurgical and building material industries alone. Many of the processes used in producing these materials are energy intensive and come with significant carbon footprints. It is estimated, for instance, that cement production currently accounts for approximately 7 percent of the global greenhouse gas (GHG) emissions annually. Because moving-bed heat exchangers can efficiently transfer energy to and from solid granular materials with minimal energy needs and a low environmental footprint, this technology may have a role to play.

In this article, we will illustrate how moving-bed heat exchangers are already playing a role in the pursuit of a better, fairer and cleaner future. Example applications include industrial waste heat recovery and reuse, electric battery manufacturing, and wood pellet production.

Moving bed heat exchangers use vertical plate technology to indirectly heat, cool or dry free-flowing granular solids.

How Moving-Bed Heat Exchangers Work

Before getting into the applications, it is important to understand how vertical-plate or vertical-tube moving-bed heat exchangers work.

The tower-like design of this exchanger uses conduction to accomplish heat exchange between granular solids and a heat transfer fluid. This contrasts with convective heat transfer (e.g., air cooling), which is the process used in many direct-contact technologies such as fluid beds and rotary drums.

With plate technology — used primarily for solid-to-liquid heat transfer — the product enters the unit and flows by gravity through vertical banks of stainless-steel plates, and a heat transfer fluid passes through the plates to cool the material. With tube technology — used primarily for solid-to-gas heat transfer — the solids flow by gravity through the tubes while the gas (e.g., air) flows outside the tubes. A counter-current flow arrangement is commonly used for both moving-bed heat exchanger types while a mass flow discharge feeder controls the rate of flow through the unit. Gravity is the mechanism that slowly moves the product through the heat exchanger.

In addition to its heat transfer efficiency, the technology's gentle handling of the product minimizes fugitive dust emissions and degradation. It also can help ensure a consistent, uniform temperature of the granular material exiting the heat exchanger. These benefits can be critical in many processes.

Industrial Waste Heat Recovery

As mentioned earlier, large amounts of granular materials are processed every year to produce myriad products. Many of these processes are highly energy intensive. The implementation of waste heat recovery technologies can play an important role in reducing primary energy consumption and GHG emissions.

Platinum, for example, is a key material used in a vehicle's catalytic converter. (The function of a catalytic converter is to reduce nitrogen oxides emitted from the burning of hydrocarbon-based fuels.) The slag byproduct from platinum production must be cooled from a molten liquid phase of around 2732°F (1500°C) to ambient temperature, so it can be safely handled. The slag typically goes through a granulation process to take it from a liquid to a solid. Once solidified, there is still a significant amount of energy in the slag.

To illustrate, at a slag production rate of 100 tph, a vertical-tube moving-bed heat exchanger — used to cool the granulated slag from 1832 to 662°F (1000 to 350°C) — can recover about 20 MW of thermal energy. When combined with a heat recovery steam generator and steam turbine operating with an overall efficiency of about 65 percent, approximately 13 MW of electrical energy can be produced. This is enough energy to power almost 100 EV superchargers.

With annual platinum production in 2019 at 180,000 kilograms, produced from ores containing just a few grams of metal per ton of ore, millions of tons of slag are produced every year. And, when you consider that platinum is a small segment of the metals industry, the scale and opportunity for industrial waste heat recovery and reuse become apparent.

Batteries

With the rapidly falling cost of renewable energy generation options, especially solar photovoltaics, there is no longer a cost advantage to fossil-fuel-based generation systems.

However, the efficient use of this energy at scale requires an effective storage medium. While there are many available options, batteries currently offer the most cost-effective and energy-dense method for storing and releasing energy.

As such, the battery industry is rapidly growing to meet increased demand for electric vehicles, consumer electronics and even grid-scale energy storage. The battery industry is expected to grow by more than ten-fold within the next decade, from approximately 185 GWh of capacity per year in 2022 to more than 2 TWh by 2030.

The bulk of this demand will come via the adoption of electric vehicles, which typically have batteries with thousands of times the capacity of those found in common consumer electronics such as smartphones. This demand is driving an explosion in the technology development of batteries.

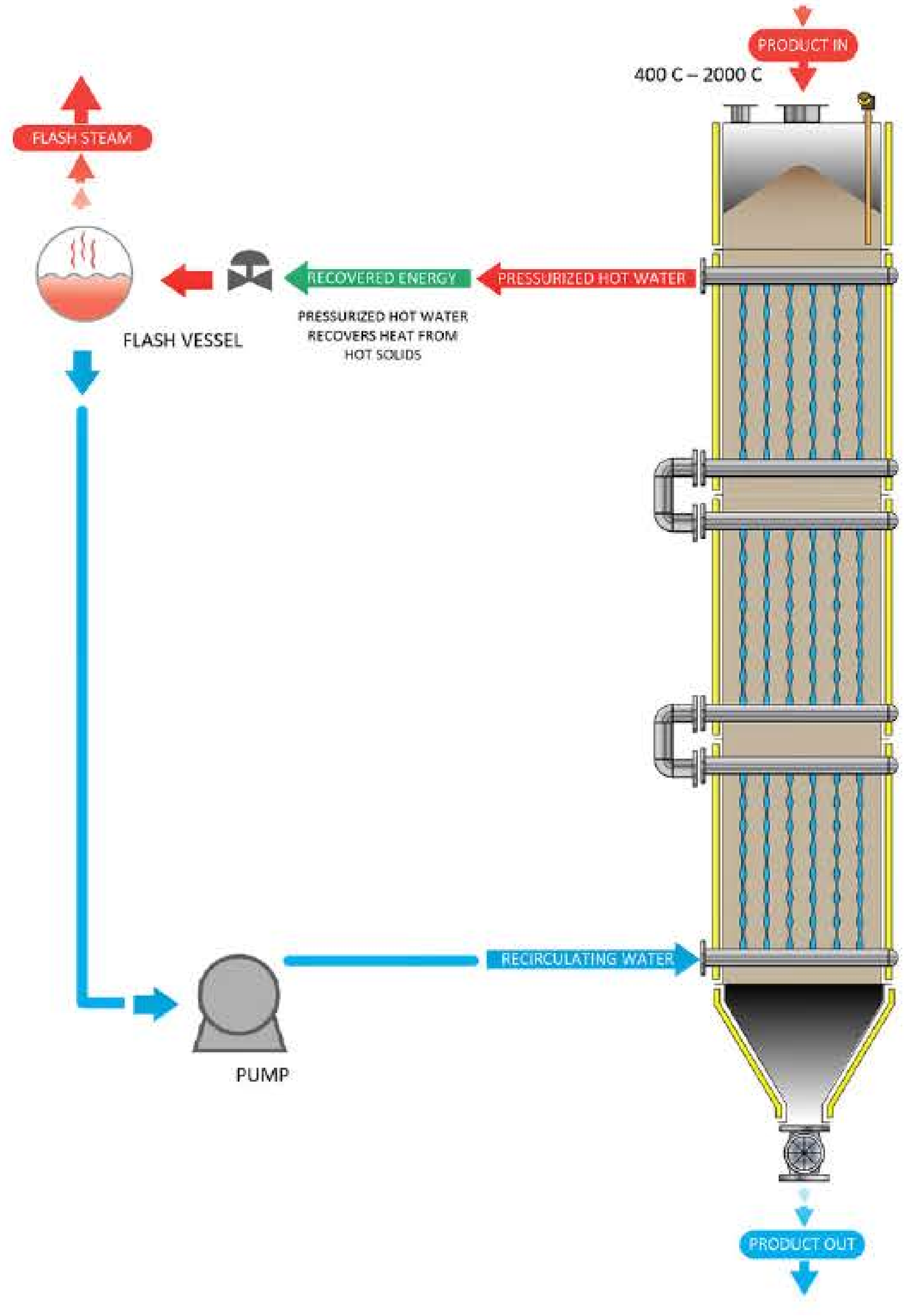
At the heart of many battery technologies are high purity solids that, when combined, yield stable, safe and high density energy storage materials.

Indirect heat exchangers play a role at many points along the supply chain for battery materials. When compared with direct heat exchange technologies, the lower energy consumption, reduced exposure of particles to air and reduced dust emissions from indirect exchangers provide distinct process benefits.

For example, at metal and mineral refineries (e.g., nickel and spodumene), indirect heat exchangers can be used to cool material downstream of kilns while reducing dust emissions and primary energy consumption. The technology also can provide opportunities to capture and reuse waste heat streams, further reducing primary energy needs.

Similarly, producers of high purity feedstocks such as technical ammonium phosphate, lithium carbonate, lithium hydroxide or graphite can look to indirect cooling equipment to maintain the purity and specific particle geometry of their products during the final cooling of the material before packaging.

Lastly, in the production of active materials (e.g., cathode powders), indirect heat exchangers can cool materials from high temperatures (post-calcination) without contamination or emission of potentially toxic and highly valuable dusts.



A conceptual energy-recovery loop shows a potential design for cooling high temperature bulk solids such as ash, petroleum coke or graphite.

Wood Pellets

Meanwhile, many energy-transition initiatives around the world are focusing on wood pellets as an alternative fuel source to coal. Last year, European regulators confirmed in the Paris Climate Agreement that burning trees for electric power would be considered a carbon-neutral energy source. Also, in the fall of 2021, President Joe Biden signed a $1.2-trillion infrastructure bill that includes actions meant to grow the wood pellet industry by promoting logging and forest biomass, as part of the $1.75-trillion Build Back Better spending bill.

Wood pellets are small pieces of compressed wood used as fuel to power homes and businesses. They are also used to differing degrees in electric power plants (primarily in European countries).

Indirect heat exchange technology is being used to help wood pellet plant operators meet growing global demand while reducing the carbon and environmental footprint of the processing stage.

The pellets are created by first removing moisture from incoming wood fiber. That fiber then is ground into a fine powder and compressed into pellets measuring approximately 0.25 to 0.3 inches (6 and 8 mm) in diameter and up to 1.6 inches (40 mm) in length. The pellets are heated, softening the lignin in the wood, which then acts as an adhesive to keep the compressed particles together.

At this point in the production process, the pellet temperature is between 158 and 194°F (70 and 90°C), making them too hot to handle, store or transport. Ideally, the pellets are cooled and dried to approximately 5.4 to 9°F (3 to 5°C) above the ambient temperature with a moisture content of 10 percent.

Two heat exchange technologies can be used at this stage: with air and without air.

With Air. The pellets enter a cooling bin. The particles are leveled off by a distributor. Cold air then is injected into an isolated bin under the bed of pellets, thereby indirectly cooling the product from the bottom up. A level sensor inside the bin determines when the pellets are discharged.

Without Air. The pellets enter a tower-like design and slowly pass between a parallel series of heat exchanger plates that contain a counter-current flow of heat transfer fluid (e.g., water). Heat transfers from the pellets to the fluid via a steel plate wall. The product cools to temperatures between 5.4 and 9°F (3 and 5°C) above ambient temperatures as, pulled by gravity, it slowly and uniformly moves downward, controlled by a discharge feeder.

One of the primary benefits of indirectly cooling wood pellets through a plate-based design is improved efficiency. Water is a more effective cooling medium than air, resulting in lower power requirements to circulate the lower volume of the cooling medium. In addition, indirectly cooling wood pellets through a plate-based design provides operators with precise control of both the product's temperature and moisture content. Using thermal modeling software helps ensure optimal cooling and drying of each pellet.

The mass flow design also ensures that uniform material flow is controlled at low velocities — typically less than approximately 1 ft/min (0.3 m/min). Because the pellets are not mechanically handled or moved, the technology is suitable for even friable grades of pellets. The approach helps prevent product abrasion, product degradation and the creation of additional fines.

In conclusion, in a 2021 report, "Net Zero by 2050: A Roadmap for the Global Energy Sector," the International Energy Agency (IEA) acknowledged the number of countries announcing pledges to achieve net-zero over the coming decades is growing. Yet, even if achieved, these goals will fall well short of meeting targets such as those set out in the Paris Agreement — notably, bringing global energy-related carbon dioxide emissions to net-zero by 2050 and limiting the global temperature rise to 2.7°F (1.5°C).

The same report notes clean and efficient energy technologies will be key to staying on the narrow path to net-zero. The IEA report says, "All the technologies needed to achieve the necessary deep cuts in global emissions already exist." Reaching net-zero by 2050 requires further rapid deployment of these available technologies.

As an established technology, moving-bed heat exchangers can play a role in this energy transition. Specifically, moving-bed heat exchangers that use vertical-plate technology to transfer energy to and from solid granular materials can contribute to a shift to what is considered possible in both traditional and non-traditional processing industries by offering a low carbon solution that aligns with operators' net-zero aspirations.

About the Author

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