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PREVENTING MATERIAL FLOW PROBLEMS IN

VERTICAL PLATE HEAT EXCHANGERS

Uniform mass flow is critical to ensuring optimal equipment performance.

By **Devon Robinson,** Solex Thermal Science

Moving bed heat exchangers (MBHEs) based on vertical plate technology have long provided a robust and simple solution to a variety of heating, cooling or drying challenges in bulk material processing. As an alternative to direct-contact methods such as fluid beds or rotary drums, vertical plate MBHEs have a low energy input, require minimal maintenance and tend to take up less floor space due to their vertical orientation and small footprint.

And while rotary drums and fluid beds are energy intensive and use somewhat "brute force" methods to ensure material flow through the process, vertical plate MBHEs can be designed to operate more passively. They accomplish this by using gravity to continuously move material through the heat exchanger while controlling flow with a discharge device at the bottom.

Using gravity to process bulk solids can still be challenging. Uniform, consistent material flow is critical to the MBHE's performance and dependability, as it dictates the material's residence time between the heat exchanger plates.

For bulk solid materials, the term "mass flow" describes when all material flows at once across the entire cross section of a hopper or other equipment. However, in a vertical plate MBHE, optimal performance requires not only mass flow but "uniform mass flow," where all material moves at the same velocity across the entire cross section.

Given the importance of uniform mass flow, an MBHE's mechanical design is key. Discharge devices, opening dimensions, critical sloped surfaces and the spacing between heat exchanger plates are all important components of an effective design. Equipment suppliers use shear cell testing to determine minimum required values for the specific material to achieve the desired uniform mass flow.

▶ The proper mechanical design of a vertical plate moving bed heat exchanger is crucial to ensure uniform mass flow. In some applications, that could require the strategic distribution of air within the banks of plates and/or the addition of a screen in the inlet hopper.

All images courtesy of Solex Thermal Science

Traditional flow challenges

In addition to ensuring uniform mass flow, vertical plate MBHEs must be designed to prevent the buildup of dust or chaff and avoid material caking that leads to blockages. The material must also flow as designed and have full contact with the heat transfer area. Dust, oversize material — in the form of lumps or flakes from buildup in upstream equipment — and foreign material such as chaff can hinder flow. In addition, some materials are inherently variable and non-uniform.

There is often an appetite to promote flow by adding vibration to the casing or injecting fluidizing air to equipment. While this may be effective for storage silos or hoppers, where any flow is good enough, these solutions in a vertical plate MBHE tend to do more harm than good. External vibration tends to consolidate the material, creating non-uniform flow properties in different areas of the MBHE that can lead to slow spots or preferential flow.

Similarly, fluidizing air tends to channel through the material bed along the shortest path to the vent, thereby aerating or fluidizing material along a specific pathway and changing the material's flow properties in that area without promoting flow in other areas. This non-uniform aeration and flowability ultimately undermines the ability to achieve uniform mass flow.

Dust, oversize material, and foreign materials such as chaff can be managed to varying degrees by including screens upstream from the MBHE, proper venting, and integration with adjacent process equipment. Other means of reducing the propensity for buildup include rounded caps on the tops of exchanger plates to limit material hangup and additional screening in the inlet hopper of the MBHE.

Caking and flow

One of the most significant threats to material flow is moisture-related caking, which impacts the same design variables as the previous challenges but requires a much more comprehensive approach. Caking is when the particles of a formerly free-flowing bulk material bind together to form brick-like solid chunks or layers. Caking is generally moisture related, but the term can also be applied to oily materials that can build up in a similar way.

Preventing moisture-related caking is a major focus in the design of any vertical plate MBHE, because air and moisture are always present along with the material being heated or cooled.

Free-flowing bulk solids always contain a large amount of void space. Typically, 40 to 50% of a bulk solid's total volume is the air that exists in the voids between the particles. In conjunction with whatever moisture exists in the material, that void-space air may also carry moisture. Heating or cooling the material can impact the effect of that moisture on the material.

In a cooler, the cold surfaces required mean that caking is almost always a risk. Even in applications with an upstream dryer, recently released moisture is often still present in the void-space air and can condense on the surface of the cold heat exchanger plates or on the cold material itself.

The air-space voids in a warm material that has just left a dryer can contain more moisture than those same voids can contain once the material has been cooled to the target temperature for the process. This is where understanding and integrating the adjacent equipment is so critical. It is never as simple as simply cooling down the material.

The primary mechanism behind caking-related buildup is simply the reduction in moisture-carrying capacity of the void-space air and the condensation of that excess moisture onto cold surfaces. As the material cools, so does the void-space air, which causes the relative humidity to increase. If the air cools below its dew point, condensation will form on the cold exchanger plates and the cooled material. When the material is water soluble and crystalline, the condensed moisture can dissolve the crystalline particles at or near the cold surfaces and result in highly bonded bricks of caked material.

The redistribution of moisture through crystalline material leaves behind what are usually called salt bridges that bond particles together wherever the moisture has been. Even with non-soluble materials, any condensed moisture on the plates may hinder material flow.

Even if the void-space air doesn't cool below its dew point, some materials are hygroscopic. This means they have an affinity for moisture and will begin to absorb the moisture from the ambient air at some threshold humidity.

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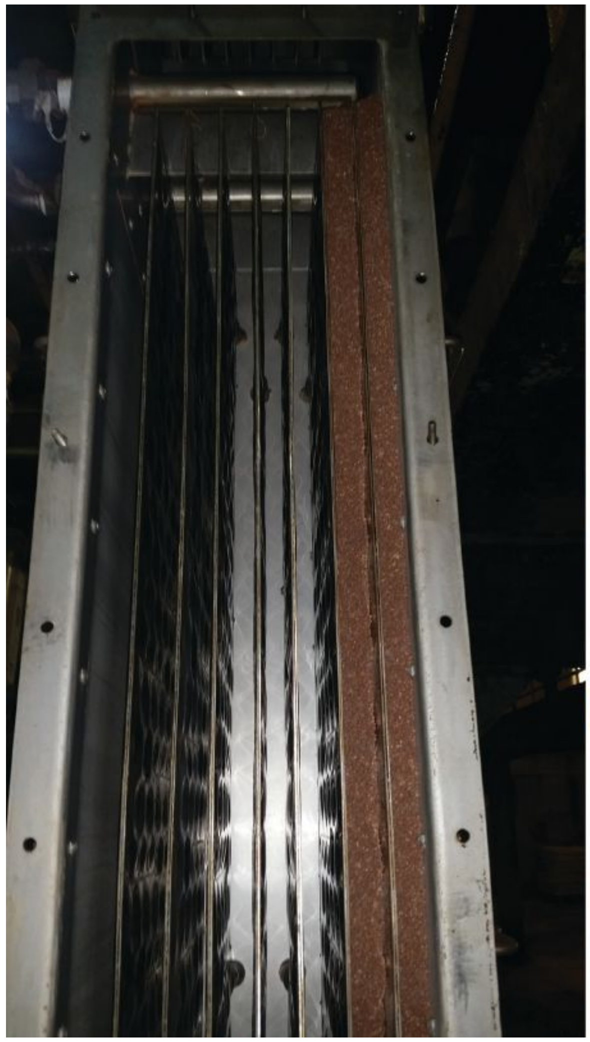

▲ In this NPK fertilizer application, the image on the left shows caking in two flow channels due to inadequate air distribution. The image on the right shows a clean set of banks once air was properly distributed in the unit.

▶ Caked material flaking off upstream surfaces and entering the vertical plate moving bed heat exchanger in this NPK fertilizer application previously led to plugging before the addition of a screen in the inlet hopper above the bank of plates.

Solving caking

The solution to caking is to understand what the air is doing and, where needed, inject sufficiently dry air to dilute or flush away the moist air from the voids. This approach is generally similar whether the material is hygroscopic or not, but some additional information and margin of safety is required in the case of hygroscopic materials.

The goal is to ensure that the dew point of the void-space air is consistently above the lowest temperature in the cooling plates throughout the MBHE. Due to the cost of dry air — especially in large quantities or at very low dew points — there

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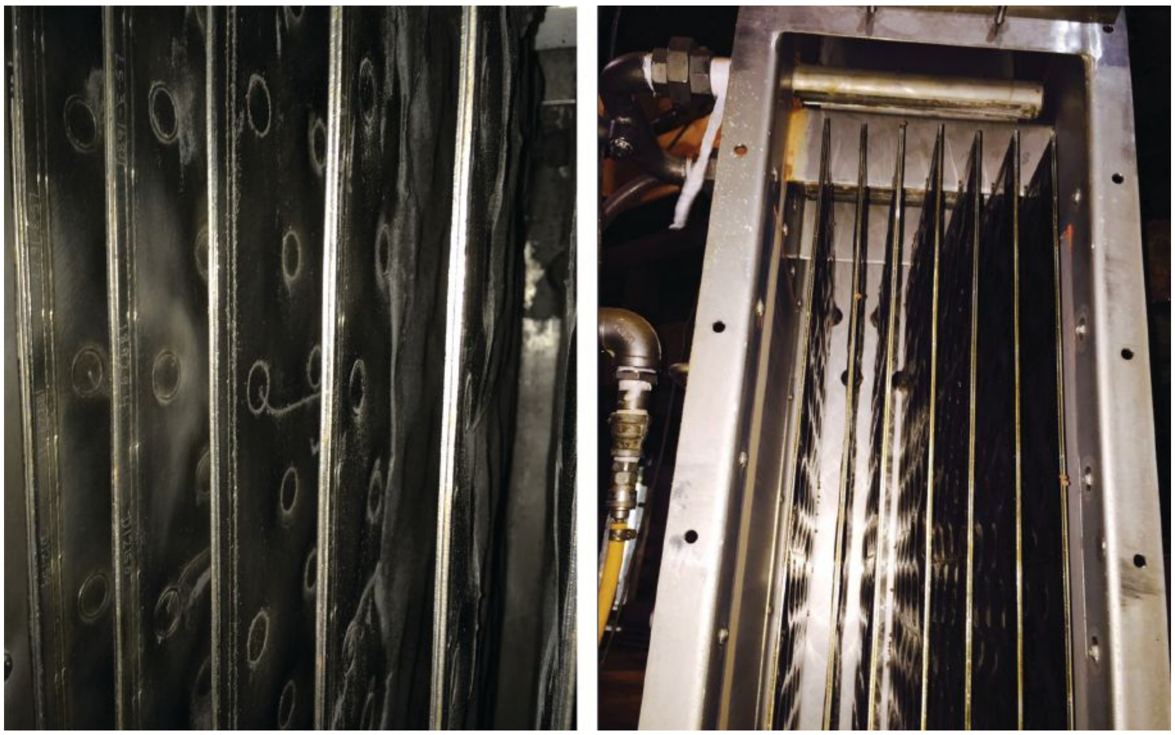

▲ In this green sand application, the image on the left shows caking on the plates that had to be scraped off. The image on the right shows the plates once the material's moisture content was better controlled with the addition of small amounts of purge air.

is good reason to not use this solution excessively.

Designing air injection for MBHEs to avoid caking issues involves a balance of size, performance, and budget. Colder process fluid/cooling surfaces are desirable to maximize cooling performance in an available volume. However, colder surfaces require lower dew points for the injection air, which must be considered in the balance of costs.

Ambient air may be injected, depending on the location and process. In most cases, if the flowing material is warm enough, ambient air is suitable to flush away moisture. Yet, when the target cooling temperature is within about 10°C of the worst-case ambient dew point of the region, some dehumidified or instrument air will likely be required to achieve the desired cooling without caking issues.

In some cases, a combination of ambient air and dry air can be used to help minimize operating costs. Ambient air in large quantities can be excellent for flushing moisture out of the material entering a vertical plate MBHE from an upstream heating or drying process step. Dehumidified air can then be used more sparingly near the cooling surfaces to control the dew point where the risk is highest to minimize usage of plant air.

Provided the material is coarse enough to allow the required air quantity to pass through it and uniform enough to allow distribution of the air, the solution is simply knowing where the air is needed and defining how much and how dry it should be.

Finally, in many fine powder applications, air injection within the MBHE is not always the solution. However, it is possible to fluidize the powder to flush out moist void-space air before the material enters the MBHE's cooling section.

Conclusion

By understanding the material, its process history, and the desired outcomes, the risk of flow issues such as caking in a vertical plate MBHE can be well understood and addressed. The challenge is often tackled as part of the overall design of the MBHE, as the implementation of solutions is closely tied to the fundamental properties of the material and design parameters of the technology.

With the right balance of air injection and cooling fluid temperatures, along with robust mechanical design, vertical plate MBHEs can attain consistent, long-term operation without caking or blockages, making them a practical and reliable technology that is easy to work with. PR

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