WORLD FERTILIZER®

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INNOVATING ENERGY FOR THE FUTURE

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explores how moving bed heat exchangers are helping fertilizer producers adapt to today's circular economy.

IN THE LOOP

The fertilizer industry's collective push towards a decarbonised, net-zero future is leading to sweeping modernisations across the process chain.

In its roadmap of how the fertilizer industry plans to help achieve the targets set out by the Paris Agreement, the International Fertilizer Association (IFA) notes an array of ongoing, sustainability-focused initiatives that range from advanced catalytic processes to water recycling, and everything in-between.[1]

The net result is that today's processes, technologies and end products are being expected to do more – and how they do it is just as important.

Moving bed heat exchangers (MBHEs) based on vertical plate technology are a leading example of this operational evolution in action. Long prevalent at the cooling stage of fertilizer operations around the world, these MBHEs are now 'doing more' than contributing to a high-quality finished product.

Continuous and practical innovation in their design has recently led to several sustainability-focused opportunities, notably:

- Waste heat recovery.
- More energy-efficient trim drying.
- Dust mitigation.

Waste heat recovery

Plate-based MBHEs blend the thermal efficiency of plate heat exchange design with the science of uniform mass flow to cool a full range of fertilizers, including urea, ammonium nitrate and CAN, NPKs, MAP, DAP, and ammonium sulfate.

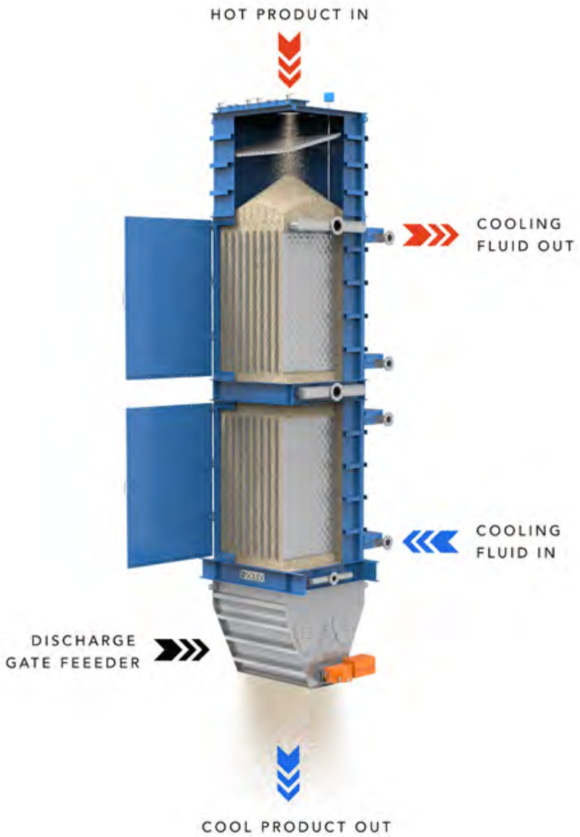

Figure 1. As different grades of fertilizer are cooled, plate-based MBHEs produce a hot working fluid that can provide thermal energy to be used elsewhere in the plant (Source: Solex Thermal Science).

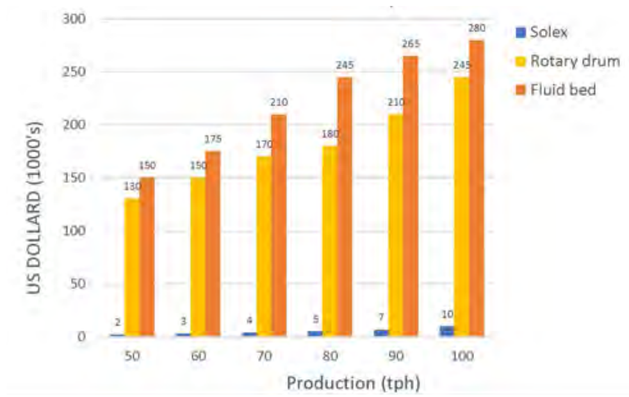

Figure 2. Annual electrical consumption cost comparisons between direct and indirect fertilizer cooling technology (Source: Solex Thermal Science).

The vertical equipment design cools the product by conduction instead of convection (e.g., air cooling). Free-flowing fertilizer granules, prills or crystalline enter the top of the exchanger at temperatures between 65°C and 120°C, slowly flowing by gravity between a parallel series of heat exchanger plates that contain a counter-current flow of water or another heat transfer fluid.

Heat from the fertilizer transfers to the heat transfer fluid through the steel plate wall. The product is cooled to a temperature between 30°C and 70°C as it slowly and uniformly moves downward, controlled by a specifically designed discharge device.

While certain details change according to the differing properties of different products, the principles of operation remain the same.

As different grades of fertilizer are cooled, the MBHE produces a hot working fluid – typically 70°C or higher – that can provide thermal energy to be used elsewhere in the plant. For example, the recovered heat can be used upstream in the production process to pre-heat combustion air in equipment such as a fluid bed or rotary drum dryer. This can materially reduce the amount of natural gas needed for drying.

Alternatively, the recovered heat can be used to pre-heat air that is used to 'trim dry' the fertilizer in a MBHE. While discussed in more detail later in this article, the trim drying stage occurs after the fertilizer has been largely dried in a rotary drum or fluid bed and some additional drying is needed. This is accomplished within the upper part of the MBHE, allowing producers to meet moisture targets more efficiently, and improving product quality while cooling in the lower part of the unit.

The heat recovery from the working fluid that has cooled the fertilizer can start by transferring the heat to air using a finned-tube heat exchanger, similar to a vehicle radiator. The hot air can then be ducted to various use points, for example the air supply, for a hot air combustion system.

With the working fluid cooled following the finned-tube heat exchanger, the load on the plant's cooling water system will then be reduced. That is, after the fertilizer cooling process, the working fluid at about 70°C is pumped to a water module for cooling and re-use. In a heat recovery configuration, the working fluid is returned to the water module at a temperature well below 70°C, thereby requiring only minimal cooling.

Current fluid bed drying-cooling systems similarly re-purpose hot air from the cooling stage and recirculate it back to the drying stage. However, fluid bed systems by nature tend to generate dust in increasing quantities as the fertilizer dries. This results in the need to clean the 'dirty' air in a scrubber or baghouse before it can be considered for reuse.

Consider that 'A' represents emissions from the drying stage and 'B' represents emissions from cooling. In this scenario, 'B' is being added to 'A.' Over time, 'A' + 'B' emissions will have a particulate load that increases incrementally the longer it is recycled.

The subsequent energy needed to run the scrubber or baghouse and respective air-handling systems means that re-using the warm air is no longer economic.

Meanwhile, plate-based MBHEs do not use air to cool fertilizer, and therefore they do not create emissions that require cleaning. In addition, these MBHEs do not require the

Figure 3. For decades, MBHEs based on vertical plate technology have acted as cornerstones in the fertilizer production process (Source: Solex Thermal Science).

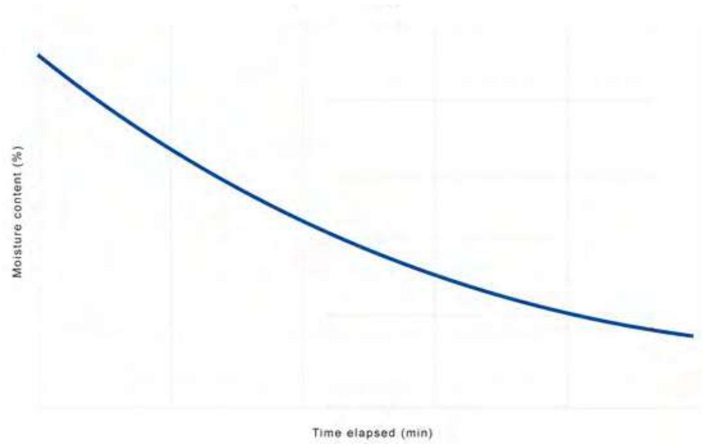

Figure 4. A typical drying curve illustrates how the energy requirements and residence time needed to dry the last few percentages of moisture can be considerable relative to the early stages of the drying cycle (Source: Solex Thermal Science).

high-horsepower fans or the duct work that fluid bed and rotary dryers require.

Lastly, MBHEs are versatile in adjusting to operational parameter changes. While fluid bed or rotary drying-cooling systems are generally limited to the original equipment's design, plate-based MBHEs are more tolerant in handling fluctuations in both product temperature and throughput due to their indirect method of heat transfer.

Trim drying

Waste heat recovery is not the only area where MBHEs are giving fertilizer producers an opportunity to cut their carbon footprint. As touched on above, the technology can also act as a final trim drying stage, following a rotary drum or fluid bed dryer that further improves the overall energy efficiency of the drying process prior to the cooling stage.

Fertilizer types such as urea, NPK, DAP and MAP will typically have 20 – 30% moisture content when being fed into the drying process. Equipment such as rotary drum dryers or static/moving fluid beds will pass a heated gas – typically air – through the product until it reaches the target moisture content. This is commonly referred to as a 'brute-force' approach – that is, using lots of hot air to force the moisture out.

Most often, the target moisture content prior to the cooling stage is less than 2%. However, it can be as low as 0.1%, depending on the operation and fertilizer type.

There are numerous consequences to having off-spec fertilizer, ranging from caking and lumping to the potential loss of physical, nutrient and chemical properties. For some nitrate-based fertilizers, it can also increase the danger of explosions and health hazards due to ammoniacal emissions.

While rotary drums and fluid beds are well equipped to take the bulk of the moisture out, both technologies face challenges as the drying progresses. It becomes an exponential relationship between the driving force (e.g., hot air) and time, versus the water vapour pressure. This is what drives the moisture out of the product. As such, the energy requirements and residence time needed to dry the last few percentages of moisture can be considerable relative to the early stages of the drying cycle.

One solution is to return the product through the drying process until it reaches target moisture levels. However, this solution affects the process throughput, and complicates processes due to the need of additional transport equipment.

Alternatively, MBHEs combined with small amounts of hot air injected into the heat exchanger allow for more efficient moisture removal at those later drying stages due to their ability to provide intimate contact between the product and heat transfer area, which is referred to as trim drying.

Fertilizer with excess moisture conveyed from the rotary drum or fluid bed into the top of the MBHE then flows slowly and uniformly by gravity through drying banks. Drying air is supplied into the bed at one level and extracted at another level through manifolds as part of the drying bank configuration.

The drying air is supplied at rates well below the fertilizers' fluidisation velocity, upward of 20 times less than that of a typical rotary drum or fluid bed for the same mass throughput.

Trim drying in the MBHE gives fertilizer the necessary residence time to form complete granules/prills, and for the last amounts of moisture to be removed with marginal energy requirements and without product degradation.

The ancillary equipment – which is comprised of a cooling fluid circulation module, as well as a bucket elevator (if required by layout), and an injection air system – all come with low horsepower requirements.

In addition, the process does not require significant air-cleaning equipment. In comparison, because rotary drums and fluid beds must heat the ambient air and then blow that air through the product bed before cleaning and releasing it, they both require large horsepower induced fans to supply air to the cooler and an exhaust fan.

De-dusting

An additional drawback to brute force drying at the later stages has been its inevitable outcome of generating dust – that being, over-dried product that ends up cracking with the subsequent formation of dust.

Dust generation from fertilizer production operations, overall, has become a growing global environmental concern. Various studies over the past decade have connected dust emissions with everything from local soil contamination to respiratory illness.[2,3]

While dust generation is often the result of sub-optimal production techniques, it is not the only source within a fertilizer operation. Dust can also be generated from:

- Poor handling during transfer points along the production process such as drop chutes and impact points on conveyer enclosures that are not properly designed, installed and sealed, which, in turn, leads to product breakage and degradation.
- Significant variations in temperature and humidity, which can cause a further loss of granule/prill integrity while fertilizer is in storage.

Fertilizer dust has traditionally been handled by scrubbers and/or baghouses and screening equipment. However, it can still find its way downstream in the production process. Therefore, the cooling stage of fertilizer production represents one of the last opportunities to minimise the spread of these ultra-fine particles.

Because plate-based MBHEs cool fertilizer particles indirectly – that is, the fertilizer flows slowly at around 0.3 m/min through banks of stainless-steel pillow plates with cooling water flowing counter-currently inside the plates – there is little risk of product abrasion or attrition, and therefore no additional dust formation or degradation of fertilizer quality.

More recently, plate-based MBHEs have also started to integrate de-dusting solutions into their process in the form of cascade aspirators. Cascade aspirators eliminate fertilizer dust which is generated upstream of the MBHE, but is carried along with the main flow of material.

Situated before the inlet to the cooler, the attached aspirator features a series of specially designed and situated 'slides' – ranging from four to six – that allow the product to fall back and forth downward by gravity. Small amounts of air are drawn upward through the product to lift the lighter particles out and into a selection chamber.

By having the air velocity slightly exceed the fertilizer's terminal velocity, the lighter fines (separation can be fine-tuned to particles typically less than 0.1 mm) are lifted into the selection chamber while allowing the heavier product to pass through the de-dusting step and proceed to the cooling section. The dust-free fertilizer then passes through the cooling MBHE.

Conclusion

Mineral fertilizers have an essential role in food production systems around the world. Yet despite the many benefits, there are also negative impacts associated with their production and use.

For example, in a report released in September 2022, the IFA recognised that limiting the global temperature rise to 1.5°C and achieving the United Nations' Sustainable Development Goals will require the fertilizer sector to change. Within IFA's recommendations, it noted the sector will need to scale up its work on all fronts, including cutting Scope 1 direct greenhouse gas emissions and strengthening relationships with providers throughout the process chain.

This type of challenge is not new to the fertilizer or food production industry. For example, the Haber-Bosch process that converts nitrogen and hydrogen to ammonia is considered one of the most important industrial chemical reactions ever developed. With this development, it became possible to produce nitrogen fertilizers at a scale and cost that helped enable a world population boom as yields from agriculture increased rapidly in a short time.

Advancements in the production and use of mineral fertilizers are continuous and constant. As we focus our efforts on decarbonising the food chain, the technology used to grow, produce and distribute food will be called upon to make the change that is needed.

Moving bed heat exchangers based on vertical plate technology demonstrates how these changes are already taking place. For decades, they have acted as cornerstones in the fertilizer production process with a near-zero-emissions, a low-energy solution that has proven to reduce the carbon and environmental footprint of fertilizer production operations.

In recent years, these MBHEs have evolved to further help decarbonise operations. A waste heat recovery process following the cooling stage is now allowing fertilizer producers to reduce natural gas consumption at the drying stage. In addition, complementary trim drying and de-dusting processes not only help fertilizers to reach the required quality without the development of dust, but further reduces the energy needed for production.

This collective pursuit of improved sustainability through technology such as MBHEs will continue to have profound reverberations throughout the fertilizer production chain. By investing in versatile technology solutions, fertilizer producers have an opportunity to meet their decarbonisation goals while still feeding the world of tomorrow. WF

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