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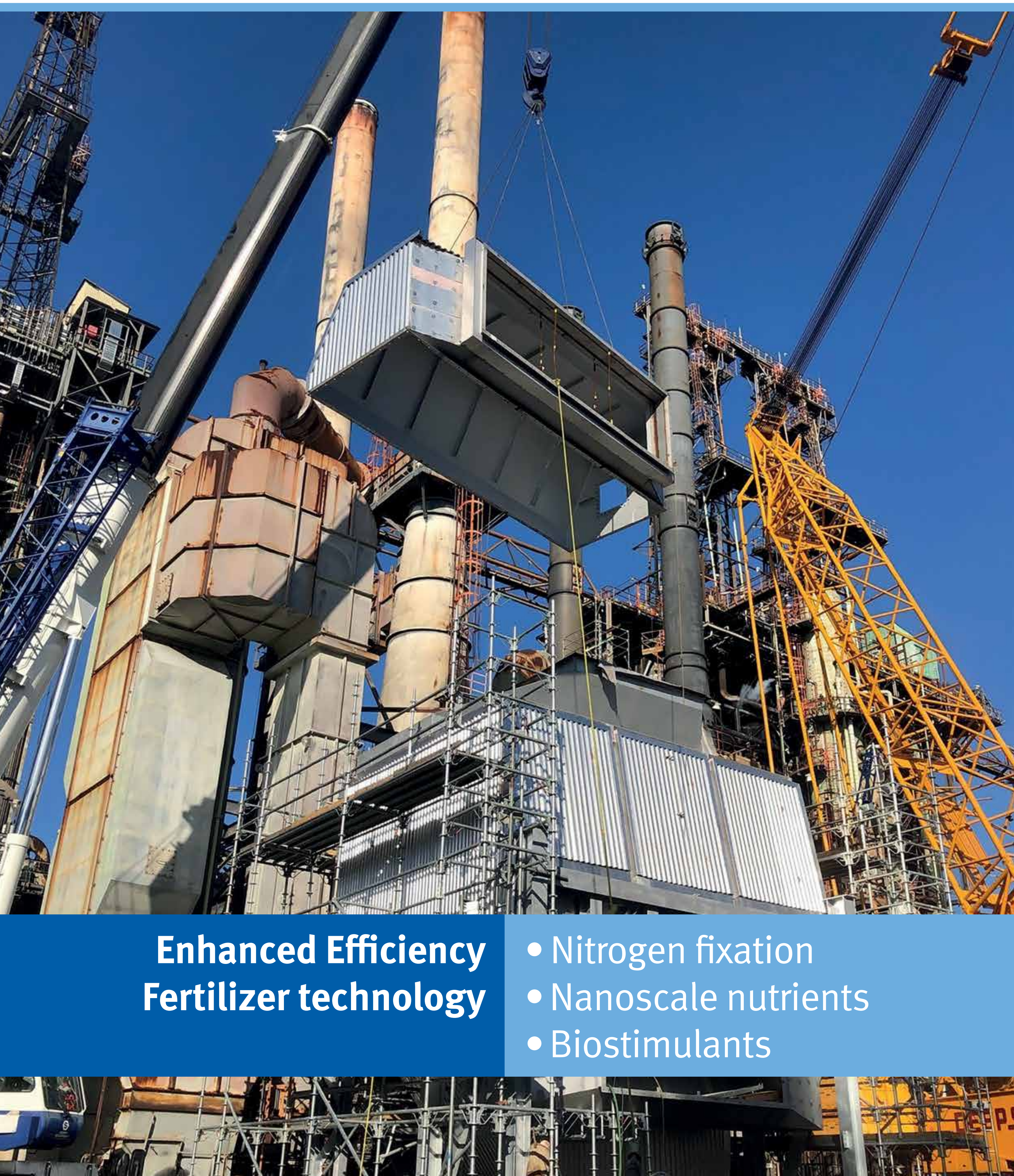
Fertilizer Focus



Enhanced Efficiency
Fertilizer technology

- Nitrogen fixation
- Nanoscale nutrients
- Biostimulants

The role of heat exchangers in fertilizer's decarbonization efforts

How plates and pipes are contributing to helping producers reduce energy input costs

Written by

Igor Makarenko, *Global Director,* ***Fertilizer, Solex Thermal Science, Canada*** and
Mark Boocock, *Managing Director,* ***Econotherm, UK***

The energy involved in the production of fertilizers represents one of the industry's most significant operating costs, as well as a being a substantial contributor to greenhouse gas emissions today. Researchers estimate that more than half of lifecycle CO_2 and N_2O emissions from agriculture crops trace back to the fertilizer production process due to the high amounts of natural gas needed for feedstock and fuel in ammonia synthesis.

Urea plants, specifically, are significant emitters due in large part to their need for energy-intensive, medium-pressure steam. Recent studies reveal the average energy consumption of steam is approximately 30.1 GJ/t urea – 80% of which takes place at the synthesis stage. Those same studies note that the synthesis stage represents more than three-quarters of greenhouse gas emissions.

The International Fertiliser Society (IFS) singles out several areas of the fertilizer production process where operators have opportunities to reduce their consumption of fuel gas - notably the radiant burners of the primary reformer, the gas turbine if applied and firing for steam superheater burners or auxiliary boiler burners.

The IFS goes on to note that operators are actively seeking out new ways to recover waste heat from these existing process loops. That includes pre-heating fuel and combustion air that would reduce fuel consumption costs together with flue gas exhaust volumes. This is where heat exchangers are playing a growing and important role.

Moving bed heat exchangers and waste heat recovery

Operators across various manufacturing tiers have long investigated the incorporation of waste heat recovery mechanisms into improved energy management practices. In many cases, they have successfully demonstrated its effectiveness in reducing energy consumption over the long, medium and short terms. However, the practical application at the enterprise levels has often been limited, whether due to significant capital investments or longer-than-acceptable payback timelines.

This has encouraged many operators to look deeper for ways to successfully bridge their respective heat sources and sinks with proven technologies. In many cases, this has led them to heat exchangers.

Researchers from Loughborough University and Heriot-Watt University in the UK and Shantou University in China recently noted in a joint paper that heat exchangers have been proposed as one of the best systems for recovering waste heat recovery energy. Of note, they single out their effectiveness in being able to re-use heat in the same process such as pre-heating combustion air in a steam boiler.

The synthesis stage represents three-quarters of greenhouse gas emissions

Plate-based moving bed heat exchangers (MBHEs) represent one example of this in action. 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 sulphate.

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 feeder.

As the fertilizer is cooled, MBHEs produce a hot working fluid that is around 70°C or higher, which is typically sent to a plant's cooling water system and the energy is rejected to the ambient air. Instead, that fluid can provide thermal energy for use elsewhere in the plant such as upstream in the production process to pre-heat combustion air in equipment such as steam boilers, fluid beds or rotary drum dryers.

Fertilizer operators can recover exhaust gas coming out of gas-fired heaters using a heat pipe heat exchanger and insert it back into the heater to reduce natural gas costs. The process is similar to waste heat recovery methods already being demonstrated via similar fired heaters in oil refineries. *Photo credit - Econotherm*

Alternatively, the recovered heat can be used to pre-heat air that can 'trim dry' the fertilizer in the upper part of the existing MBHE to meet moisture targets more efficiently while also improving product quality as it is cooling in the lower part of the unit.

Lastly, MBHEs are being uniquely combined with industrial heat pumps to upcycle the energy from waste to a heat source. By using a heat pump, the temperature of the cooling water can be increased to levels that are useful to plant operators.

Temperatures between 110°C and 150°C are easily achievable, with the ability to reach around 180°C in some cases. Also, because heat pumps are electrically driven, they also do not create any additional direct CO_2 emissions.

Heat pipe heat exchangers and waste heat recovery

Meanwhile, the use of heat pipe heat exchangers for waste heat recovery in the fertilizer industry provides new opportunities for waste heat recovery using a decades-old technology.

Heat pipe heat exchangers recover waste heat from exhaust heat by taking the latent heat of vapourization

> ***Heat exchangers can recover thermal energy from particle-laden air***

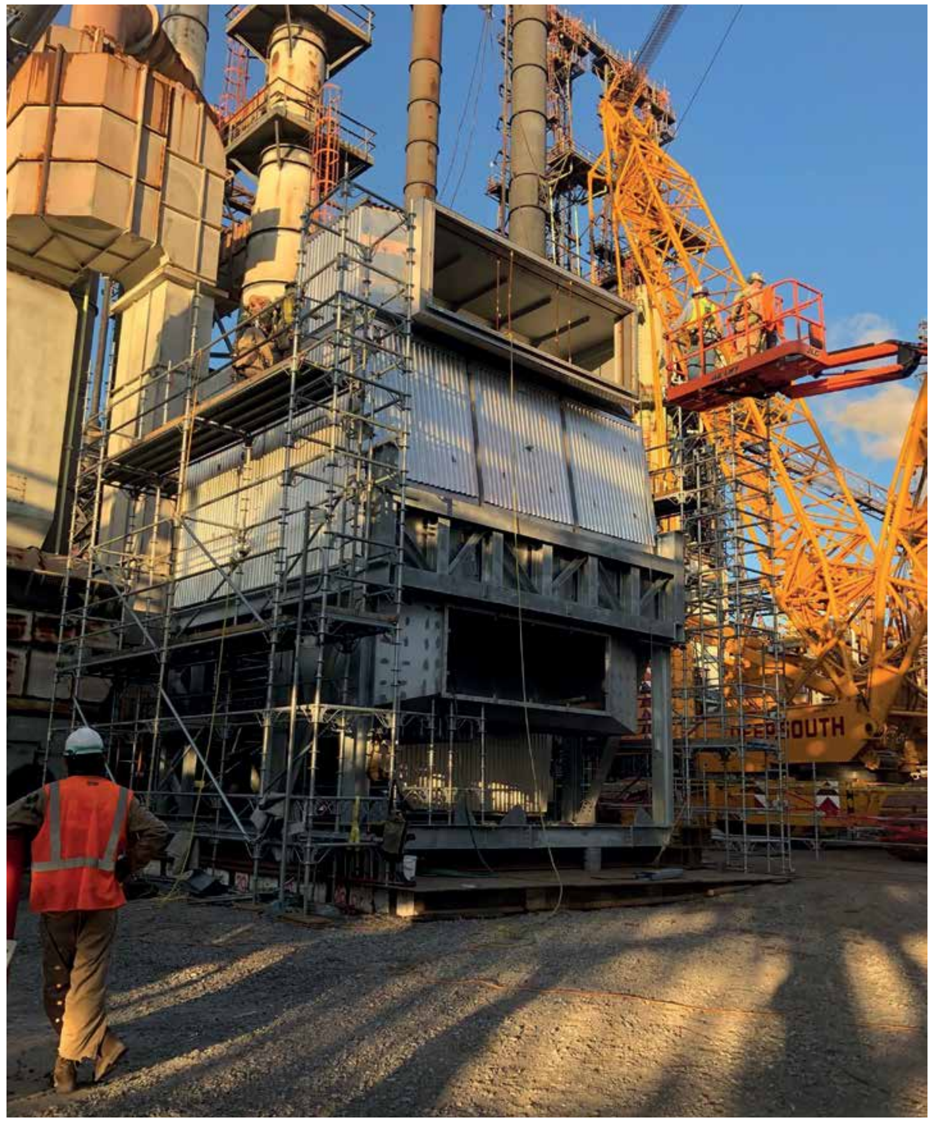
from the working fluid in the heat pipe – for example, from a liquid to a gas – to absorb the heat contained in the hot exhaust gas or liquid. The vapour subsequently rises to the top of the heat pipe where the heat pipe is in contact with a cold fluid – air or water – that causes the vapour to condense and release its heat. This heat is then absorbed by the cold fluid.

As an example of their application within the fertilizer industry, heat pipe heat exchangers can recover thermal energy from particle-laden air that is exhausted from the drying process. The exchangers accomplish this by taking this ‘one-pass air’ and extracting heat from it that can then be used to pre-heat ambient air that goes back into the dryer. In doing so, fertilizer producers can reduce the natural gas consumption needed for drying fertilizer, while also reducing the temperature of the air that is being sent to the scrubbers to reduce scrubbing capacity.

In the process, heat pipe heat exchangers can also remove some of the particulate load in the air stream. A dust collector under the unit collects the particulate so operators can dispose of it separately.

The ammonia and nitrate-making steps of fertilizer product represent additional areas where heat pipe heat exchangers can be used to capture otherwise-wasted heat.

Turbines and condensers within the nitric acid production process represent large heat sinks. Specifically, exhaust streams coming out of the front-end turbines represent as an ideal opportunity to recover waste heat.



The pipes in heat pipe heat exchangers provide operators with greater reliability in that they can expand and contract without applying stress to casing. This, in combination with thicker walls, reduce erosion and can handle hot and highly acidic gases that are typical in fertilizer production plants. *Photo credit - Econotherm*

Recovering heat from the exhaust gas

Meanwhile, ammonia production features large gas-fired heaters that supply heat to steam reformers. Operators can recover heat from the exhaust gas coming out of the gas-fired heater using a heat pipe heat exchanger and insert it back into the heater.

This process is similar to waste heat recovery methods already being demonstrated via similar fired heaters in oil refineries where operators have been able to substantially reduce the amount primary energy needed to produce their steam consumption.

In these cases, refinery operators are typically replacing shell-and-tube configurations with heat pipes. Shell and tubes have shown to be difficult to operate and maintain due to thermal stress cracking caused by differential expansion between surface and casing, as well as cold spots that induce condensation and lead to corrosion. Their traditional thin metal surfaces are also being vulnerable to erosion and corrosion.

The pipes in heat pipe heat exchangers provide operators with greater reliability in that they can expand and contract without applying stress to casing. Isothermal operation also eliminates cold spots and condensation, which reduces corrosion.

Multiple redundancies created by the independent function of each heat pipe within the heat exchanger reduces the chance for catastrophic failure. Heat transfer in the pipes is also not affected by wall thickness, which allows for thicker walls that reduce erosion. The thicker walls offer the added benefit of being able to better handle the hot and highly acidic gases that are typical in fertilizer production plants.

Reducing primary energy use

The high cost of fossil fuel use is something the fertilizer industry is no longer able to bear. Calls continue to mount for fertilizer producers to reduce the environmental impact of their activities in alignment with the Paris Agreement's goal of holding global temperatures to no higher than 1.5°C above pre-industrial levels.

This is in combination with highly volatile energy prices over the past decade that have tested the industry, leading to historically high fertilizer prices and, in extreme cases, the forced closure of plants around the world.

One of the opportunities that lies ahead is in recognizing areas of the fertilizer production process where primary energy use can be reduced through waste heat recovery methods. Energy-intensive steps such as ammonia synthesis and fertilizer drying are just two examples of areas where producers can tap into previously unrealized heat sinks and reduce both primary energy consumption and subsequent GHG emissions.

The next step will be to combine those heat sinks with technologies such as plate and heat pipe heat exchangers, which are expected to play an important part of fertilizer producers’ path toward sustainable progress. ■