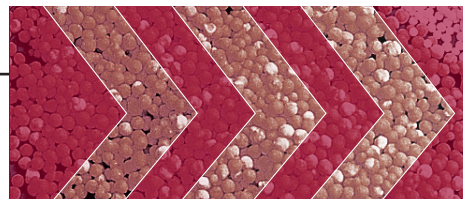


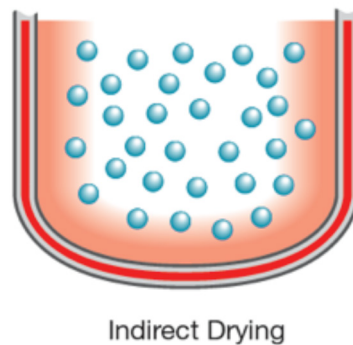
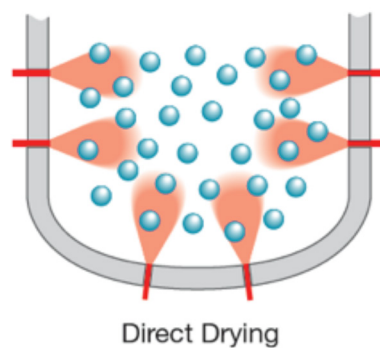
Solids processing for temperature-sensitive products: Two drying methods that optimize quality and efficiency

Direct drying and indirect drying technologies both offer the advantages of low residence times. Two types of dryers – mechanical flash dryers (direct drying) and thin-film paddle dryers (indirect drying) – offer optimal solutions for heat-sensitive material. The requirements for each application will determine the choice of dryer.



Manufacturers in the chemical, food, mineral and other industries continually evaluate their industrial processes to ensure materials are produced with minimal waste, optimum efficiency and highest quality. Thermal processing is integral to the processing phase and requires thorough analysis of the material's moisture content and other characteristics. Each industrial process is unique; manufacturers are assured of highest performance only after a careful development process that includes material evaluation, batch testing, pilot-scale trials and commercial evaluation. Two approaches to drying temperature-sensitive material optimize process and product quality for a variety of materials, including polymers, fertilizers, starches, flours, yeast and other animal supplements including polymers, fertilizers, plant proteins, starches and yeast (also for animal supplements).

Figure 1: Direct and indirect drying for temperature-sensitive processing



TWO TYPES OF DRYING TECHNOLOGIES

Drying is a unit operation in which a liquid is separated from a solid by other than mechanical means. This generally requires supplying heat, resulting in evaporation of the liquid. Two types of drying technologies, direct drying and indirect drying, can be applied for temperature-sensitive processing. (Figure 1)

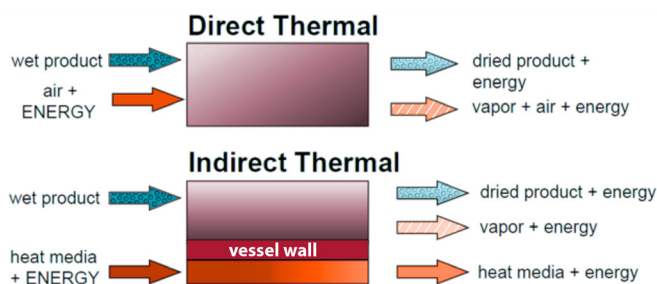
Direct Drying

Direct—or convective—thermal processes (*Figure 2*) typically mix heated or ambient gas (e.g. air or nitrogen) directly with the material to be treated. Some direct thermal technologies employ a mechanical agitator to increase the mixing of the material with the gas, and almost every direct technology uses pneumatic conveyance to move the material through the process.

Because this process relies on gas as the heat transfer medium, exhaust treatment and environmental considerations can make this process less desirable than indirect processing for a given application.

However, given the presence of a high volume of air/gas, direct drying operations benefit from evaporative cooling, when the evaporated water cools the air stream, subsequently cooling the dried material. This in turn helps maintain a low working temperature, avoiding degradation in temperature sensitive materials.

Figure 2: Direct and indirect thermal concepts



Indirect Drying

Indirect—or conductive drying processes transfer heat to the material indirectly through contact with a heated surface. The material is separated from the heat transfer medium by a metal wall, and the heat is conducted through the material or heat transfer medium, usually steam or hot oil (also water, glycol solution, electrical resistance or molten salts). The material itself never comes into direct contact with the heat transfer medium. To enhance even heating and provide conveyance, indirect systems use mechanical agitation to move the treated material across the metal surface and onward to the next process step.

Indirect thermal processing is especially beneficial when space is limited, for short-distance conveying or for reducing conveying equipment in a process. Indirect thermal processing often eliminates material handling issues and increases the value of the final product.

Direct and indirect dryers for temperature-sensitive materials

While several types of dryers can perform the task, two in particular are ideal for drying heat-sensitive materials: mechanical flash dryers and thin-film paddle dryers. The requirements for each individual application, will determine the choice of dryer. Each application requires a thorough development process to test, design and specify a precise match for the application. *See sidebar: Evaluate, test and sample material for best results.*

Evaluate, test and sample material for best results

Whether starting from scratch, looking to incorporate a new process step into an existing system, or optimize their current operation, manufacturers can work through one or all of the following steps with their solids processing partner to meet their material requirements:

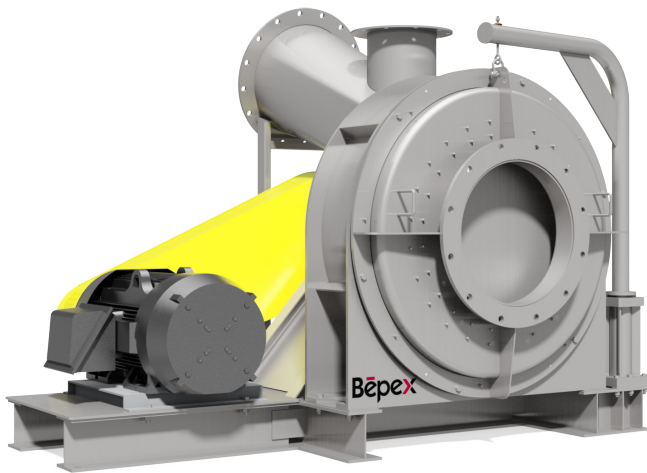
- **Bench Testing:** Review a small sample of material for initial feasibility
- **Pilot-Scale Testing:** Run representative trials on customizable systems
- **Scale-Up:** From pilot-scale tests results, size an industrial process system that meets operational requirements
- **Commercial Evaluation:** After scale-up, provide a complete offering for CAPEX and OPEX evaluation
- **Custom Process Definition:** Produce product samples in a continuous process for market evaluation

Careful evaluation using industry proven technologies helps manufacturers develop the right material for their application and speeds time to market.

Flash dryer

Flash dryers are based on direct thermal technology and are designed to dry high-moisture temperature-sensitive materials in difficult-to-handle forms, such as wet/filter cakes, pastes, and slurries. (Figure 3) Traditional flash dryers are non-mechanical spray dryers or ring dryers. An alternate type of flash dryer is mechanical and offers greater particle flexibility compared to spray dryers or ring dryers. Spray dryers typically produce only fine powders, while ring dryers typically produce larger granules, and need additional milling steps to produce a powder. A mechanical flasher dryer can produce a fine-milled powder ($\sim 5\mu\text{m}$) or larger granule (generally up to 1-2mm).

Figure 3: A mechanical flash dryer provides high drying efficiency.



BEPEX PCX flash dryer

The dryer's intense mixing increases product surface area to ensure rapid evaporation for high drying efficiency. The mechanical flash dryer utilizes heated air streams and rotating dispersion plates to generate a thin layer of material. This thin layer provides intimate contact between the particles to be dried and the heated gas stream. Given its dispersion as a thin layer, the mechanical flash dryer typically requires a smaller footprint compared to ring and spray dryers.

Material residence time inside the dryer itself is short, at an average of two to three seconds. Once discharged from the dryer, material is pneumatically conveyed to separation components, typically a cyclone followed by a baghouse. During the conveyance period, the moisture-laden air provides evaporative cooling of the dried product, quickly lowering material temperature to avoid degradation or color change that occurs with extended time and temperature exposure. Mechanical flash dryers typically don't require any upstream or downstream thermal processes, such as fluid beds or holding steps common in some flash-drying operations.

Mechanical flash dryers can also simultaneously mill and dry filter cakes, slurries or solutions, which generates a usable powder material directly from the dryer and reduces energy consumption downstream if subsequent milling is needed. Mechanical flash dryers are an efficient and compact alternative to non-mechanical spray dryers and ring dryers, reducing both total cost of ownership and installation costs without sacrificing product quality.

Thin-film paddle dryer

Thin-film paddle dryers (Figure 4) are based on indirect thermal technology, which relies on heat energy reaching the product through heated surfaces. Thin-film dryers have the greatest thermal efficiency of indirect thermal processing because the high tip speed keeps the material in constant contact with the heating/cooling surface. The continuous agitation of a thin-film dryer also provides an excellent mixing mechanism for incorporating multiple feed streams and/or minor ingredients. Thin-film dryers produce particle sizes in the range of 1 to 3,400 microns and are designed to operate on solutions, slurries, pastes, centrifuge cakes, filter cakes, and free flowing solids.

Figure 4: A thin-film paddle dryer produces excellent heat-transfer coefficients.



**BEPEX SOLIDAIRE®
thin-film paddle dryer**

Thin-film dryers rely on a mechanical agitator rotating in a cylindrical housing. The cylindrical housing has a heat-transfer jacket which may be constructed for steam or liquid heat-transfer media. A rotor inside the heated cylindrical vessel operates at high tip speeds (five to 25 meters per second), which forces the material into a thin layer along the heated cylindrical vessel wall. This provides the conductive heating to carry out evaporation. The wall's hollow jacket constitutes the entire heat transfer surface. A heated gas stream (often inert) typically runs counter-current to material flow, picking up evaporated moisture and carrying it to a condenser for collection. Since the purge gas is not used as the primary heat source, the quantity of gas required is minimized, providing for more efficient operation and lower operating utility requirements.

The rotor consists of paddles installed along the length of a rotating shaft. The angle of each paddle can be adjusted to control the conveyance speed and residence time of the material. Not to be confused with a bed paddle dryer, the paddles in a thin-film paddle dryer do not provide any heat transfer. These dryers can be force-fed through a port in the side of the vessel or gravity-fed through the top. Product is typically discharged from a port in the opposite end and is only suited to continuous processes.

Thin-film dryers are ideal for cooling, pasteurizing and wet-cake drying and are more efficient compared to flash dryers. Their high-speed paddles break up lumps and loose agglomerates for uniform thermal treatment.

Multiple feeding options, including screw feeding, pumping and spraying into the vessel, make this option suitable for materials of nearly any consistency. The dryer's short residence time—the amount of time that the treated material spends in the machine—allow for strict control of the material temperature.

Mechanical flash dryers and thin-film contact dryers are optimal for thermal-processing of heat sensitive materials due to their short residence times or strict control over time and temperature exposure. Depending on the nature of the material to be processed, several other dryer types are also available. Dryers classified as dilute dispersion or thin-film include: thin-film contact dryer, spray dryer, drum dryer, flash dryer, and steam-jacketed rotary dryer.

Optimal dryer designs

The optimal dryer design should provide the following features:

1. Time-temperature exposure

Loss of product quality usually results from the combined effects of exposure time and drying temperature. If the dryer design employs a long exposure time, the temperature of the heat source should be kept low. On the other hand, dryers which operate with short residence times can use higher heat source temperatures, without risking product quality degradation.

Dryer designs have varying exposure times (*Table 1*). The mechanical flash dryer operates with extremely short residence times of less than 3 seconds. The thin-film paddle dryer is capable of operating with a wide range of residence times, up to 30 minutes.

Table 1: Solids exposure to heat conditions

Typical Residence Time:	0-10 (Sec.)	10-30 (Sec.)	5-10 (Min.)	10-60 (Min.)	1-6 (Hr.)
Convection Dryers					
Belt Conveyor Dryer				X	
Flash Dryer	X				
Fluid Bed Dryer				X	
Rotary Dryer				X	
Spray Dryer		X			
Tray Dryer (Batch)					X
Tray Dryer (Continuous)				X	
Conduction Dryers					
Thin Film Contact Dryer	X	X	X		
Cone Dryer (Batch)				X	
Drum Dryer		X			
Steam Jacket Rotary Dryer				X	
Tray Dryer (Batch)					X
Tray Dryer (Continuous)				X	
Bed (Trough) Dryers					
Hollow Disc				X	
Hollow Paddle				X	
Screw Conveyor				X	

2. Air exposure

To compensate for reduced time-temperature exposure, the dryer design should maximize evaporative mass transfer efficiencies. One method of achieving this effect is to provide intimate contact among discrete particles being dried with the air (or inert gas) stream. Individual particle contact with the air stream allows for good moisture stripping ability, by increasing the differential partial pressure driving force for evaporation.

The degree of air exposure varies by dryer. The flash dryer, fluid bed dryer, spray dryer and thin-film paddle dryer all operate with high degrees of discrete particle-air contact.

3. Temperature gradients and residence-time distribution

It is important to minimize temperature gradients within the product material being heated during the drying operation. Narrow residence time distribution of the product material within the dryer will ensure uniform product quality.

Dryer designs in which the product material is heated as a dilute dispersion or as a thin film in plug flow condition will satisfy these criteria. Dryers in which the product material is in the form of bulk mass may be more prone to temperature gradients and/or residence time distribution effects.

Thermal efficiency comparison: flash dryer vs thin-film dryer

The thermal efficiency of a flash dryer is a function of its outlet gas temperature and of its delta temperature (inlet/outlet gas temperature difference), which establishes the gas flow requirement for heat balance. The lower the gas outlet temperature becomes, the higher the thermal efficiency. The larger the gas temperature differential becomes, the lower the rate of gas flow, and the greater the thermal efficiency.

The maximum allowable moisture content in the discharged product will normally place a lower limit on the flash dryer's outlet gas temperature. The product

material's temperature sensitivity will normally define the upper limit for the mechanical flash dryer's inlet gas temperature, thereby establishing the maximum allowable delta temperature condition. The net result is that for most drying applications, the mechanical flash dryer's heat duty is typically 1500-2000 BTU's per pound (3489-4652 KJ/Kg) of water evaporated.

The thermal efficiency of the thin-film dryer is a function of its outlet gas temperature, and system losses similar to the flash dryer. However, the thin-film dryer does not depend on the quantity of gas flow for heat balance requirements. The reduced gas flow rate results in the dryer's heat duty falling in the range of 1000-1400 BTU's per pound (2300-3250) KJ/Kg) of water evaporated.

Summary

Processing temperature-sensitive products for chemical, food and mineral industries requires a careful analysis of the drying process to ensure product quality, optimal efficiency and minimal waste. Direct drying and indirect drying are two types of drying technologies ideal for temperature-sensitive processing. Mechanical flash dryers and thin-film paddle dryers offer optimal solutions, although application requirements will determine the choice of dryer. Thorough analysis of the process, plant and capital requirements will identify the technology that best fits specifications.

About Bepex International

Bepex International, with roots dating back to 1897, serves the global food, chemical, and polymer markets by providing process development services and custom-designed industrial scale process systems and equipment. With a wide array of proprietary platform technologies, including thermal, size reduction, compaction/agglomeration, mixing and blending, and mechanical dewatering, Bepex custom-designs each piece of process equipment to the exacting requirements of each process and customer, reducing time-to-market and increasing processing efficiency.



333 Taft Street Northeast • Minneapolis, MN 55413 USA • 612-540-0053

www.bepex.com