Direct or Indirect Cooling: Which technology is more efficient for bulk solids cooling?

Bulk solids cooling is a common step in many chemical processes. It generally occurs near the end of the processing sequence when powders or bulk solids must be cooled prior to storage or packaging to allow for safe handling and storage.

Most engineers would agree that direct cooling appears to be more efficient than indirect cooling, and from a purely technical standpoint, it is. Cooling a bulk solid by passing cool air through it brings the cooling medium and the product into direct contact. While this would appear to be the most efficient approach, when it comes to bulk solids cooling, a counter-intuitive approach is required to maximize efficiency.

The most common approach to bulk solids cooling is to use air in direct contact with the bulk solid material. With direct cooling, ambient air is taken in using large fans and, in most climates, the air must be chilled before being blown across the product using large horsepower fans. It is then discharged through an emissions stack. Both the chilling process and the circulating fans have high energy requirements.

The alternative is to cool bulk solids indirectly using water. With indirect cooling technology, chilled water is pumped through a vertical bank of hollow stainless steel plates while the bulk solid passes between the plates at a rate sufficient to achieve the required cooling. The water circulates counter-current to the product flow for higher thermal efficiency. Often a plant's existing cooling towers are sufficient to provide the necessary water and a low horsepower pump is the only source of energy consumption.

BULK SOLIDS COOLING - COMPARATIVE ANALYSIS

A comparative analysis demonstrates that indirect cooling of bulk solids is not only more efficient than direct cooling but offers other advantages as well. How can this be?

Capacity

Direct: One of the main features of using a direct air cooled unit for bulk solids cooling is that a very large amount of air is required to achieve sufficient cooling. For example, a typical 100 tph sugar cooler can require between 30,000 – 50,000 m3/h of air to enable the cooling process. Such a quantity of air requires an air handling system incorporating large fans and extensive ducting that occupies a great deal of space and draws heavily on the plant's power system. Installation costs are relatively high and the large size of the equipment and ancillary air handling system make space considerations an issue when retrofitting existing plants.

Indirect: Cooling water is often available from a variety of sources, whether it be a nearby river or an existing cooling water circuit with cooling towers. The Solex bulk solids cooling unit itself is compact with simple vertical construction and high modularity that makes it readily adaptable to new or existing facilities. The only ancillary equipment is the piping running from the water source to the cooling unit. Power consumption is limited to the drive for the small horsepower water pump. With the use of a closed loop system, the water can be recycled repeatedly so that only a limited quantity is required.

Operating Costs

Direct: In most climates, the temperature of the ambient air is higher than that required to achieve cooling, so the air must be cooled prior to use. Another issue is the saturation point of the cooling air. If this is not addressed, moisture can migrate from the air to the product which results in agglomeration and subsequent spoilage. In order to ensure saturated air does not come into contact with the product, air must be cooled below the required temperature to condense the water out and then reheated to the optimum cooling temperature. Chilling and reheating ambient air consumes significant amounts of energy. The process of condensing the water out of the air requires three times the energy as using chilled water.

Indirect: Using indirect bulk solids cooling technology circumvents the problem of saturated air. Cooling water is often available within the plant system. The water-cooled plates allow for low product temperatures even in hot summer months. Furthermore, in situations when it is necessary to chill the water, the plant water cooling system can usually accommodate the extra load and even if a dedicated water chiller is required, the energy required to cool water is much less than the energy needed to chill air.

Emissions

Direct: Direct cooling of bulk solids results in high emissions. Using air to cool bulk solids is a "once-through" proposition. Air is taken in, chilled, passed across the product, and must then be disposed of through a stack. The large quantity of air required for direct cooling results in a large quantity of dust and emissions. Permits for stacks are becoming more difficult to acquire, and with ever-tighter pollution controls, emissions must be cleaned and scrubbed before being dumped into the atmosphere. Associated costs are high.

Indirect: With indirect cooling, the water is re-used repeatedly by being recycled in a closed loop system. The cooling media does not come into direct contact with the product, so no dust or emissions are created. This eliminates the need for pollution control equipment and makes tight emission limits easier to meet. In addition, indirect bulk solids cooling minimizes product abrasion and degradation.

Total Energy Consumption

A detailed comparison of the energy consumed by different types of cooling units demonstrates the significant degree to which indirect cooling of bulk solids outperforms direct cooling in terms of energy efficiency. Let's use the example of cooling sugar and say we are cooling 100 tph of white sugar from an incoming temperature of 55°C to an outgoing temperature of 30°C.

Direct: Consider total energy requirements for common types of direct cooling units.

- *Rotary Drum: 560 kW*
  Equipment includes driver motor, FD fan, ID fan, and air chiller.
- *Multi-tube: 780 kW*
  Equipment includes driver motor, ID fan, and air chiller.
- *Fluid Bed: 806 kW*
  Equipment includes ventilator and air chiller.

Indirect: Two different scenarios apply for indirect cooling units.

- *Available Plant Water: 32 kW*
  This applies when chilled water is available from a source within the plant – equipment includes bucket elevator, vibrating discharge feeder, and cooling water pump.
- *Chilled Water: 282 kW*
  This applies when water must be chilled for use in the cooling unit – equipment includes bucket elevator, vibrating discharge feeder, cooling water pump, and water chiller.

Summary

Although direct cooling appears, on first consideration, to be the most efficient method of cooling bulk solids, comparative analysis shows that indirect cooling offers much higher energy efficiency, as well as other advantages. The inherent problem with using air to directly cool bulk solids is the large quantity of air required and the expense involved in chilling, processing and cleaning that air. As the comparative figures demonstrate, the total energy consumption of direct cooling technology can be as much as 25 times higher than that of indirect cooling. The beauty of indirect cooling is that the cooling water is already in the plant. As well as low energy costs, it offers the advantages of improved product quality, no emissions, low space requirements and high retrofitting adaptability. In short, indirect cooling technology is a simple, lean and more efficient means of cooling bulk solids.

CASE STUDY: Improved Product Quality

Sugar Refinery, Portugal

The refinery's objective was to reduce lump formation in 50 kg and 1 ton bags. Sugar at the refinery was being cooled with ambient air so the sugar temperature leaving the dryer was dependent on the ambient temperature which fluctuated between a maximum of 45°C in summer and a minimum of 20°C in winter. Relative humidity remained fairly constant at 60 percent. During the summer, the temperature difference between sugar leaving the dryer and storage ambient was higher than 20°C. The result was agglomeration in the warehouse resulting in a high number of complaints from customers, subsequent returns and associated reprocessing costs.

The facility was looking for a cooler to process 30 tph of white sugar from 45°C to 30°C. Adding a cooling air conditioning system to the existing rotary dryer entailed unacceptably high energy consumption (164 kW). Space restrictions in the refinery made it unfeasible to install a fluid bed dryer, and construction of a silo was not considered because of the high capital cost.

Outcome

The refinery chose to install Solex indirect cooling technology. The Solex Cooler offered low installation costs and low energy requirements with a total electrical consumption of only15 kW. The new system produced effective cooling of the product, eliminated agglomeration problems, and increased customer satisfaction.

CASE STUDY: Increased Capacity

Sugar Refinery, Sweden

As one of the largest sugar producer sin Europe, this refinery had increased production at its plant in Sweden by 40 percent over a three-year period. At the increased rate of 85 tph, the cooling capacity of the plant's existing equipment was no longer adequate and the temperature of outgoing sugar had increased to between 35°C and 40°C. This was a problem because the recommended temperature to prevent caking and maintain product quality in storage is below 30°C.

The engineers at the refinery carried out a two-week on-site pilot test of the Solex Sugar Cooler. On the basis of the positive trials, acquisition of the equipment was fully endorsed by the management, engineering and maintenance departments, and the Solex Cooler was successfully installed prior to the plant's next sugar campaign.

Outcome

The refinery reported that the equipment was compact and easy to install and the investment cost of the installation was lower than that of fluid bed and drum coolers. At full capacity, the equipment met or exceed the expected cooling duty, cooling 85 tph of sugar from 40°C to 25°C with cooling water supplied at 16°C. Sugar quality was improved on two fronts: one, the product had a lower relative humidity than theoretically expected; and two, the Solex Cooler minimized abrasion of the product resulting in less sugar dust and a higher quality product. With few moving parts and easy operation, maintenance costs were extremely low. With less than 100 kW installed electrical power (including new conveyors, dry cooler fans, and cooling water pump associated with the cooler installation), operating costs were also low. Given that the equipment did not use any air in contact with the sugar, there were no emissions and no sugar sent to remelting.