SOLEX THERMAL SCIENCE

World leaders in the science of heating and cooling bulk solids.

TECHNICAL ARTICLE

The SIGMA Series cooler – a low energy solution for cooling granular and prill fertilizers

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Approximately ten years ago the Solex SIGMA series cooler was introduced into the fertilizer industry as an alternative method of cooling fertilizer granules and prills before storage. A heat exchanger for bulk solids was a new concept combining the engineering sciences of heat transfer and mass flow of bulk solids.

With more than 40 fertilizer installations worldwide in nitrogen, NPK and phosphate fertilizer plants, this paper describes the Solex Heat Exchanger technology and the advantages it brings – very low energy consumption, low air emissions and compact design. Particular reference is made to applications in urea granulation and prill plants and to the subject of retrofitting in existing plants.

Topics covered include the use of multiple banks in series to improve efficiency, dry purge air to avoid caking and the importance of good access for maintenance.

INTRODUCTION

Ten years ago, the Solex Heat Exchanger was introduced to the fertilizer industry. It was a new piece of process equipment for cooling bulk solids and was ideally suited to cooling granular and prilled fertilizers. The Solex Heat Exchanger provided an alternative to the fluid bed and rotary coolers that had been up to that point the industry standard. With almost 40 Exchangers now in use in the fertilizer industry, this paper reviews the important considerations in designing Solex Heat Exchangers for fertilizer cooling.

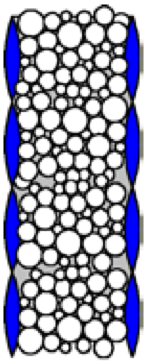
DESCRIPTION OF SOLEX HEAT EXCHANGER

The Solex Heat Exchanger is conceptually a simple piece of equipment, which as the name implies, is a heat exchanger for bulk solids. The heat exchanger part consists of a bank of vertical, closely spaced, hollow stainless steel plates. Bulk solids pass slowly by gravity between the plates in mass flow. Cooling water flows through the plates. As you would expect in a heat exchanger, the water flow is counter-current to the product flow. Below the Plate Bank is a Feeder that controls the flow of the granular material through the unit.

INDIRECT HEAT EXCHANGE BY CONDUCTION

The concept is the same as a conventional heat exchanger such as a shell and tube, but having a granular material on one side of the exchanger raises interesting challenges:

- The bulk granules are a poor conductor of heat so a long residence time is required to achieve adequate cooling
- The granules flow in a strictly laminar pattern between the plates (compared to turbulent flow in the majority of liquid or gas exchangers)

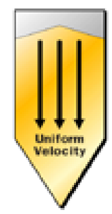


MASS FLOW OF BULK SOLIDS

The starting point of the design is to ensure that the granules are flowing in "mass flow" through the cooler.

Mass flow is a critical element in the successful design of a Solex Heat Exchanger. To achieve uniform cooling, the material should be moving with uniform velocity over the full cross section of the cooler. To achieve mass flow we must start at the bottom of the unit with a discharge device that will create uniform flow. Uniform flow at the bottom will create uniform flow through the plate bank section of the cooler. A natural cone of material distributes material to the plates. The discharge also controls the flow of material through the exchanger.

Mass Flow: The science of mass flow was pioneered in the 1960,s by Jenike and Johansen, and established methods of characterizing bulk solids and predicting their flow properties so that bins and silos could be engineered to discharge freely and avoid dead zones or material hang up. Typically mass flow bins have steep walled, discharge cones. When a material is discharging from a mass flow bin, all of the material in the bin is moving.

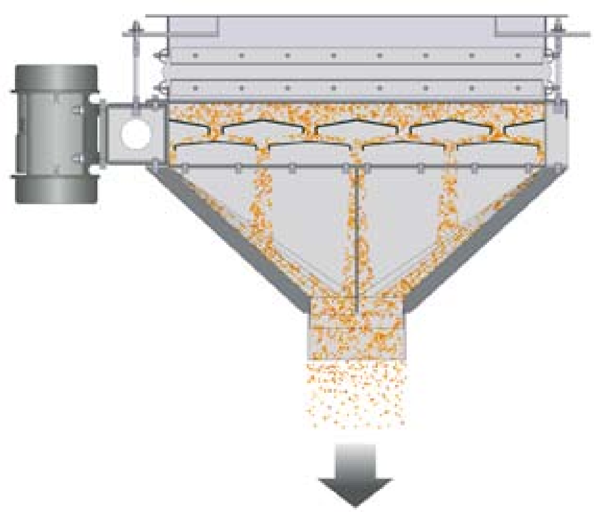


DISCHARGE FEEDER

Mass flow is created in the Solex Heat Exchanger with the Discharge Feeder. The Discharge Feeder also regulates the flow of solids through the Exchanger. For fertilizer applications, we generally use a Vibrating Tray Feeder

Vibrating Tray Feeder

- Overlapping trays
- Feeder covers full cross section of Exchanger
- Drive with twin vibrator motors
- Variable frequency drive controls flowrate
- Small amplitude 0.5 – 1.0 mm
- Product Shut-off at zero frequency

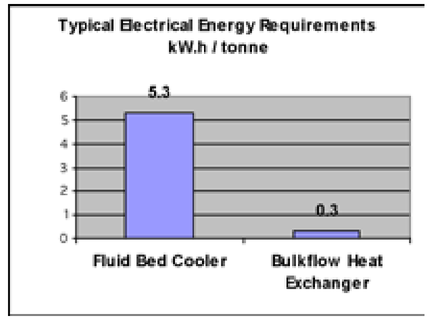


SOLEX HEAT EXCHANGER ADVANTAGES

The Solex Heat Exchanger offers a number of advantages compared to fluid bed or rotary coolers:

- No air emissions
- Low energy consumption
- Compact design
- Lower installed capital cost

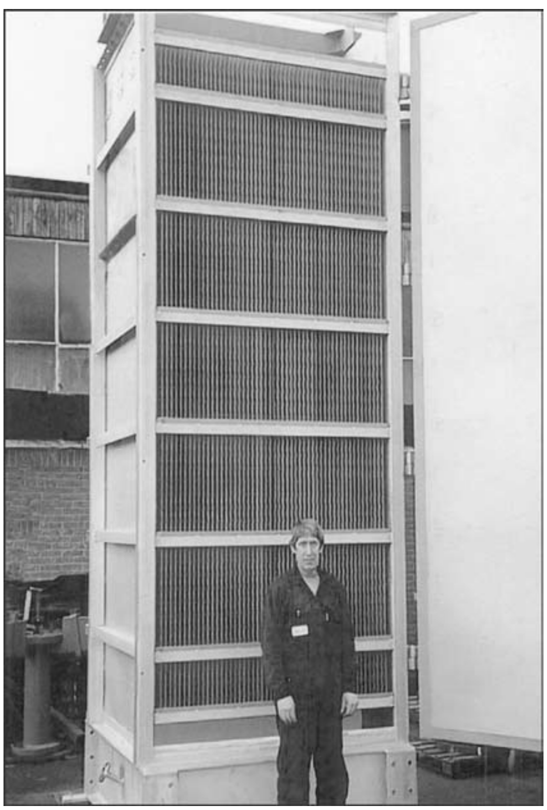
COOLING UREA GRANULES



In a typical fluid bed granulation plant, the product discharges from the granulator between 90 and 100 °C[1]. The preferred storage temperature is generally about 40°C to avoid caking (there is some variation in this temperature depending on the geographic location of the plant and the preferences of the process licensor or owner.) Depending on the process, the cooling may be a single step, or carried out in 2 stages with primary and secondary coolers. The product is screened before cooling and the recycle returned to the granulators.

To date the preference has been to install the Solex Exchanger as a secondary cooler, although testing and a reference installation in the Toyo process shows that the Solex Heat Exchanger will operate just as successfully as a primary or single step cooler. However we will focus on the application as a secondary cooler.

Typical process conditions specified for a secondary cooler are:



Upper bank of large CAN Cooler

Product Flowrate	62500 kg/h (1500 t/d)
Product Inlet Temperature	60°C
Product Discharge Temperature	40°C
Specific Heat of Urea	0.42 kcal/kg.°C
Cooling Water Inlet Temperature	30°C
Granule size	d50 3.5 to 5.0 mm
Ambient conditions:	35°C & RH 70% (summer)

DESIGN CONSIDERATIONS:

PLATE BANK: Two exchanger banks mounted in series so that the specified duty can be achieved in a single piece of equipment. The exchanger plates would be 316L stainless steel, and the casing 304L stainless steel. The double bank exchanger operates with a high thermal efficiency by offsetting the plates in the top bank relative to the plates in the bottom bank.

COOLING WATER: Regular plant cooling water from a cooling tower circuit can be used. Cooling water flow is in series through the 2 banks. The design water flowrate for the process conditions specified is 88 m3/h based on a cooling water temperature differential of 6°C and the pressure drop through the 2 banks is approximately 1.5 bars. As a guide, the chloride content of the water should be less than 150 ppm to minimize the risk of stress corrosion cracking in the stainless steel heat exchanger plates[2].

[1]*The information presented here is generic and does not apply to any particular granulation process.*

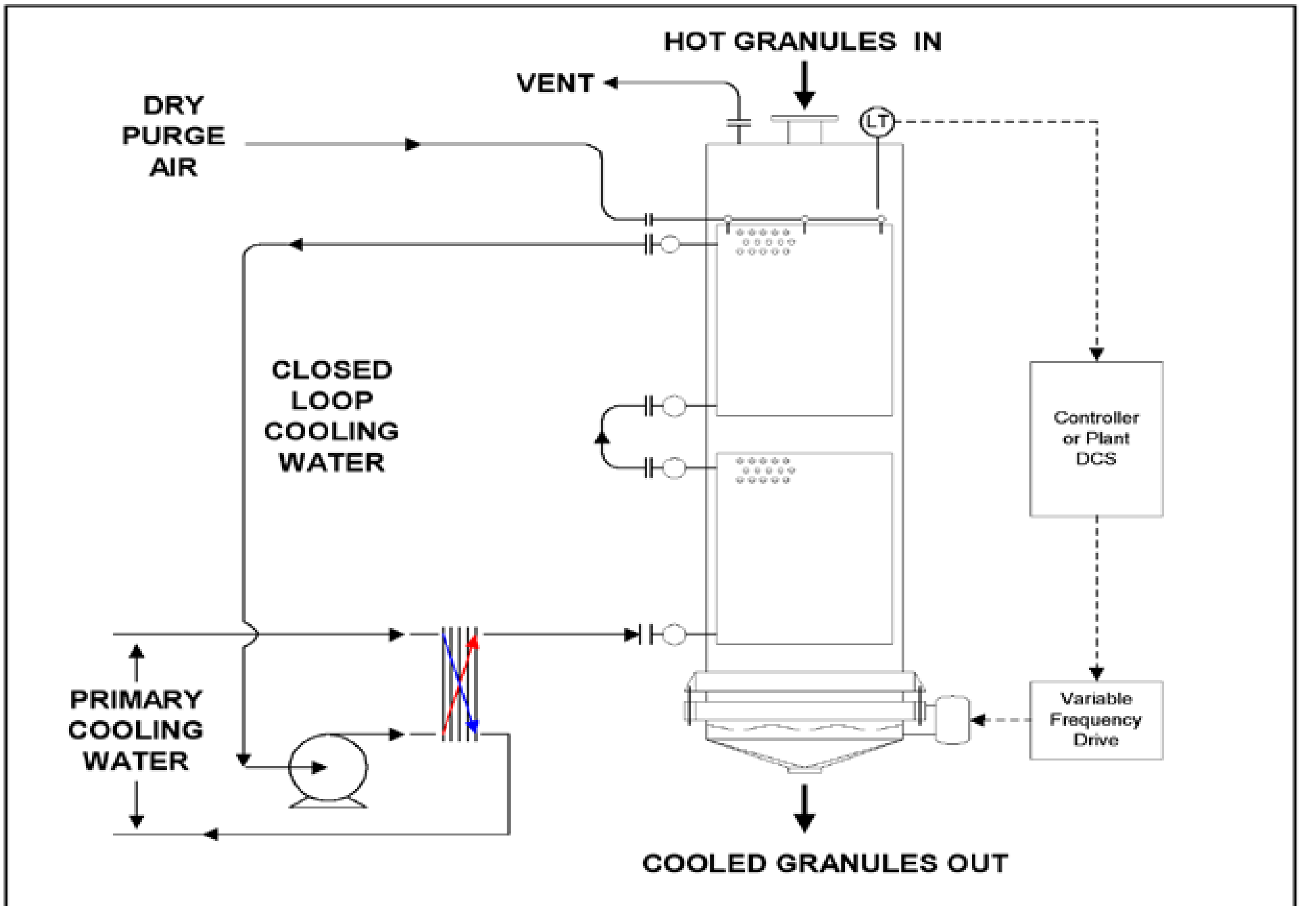
[2]*Stress corrosion cracking in austenitic stainless steels is a complex subject with many factors including temperature. The 150 ppm indicated in the paper does not provide any absolute guarantee that stress corrosion cracking will not occur, however at the process temperatures indicated, experience shows the risk to be low.*

Alternatively if the plant operates with sea-water or brackish water on the primary cooling water circuit, a closed loop cooling water system can be used for the Solex Heat Exchanger using a plate heat exchanger between the sea-water and the closed loop. This arrangement is shown on the flowsheet.

DRY AIR INJECTION: In locations with high summer temperatures coupled with high relative humidity, there is a risk of condensation on the exchanger plates. Moisture on the plates may lead to caking on the plates reducing cooling performance and potentially causing blockage of the unit. To avoid condensation, dry air is injected to reduce the dew point of the air in the exchanger to a value below the cooling water temperature. Typical air injection rates are 250 Nm3/h

FEEDER: Either Vibrating Feeder or Mass Flow Hopper with Gate. Recently the Vibrating Feeder has generally been chosen, since it operates effectively over a wider range of flowrates, which provides more operating flexibility.

ACCESS FOR MAINTENANCE: Large hinged doors are installed on the back of the cooler giving full access to the Plate Banks if cleaning is required.



Typical Schematic for Granule Cooler with closed loop coolin gwater

DISCUSSION OF OTHER FERTILIZER APPLICATIONS

Solex Heat Exchangers have been used to cool the full range of fertilizers:- urea granules and prills, ammonium nitrate and CAN, NPK's, MAP, DAP, TSP, ammonium sulphate.

The principles of operation are similar for each type of fertilizer, but certain details change to allow for the somewhat different properties.

UREA PRILLS

In the majority of urea prill plants, there is no separate cooling after the prill tower. In the original plant design, the prill tower was high enough and had sufficient air to cool the prills to an acceptable temperature for storage. The situation changes when the plant capacity is increased – a very common scenario today with many innovative technologies available for increasing urea plant outputs such as provided by Urea Casale.

The increased capacity in the urea plant reaches a bottleneck at the prill tower, since the cooling capacity is in large part fixed by the height of the tower. A solution to the problem is the Solex Heat Exchanger, which provides additional product cooling after the prill tower and before storage.

The Solex Heat Exchanger is installed after the prill tower. The discharge elevation from the prill tower is low, typically by means of a rake and conveyor. Generally a bucket elevator will be required to feed the Exchanger. An important detail is to include a small vibrating oversize screen at the inlet to the cooler to prevent lumps entering the exchanger. Lumps occasionally form on the walls of the prill tower, rake, elevator casing etc.

Generally the same comments apply as discussed for the urea granule cooler. One additional point is to include a good ventilation system. Urea prills have less mechanical strength than granules, this tends to create more dust in the product. High dust levels increase the risk of caking in the Exchanger, a good ventilation system venting from the Inlet Hopper of the Exchanger reduces the dust level and improves Exchanger performance.

AMMONIUM NITRATE AND CAN – the interesting design consideration with ammonium nitrate products is allowing for the various exothermic phase changes that occur as ammonium nitrate cools down. This adds a significant additional heat load to the Exchanger. In particular, careful consideration needs to be taken of the III to IV phase change that occurs at approximately 32°C. First of all the decision has to made regarding the target discharge temperature from the cooler, above or below the transition. If it is required to cool through the transition, the cooling water temperature becomes an issue, since it will in all probability be close to the transition temperature, which means that there is little thermal driving force for the heat transfer. In these circumstances, the economic choice is generally to use chilled water. The double bank exchanger works well in this situation, by using regular cooling tower water on the top bank and chilled water on the bottom bank. This arrangement minimizes the higher energy consumption of a chiller.

NPK FERTILIZERS – NPK plants normally produce a wide range of NP and NPK formulations. The process conditions such as flowrate and the thermal properties of the different compositions can vary. It is important to analyze the "worst case" conditions so that the Exchanger can be sized accordingly.

MAP, DAP & TSP – Phosphate fertilizer plants are inherently less stable than a nitrogen plant, because they have to deal with the variations in raw material feed. This variation in process conditions, coupled with higher moisture in phosphate fertilizers slightly increases the tendency for caking. This caking is common throughout the granulation section of a phosphate plant and the plants are routinely shutdown for cleaning. To allow for this, a more conservative design is used for the Exchanger, allowing a larger factor of safety in sizing the unit and an increased plate spacing. This means that the Exchanger can operate with a certain level of caking and still meet the specified discharge temperatures, this way the equipment can follow the overall plant cleaning schedule. In addition since cleaning is a known requirement, good maintenance access is provided and the plant needs to arrange a convenient system for the wash water supply and disposal.