INNOVATIVE COOLING SOLUTION FOR BIOSOLIDS

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Abstract

Biosolids that undergo a mechanical heating and drying process then granulation or pelletizing should be cooled before storage, bulk load out, or packaging. If the biosolids are not cooled appropriately they can experience auto-ignition that may lead to smoldering and potentially fires or explosions. The cooling process should ensure that each particle is thermally stable through to its core and has a narrow temperature profile about the bulk solids average temperature.

Traditional cooling technology employed has been belt coolers and fluid bed coolers. Many of the recent plants or new expansions and revamps (particularly in North America) are using plate type cooler technology as supplied by Solex Thermal Science. The Solex biosolids cooler does not use air for cooling therefore it does not create high dust emissions and as a result consumes very little energy compared to traditional technologies. The heat transfer is by conductivity with the biosolids flowing slowly vertically downward between heat exchanger plates that internally have water (or process effluent, cooling tower water, or process chilled water) flowing counter-current to indirectly cool the solids.

Keywords

Biosolids, Cooling, Heating, Bulkflow, Solids, Powder, Indirect Heat Exchanger,

Introduction

Traditionally, rotary drum, fluid bed, and jacketed screw conveyor technologies have been the industry standard for heating and cooling bulk solids and powders. In this presentation I will take a look at specialty designed equipment (see Fig.1) for heating or cooling bulk solids and powders with technology developed approximately twenty five years ago by Cominco Fertilizers, (now Agrium Inc).

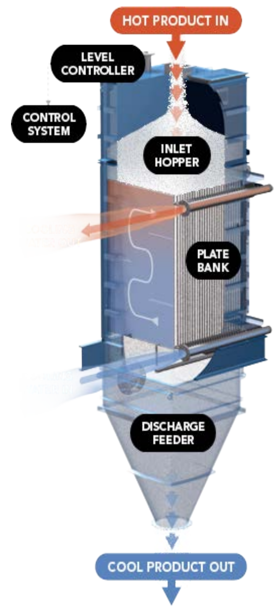

Figure 1 - 3D view of Bulk Solids Cooler

The driving force behind this development was the high CAPEX and OPEX costs of rotary drum and fluid bed equipment, in particular, the retrofitting of a fluid bed cooler and the associated air handling, chilling and wet scrubbing system costs. The innovative yet very simple technology of the Solex Heat Exchanger has enabled it to find a niche in the powder and bulk solids handling industry worldwide.
The Solex Heat Exchanger is a simple piece of equipment designed for heating or cooling powders and bulk solids. This technology combines mass flow of bulk solids with conventional plate heat exchanger design.

Description of the technology

In this column type heat exchanger, the material passes under gravity by mass flow through a vertical bank of hollow steel plates (see Fig. 2) of carbon, stainless, duplex or titanium depending on product being handled. For cooling applications, water or glycol/water mix is circulated through the plates. For heating duties, steam is commonly used, but hot water or heat transfer oil can also be used. The plates have welded connections to inlet and outlet manifolds. As with conventional liquid or gas exchangers, the heat transfer fluid and product flows are counter-current to gain greater thermal efficiency. Below the plate bank is a mass flow discharge device which creates true mass flow and also controls the material flowrate (and thus residence time) through the exchanger. The following are typical discharge devices available dependant on the specific material flow characteristics;

- Vibratory feeder (fixed vanes)
- Rotary valve
- Circular feeder
- Gate feeder (variable opening)
- Screw feeder (variable pitch/section)

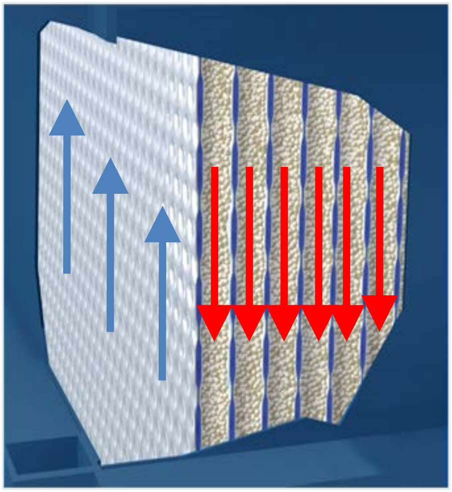

Figure 2 - Exchanger Plate with true counter-flow water

The material moves slowly through the unit to create sufficient residence time to achieve the required heating or cooling. The slow material movement ensures that there is no attrition and thus no dust formation or product degradation. The unit is always full of material when it is in operation to ensure effective heat transfer control, prevent condensation formation and mitigate wear on the plates. A level control system ensures that the unit operates at its optimum configuration. Indirect heat exchange, a feature of this heat exchanger, offers several advantages over the rotary drum and fluid bed type coolers that use air in direct contact with the product. These advantages include:

- No air handling requirements -- Eliminates emissions.
- Gentle product handling -- No product degradation, low abrasion, mass flow design.
- Low operating cost -- Substantial reduction in operating costs as the only drives required are for a water pump and outlet device.
- Low installed capital cost -- Much simpler system without ancillary equipment such as fans, scrubbers, or ductwork.
- Low space requirement -- Equipment is compact and operates by means of gravity flow resulting in a small 'footprint' which makes it easier to install into restricted space in an existing plant.

Heating or cooling a powder or a bulk solid material is a common step in many process industry plants. While heating of a product with the Solex technology is limited to around a maximum of around 230^{0}C (with oil) or 650^{0}C (with air), cooling capacity is much higher with material inlet temperatures of over 2,000^{0}C already experienced and successfully cooled in products such as carbon black and graphite.

Cooling is generally one of the final steps in the process and frequently follows drying. The process industry is very diverse and there are countless situations where heating or cooling is required. Powders and bulk solids must often be cooled prior to conveying and packaging to allow safe handling and storage or safe loading into rail cars trucks or ships. Many bulk solid materials are also hygroscopic (i.e. fertilizers, sugar, biosolids etc.) and must be cooled before storage to prevent moisture absorption from the ambient air and thus mitigate the possibility of agglomeration (lumping and caking) – an example is described in the following pages.

Problems facing the powder and bulk solids industry

Some of the problems the powder and bulk solids handling industry is faced with using traditional cooling and heating technology can be described as follows:

- Emissions -- Powder and bulk solids manufacturing facilities are recognized as having relatively high air emissions. Permissible limits of emissions from stacks are being reduced around the world. The major sources of emissions are from prill towers, granulators, dryers, furnaces and air coolers Rotary Drum and Fluid Bed).
- High retrofitting costs for fluid bed coolers and drum coolers – This occurs particularly in providing or upgrading air handling systems and the wet scrubbing system associated with it.
- Quality issues -- It is important to have effective cooling of powder and bulk solids prior to storage or packaging. Many powders and bulk solids have a tendency to cake in storage if they are stored at elevated temperatures. If the product is not effectively cooled it can lead to rejection of the product by customers, create production loss, or it can cause a decrease in potential production capacity.
- Increasing production (debottlenecking) -- When retrofitting existing plants, space is at a premium, which makes it difficult to install large equipment. In addition, new equipment imposes extra loads on plant utilities which significantly increases overall power consumption. In the case of rotary drum or fluid bed coolers, the fan motors do draw high electrical loads. It may also require upgrading of the electrical distribution system and finding space in a frequently overcrowded MCC room.
- Installation costs of new equipment can be very high -- Standard cooling and heating equipment such as rotary drums, fluid bed coolers, water-cooled trays and screw conveyors have relatively high installed capital costs. In some cases, there is the need for associated pollution control equipment which increases costs.
- Operating costs -- Large horsepower fans used in fluid bed coolers and drum coolers have high associated operating costs both in energy usage and maintenance.

Solutions offered by the new technology

The new technology offers effective solutions to all of the above-mentioned problems that are normally associated with heating or cooling powder and bulk solids.

- Emissions -- Changing to a Solex Heat Exchanger eliminates emissions from the cooling step as it does not use air in direct contact with the product. As such, there is no need for pollution control equipment and tight emission limits can easily be met.
- High retrofitting costs for fluid bed coolers and drum coolers -- The heat exchanger requires minimal ancillary equipment. Therefore, it provides a cost-effective solution in comparison to drum or fluid bed cooling equipment.
- Quality issues -- The heat exchanger provides efficient heat transfer performance incorporating mass flow design without product degradation or abrasion. For cooling applications, the product is cooled by indirect heat transfer with water-cooled plates allowing for low product temperatures even in hot summer months. Lower temperatures provide safe handling and packaging as well as preventing caking or lumping of material in storage.
- Increasing production (debottlenecking) -- The only significant utility that the Solex Heat Exchanger requires is cooling water, (for cooling), or steam, hot water or oil, (for heating). In both cases, the heat transfer load is relatively low. In cases where cooling water is required, existing cooling towers are usually sufficient to accommodate the extra load.
- Installation costs of new equipment can be very high -- Due to simple vertical construction and it's modular design, this heat exchanger can be erected in a timely and cost effective manner while existing plant is in operation. Without the need for ancillary

equipment, the unit can offer considerable savings when installed in a new or existing facility.

- Operating costs -- The only power consumption associated with operation of this heat exchanger are the drive(s) for the cooling water pump and possibly the discharge feeder. These drives yield a very low annual electrical (and maintenance) cost in comparison to a fluid bed cooler or drum cooler.

Cooling of Sludge Pellets to mitigate combustion during storage and transport

Sludge Pellets (and certain other pelletized/granulated bio-solids) can spontaneously combust in certain environmental conditions. In addition to the heat applied for the drying process, the material can further self heat leading to ignition and a slow burn which may be accelerated with the ingress of uncontrolled additional air into the process and in some circumstances can cause explosion (explosions and fires in dryers and associated processing plant have occurred in the UK, Europe and North America). One of the current recommendations from within the industry (and government bodies i.e. UK HSE) for mitigating the possibility of fires and explosions is to cool all the product below 38^{0}C (~100^{0}F) with an average temperature less than 35^{0}C (95^{0}F) before sending to final storage, load-out or packaging.

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A further potential problem with storing sludge pellets at elevated temperature is the likelihood of moisture attraction due to its hygroscopic nature, this along with any small amount of dust present can lead to the finer dust particles bonding the pellets together causing agglomeration/caking and result in bridging within the silo and thus blockages at discharge points.

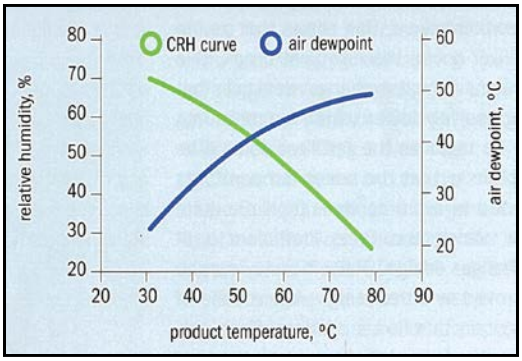

Figure 3 - Critical Relative Humidity / Dewpoint

Low levels of moisture can also be present in both the air and product at the discharge point from the dryer. Moisture is the number one enemy for many hygroscopic materials (i.e. Fertilizers). The challenge is to find the right way to keep moisture out of the cooler and to still offer an economical cooling solution. For this reason it is necessary to understand exactly where the moisture comes from:

- Moisture in the product (usually 5% to 8% but can sometimes be as high as 10%)
- Moisture in the air coming in with the product (more challenging are applications in hot and humid countries like India etc.)

With the above and in conjunction with incorrectly chosen temperature profiles in the cooler

- Condensation on the plates is created with the consequence of dust accumulation, reduced thermal performance, caking and finally plugging of the cooler.

However with a clear understanding of the science, the condensation mechanism is predictable and can be eliminated to achieve long on-stream time without the need for cleaning.
As previously stated, bio-solids can be hygroscopic, in other words product will absorb moisture from the surrounding atmosphere when the vapour pressure of the air is greater than that of the product. Conversely, water transfers from the product to the surrounding air when the vapour

pressure of the air is lower than that of the product. The tendency for moisture to migrate either from the product to the air, or from the air to the product is defined by the critical relative humidity of the product. A typical critical relative humidity curve for a product is illustrated in Fig 3 above.
The first observation that we can draw from this graph is that the critical relative humidity changes with temperature. So in a heat exchanger, the product cools as it passes through the exchanger, therefore the vapour pressure of the product decreases as the product moves through the exchanger and corresponding to this, the dew point also decreases. This gives us the scientific method of predicting the dew point at each point through the exchanger. This is shown in the example below (Fig 4.) where product temperature and the dew point under equilibrium conditions are plotted as the product flows through the exchanger.

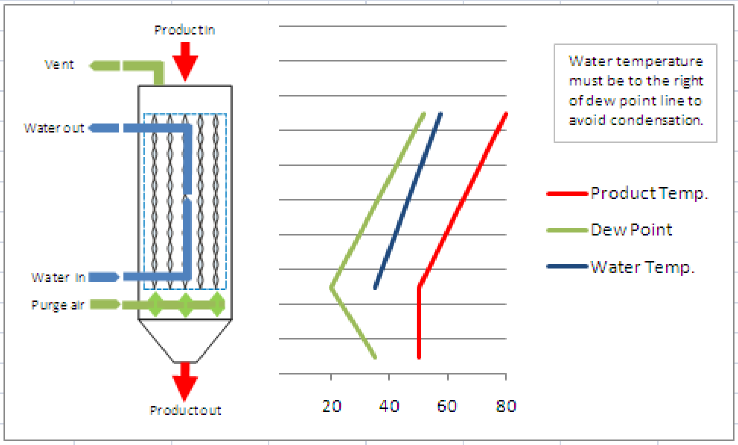

Figure 4 - Product Temperature and Dew Point through Heat Exchanger

From this graph we see that the dew point falls as the product cools down, we can take advantage of this by selecting water temperatures that follow the dew point line. This shows that at the top of the cooler the water needs to be warmer to prevent condensation but progressively cooler water can be used as we move lower in the exchanger, with the coldest water at the bottom. This allows using the most efficient counter current design for the cooler. Additionally by injecting small amounts of air with a lower dew point helps to decrease the dew point of the entrained air and enables the use of lower cooling water temperatures

Solex has developed its own proprietary design software called ThermaPro® which continues to be improved through ongoing application experience and internal R&D leading to better understanding of product CRH curves. Thus ThermaPro® allows us to exactly predict the product temperature profile throughout the cooler for each type of product and thus design a cooler in the most economical way:

1. Water Temperature: the water temperature profile needs to be carefully selected based on the hygroscopic characteristics of the fertilizer.
2. Counter Flow Design: true counter flow design is required on the water side to parallel the dew point curve to maximize thermal efficiency. To take advantage of this, the fluid connections to the plate are at the top and bottom. This arrangement is shown in Fig 5 opposite.

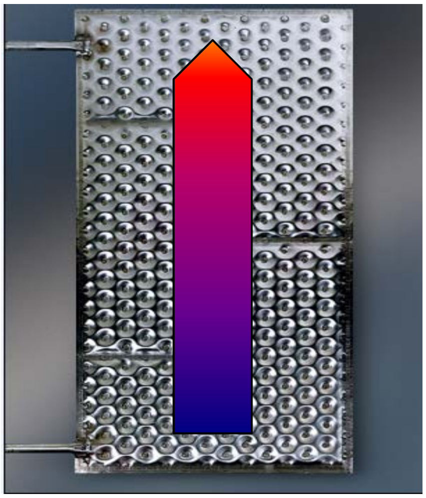

Figure 5 - Exchanger Plate showing counter-flow water

3. Temperature Controlled Water Supply: the cooling water temperature needs to be controlled at the inlet and outlet of the plates to ensure that the desired water temperature profile can be maintained under different operating conditions including start up and shutdown.

4. Purge Air: a purge air system to inject small amounts of air can help to lower the dew point in the product cooler to allow lower water temperatures to be used and improve the thermal efficiency. Depending on the ambient conditions, use of ambient air is often sufficient or conditioned air for particularly hot/humid climates.
5. Venting: Although the amount of air injected is small good venting and removing of the moist air is essential. Most times the connection to the plant dedusting system is sufficient or even a single filter sock design.
6. Insulation: evaluation of the dew point of the air in the product cooler may show that condensation will occur on the inside wall in some parts of the cooler which may lead to caking. Condensation can be prevented by insulating the cooler particularly at the inlet hopper and discharge cone/device.
7. Comprehensive Instrumentation: comprehensive instrumentation for the product, water loop and purge air is required so that the information is available to optimize the performance of the exchanger under varying operating conditions.

Experience with the Solex Bulk Solids Cooler in challenging conditions such as cooling hot urea granules in a humid climate in India, has shown that with the correct combination of water temperatures and purge air, long term, reliable cooling can be achieved.

New opportunities for the technology

In recent years energy conservation has become of great importance for both economic and environmental reasons and this technology lends itself very well to energy recovery in several industrial processes. With the development of our High Temperature (> 400 ^{0}C) units which can cool product from over 2,000 ^{0}C (carbon black, graphite etc.), At these elevated temperatures there is an opportunity to recover valuable energy in the form of hot water, thermal oil or even air (flue gases) which can be utilised for preheating combustion air, providing pressurised hot water for flash steam and also for preheating of raw materials as shown in Fig 6.

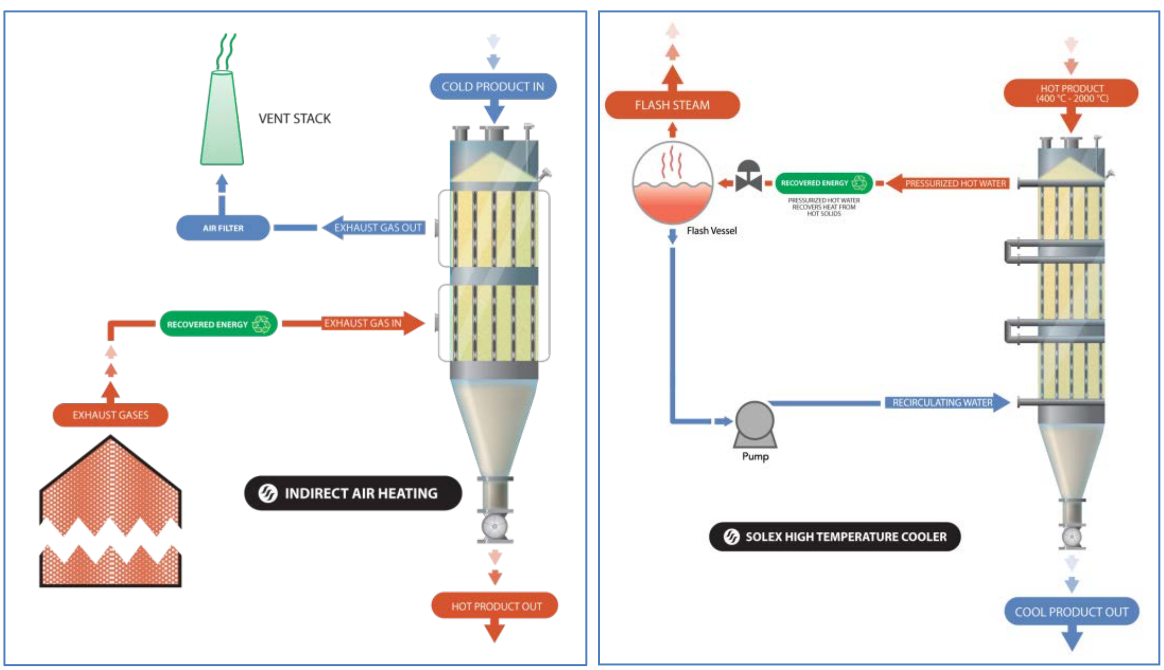

Figure 6 - Two examples of energy recovery, left - drying/heating of bulk product and right recovery of energy to generate pressurised water (for flash steam) through cooling of bulk product.

Conclusion

The new technology offered by this particular heat exchanger is an alternative method for cooling or heating bulk and powder products. It offers many advantages over traditional technologies, particularly zero emissions, small space requirements, low energy costs and potential for energy recovery as indicated in Fig 7.

	Solex Technology	Fluid Bed Technology	Rotary Drum Technology
Energy Consumption	Low	High	High
Installed Capital Cost	Low	High	High
Maintenance	Low	Medium	High
Product Degradation	None	High	High
Modular Construction (ease of expansion)	Yes	No	No
Compact Design (small installation footprint)	Yes	No	No
Cooling Air Required	No	Yes	Yes
Air Emissions	None	Yes	Yes

Figure 7 - Comparison between Fluid bed, Rotary Drum and Bulk Flow Technologies

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